

Implementation of Problem Solving-Based Electron Configuration E-Modules to Improve Student Learning Outcomes

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ABSTRAK

Tujuan dari penelitian ini adalah untuk menganalisis peningkatan hasil belajar siswa dalam penerapan e-module konfigurasi elektron berbasis problem solving. Metode true-experiment dengan pretest-posttest design digunakan dalam penelitian ini agar dapat dibandingkan hasil belajar dari kelas control dan kelas eksperimen. Hasil penelitian menunjukkan selama proses penerapan e-module, aktivitas siswa berjalan sangat baik. Pada tahap menganalisis masalah, membuat hipotesis, mengumpulkan data, menguji hipotesis, dan membuat kesimpulan secara berturut-turut siswa mendapatkan nilai rata-rata 84,25; 82,5; 80,5; 100; dan 89,5. Uji statistik hasil belajar siswa kelas control dan kelas eksperimen dengan Mann-Whitney U test menunjukkan nilai signifikansi 0,013 sehingga dapat disimpulkan bahwa terdapat perbedaan yang signifikan antara hasil belajar siswa dengan penerapan e-module dan tanpa penerapan e-module dalam pembelajaran.

ABSTRACT

This research aims to analyze the improvement in student learning outcomes in the application of the problem-solving-based electron configuration e-module. The true-experiment method with a pretest-posttest design was used in this research so that learning outcomes from the control class and the experimental class could be compared. The research results show that during the process of implementing the e-module, student activities went very well. At the stages of analyzing problems, making hypotheses, collecting data, testing hypotheses, and making conclusions respectively, students got an average score of 84.25; 82.5; 80.5; 100; and 89.5. The statistical test of student learning outcomes in the control class and experimental class using the Mann-Whitney U test shows a significance value of 0.013 so it can be concluded that there is a significant difference between student learning outcomes with the application of e-modules and without the application of e-modules in learning.

1. INTRODUCTION

The profound impact of the 21st century on human existence manifests across various facets of life, distinctly diverging from preceding centuries, particularly evident in the learning process and utilization of educational media (Wijaya et al., 2016; Patras and Hidayat, 2013). The acquisition of 21st-century skills holds paramount importance for students, aligning with the demands of contemporary society (Zulfikar, 2021). These skills necessitate cultivation from early childhood, particularly within educational settings, to cultivate attributes reflective of 21st-century realities. Among these crucial competencies are creative thinking, adeptness in critical thinking and problem-solving, effective communication, and collaborative abilities—the renowned 4C skills—integral to the educational landscape in Indonesia, as emphasized within the framework of 21st-century learning (Zakaria, 2021; Sunarya et al., 2022).

The mastery of 21st-century skills stands as a pivotal imperative for every student; however, empirical evidence indicates a concerning disparity wherein students often lack proficiency in and exposure to practising these skills, notably in critical thinking and problem-solving domains (Mauliyda et al., 2019). Yet, these competencies serve as pivotal methods to enhance comprehension and mastery of academic content among students (Ijirana et al., 2021).

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Problem-solving skills are essential facets cultivated within the educational journey, with particular significance evident in the realm of chemistry education. Among the array of subjects encountered in academic settings, chemistry emerges as notably challenging. Rooted in the exploration of properties, structures, energy, and their associated transformations, chemistry encompasses a breadth of complex and abstract material (Sukma et al., 2020). Chemistry material is complex and some is abstract so it is difficult to learn. This complexity poses formidable barriers to effective learning, compounded by the necessity for students to adeptly navigate three levels of representation to elucidate chemical phenomena (Ramnarain & Joseph, 2012).

Efforts to optimize the efficiency of chemistry education underscore the paramount importance of employing suitable instructional media and methodologies. However, current practices in the field reveal a prevailing reliance on monotonous lecture-based approaches, which fall short of nurturing students' problem-solving abilities (Pusporini et al., 2012). Indeed, the choice of instructional methods and models significantly shapes student learning outcomes. Absent a pedagogical emphasis on problem-solving approaches (Damayanti & Jirana, 2018). Students' skill development may be stunted. This deficiency is further compounded by the scarcity of interactive learning media capable of fostering problem-solving competencies, a crucial component in enhancing student engagement during the teaching and learning process (Harling, 2021). Notably, a survey conducted in the field reveals a prevalent reliance on printed textbooks as the primary learning resource in most educational institutions, potentially contributing to waning student interest and motivation, particularly in the intricate domain of chemistry (Salsabila & Nurjayadi, 2019).

These challenges can be effectively addressed through the implementation of engaging and interactive learning mediums, such as learning modules. In today's digital age, students increasingly rely on electronic devices such as computers, smartphones, and tablets for accessing information, leading to a surge in the integration of technology within educational practices (He et al., 2012). Leveraging e-modules presents a promising avenue to enhance student outcomes, with various modules tailored to diverse learning needs. For instance, previous research has demonstrated that the utilization of professional PDF flip-based e-modules focusing on inorganic chemistry can substantially bolster students' comprehension (Ramlawati et al., 2022). However, while such interventions yield moderate improvements in conceptual understanding, alternative studies propose that e-modules dedicated to topics like buffer solutions can significantly pique student interest, with reported engagement rates as high as 91.1% (Julia, 2020). Harnessing e-modules not only fosters student engagement but also holds the potential to enhance learning outcomes, particularly within the domain of chemistry education (Oknaryana & Irfani, 2022).

Among the myriad of chemistry concepts demanding mastery, electron configuration stands out as a foundational and indispensable topic. Understanding the electron configurations of elements and ions serves as a linchpin for comprehending chemical reactions (Adhikary et al., 2015). Proficiency in electron configuration is fundamental, laying the groundwork for students to delve into more advanced chemical materials (Rahman et al., 2016). Despite its pivotal importance, a staggering 75% of students still grapple with identifying elements on the periodic table, highlighting a concerning gap in foundational knowledge. This discrepancy underscores a notable deficiency in the teaching and learning process, with over 70% of students struggling to articulate the constituents of the periodic system, thereby impeding their grasp of the periodic trends and chemical properties inherent in these elements (Rahman et al., 2016).

Mastering electron configuration material presents challenges due to its abstract and conceptual nature. Its abstraction stems from the inherent difficulty in finding real-world analogies to illustrate electron configuration concepts, rendering it challenging to comprehend (Aswan et al., 2021). Moreover, electron configuration serves as a cornerstone for subsequent topics, thus qualifying it as a conceptual subject crucial for building a solid foundation in chemistry.

Addressing these hurdles necessitates the implementation of appropriate learning methodologies and media to enhance students' conceptual grasp, academic performance, and problem-solving abilities. Introducing problem-solving-based e-modules tailored to electron configuration emerges as a viable solution. These e-modules are designed to facilitate deeper understanding and foster problem-solving skills among students, aiming to elevate learning outcomes in comparison to conventional methods. To empirically assess the efficacy of e-modules in enhancing student performance, a true experimental approach employing a pretest-posttest design was employed.

2. METHOD

The research methodology employed in this study adopts an experimental design, specifically a true experiment featuring a pretest-posttest paradigm with a control group. The investigation was carried out among 10th-grade students at SMA YAS Bandung, with a total of 40 participants distributed across two classes. These classes were categorized into control and experimental groups. The control group underwent

traditional instructional methods, primarily relying on lecture-based learning without any additional interventions. In contrast, the experimental group received a specialized intervention comprising problem-solving-based learning supplemented by e-modules. This approach was chosen based on the demonstrated efficacy of problem-based learning strategies in enhancing students' problem-solving skills, as evidenced in prior research (Valdez & Bungihan, 2019). The research design is presented in Figure 1.

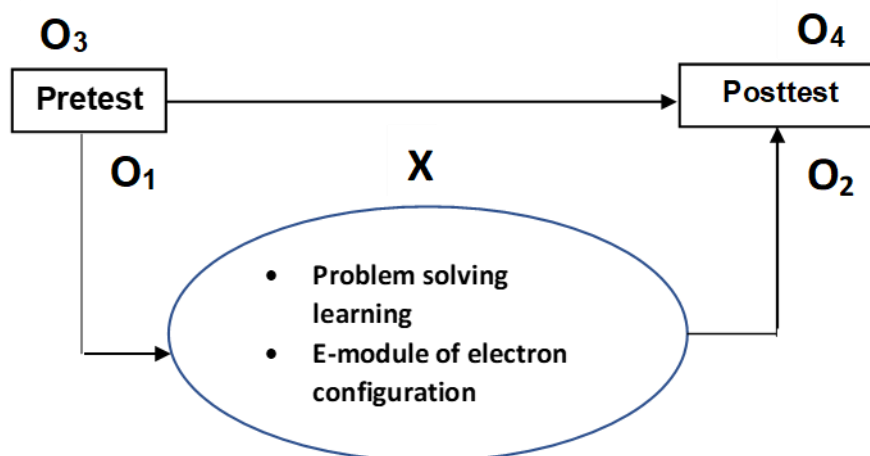


Figure 1. Research design

Research and data collection activities were carried out in the even semester of 2022/2023. Data collection started from the first week of March to the second week of April. The primary aim of this study is to enhance student learning outcomes by implementing problem-solving-based learning strategies. Data collection for this research involved employing observation methods alongside written tests. The instruments utilized encompassed student observation sheets, worksheets, as well as pretest and posttest assessments. Data sources were derived from both control and experimental class students, as well as from observers tasked with evaluating the learning process. The pretest and posttest data that have been obtained are then analyzed using SPSS software with categories as shown in Table 1.

Table 1. Interpretation of Normalized Gain Score

Normalized gain Value	Interpretation
$g \leq 0.30$	Low
$0.30 \leq g \leq 0.70$	Medium
$0.70 \leq g \leq 1.00$	High

Student worksheets that have been done are analyzed and then given a value by the rubric. The stages of conducting worksheet assessment are checking the worksheets that have been filled in, giving points to each stage of the worksheet that has been done, and finally calculating the total value obtained. The interpretation of the worksheet assessment criteria can be seen in Table 2.

Table 2. Interpretation of Worksheet Score

Score range	Interpretation
0-39	Failed
40-55	Lack
56-65	Plenty
66-79	Good
80-100	Very Good

3. RESULT AND DISCUSSION

Result

This research aims to analyze students' abilities in completing worksheets on the application of the electron configuration e-module based on problem-solving to improve student learning outcomes. This implementation process can be seen in students' ability to complete worksheets.

The stages contained in the worksheet are based on the stages contained in the e-module, namely problem orientation, describing the problem, making a hypothesis, collecting data, testing the hypothesis, and making conclusions. Below is an analysis of each stage of the worksheet based on problem-solving (Pusporini et al., 2012).

a. Problem Orientation

At this stage, each group is required to analyze the problems on the worksheet and the problems on the e-module. Students must understand the phenomenon of iron (Fe) and sodium (Na) when they react with water which is presented at the problem orientation stage. The problem orientation display on the worksheet and e-module can be seen in **Figure 2**.



Figure 2. E-module display at the problem orientation stage

b) Analyze the Problem

The second stage of the worksheet is analyzing the problem. At this stage, each group is required to analyze the problems that have been presented at the problem orientation stage. Students write the results of their problem analysis on a worksheet. The e-module display in the second stage can be seen in **Figure 3**.



Figure 3. E-module display at analyze the problem stage

b. Create a Hypothesis

The next stage in the worksheet is creating a hypothesis. Each group discusses and plays an active role in the hypothesis-making stage. Hypotheses are made based on the results of problem analysis that have been obtained previously.

c. Data Collection Stage

The next stage is the stage of collecting data. Each group continues the instructions in the e-module and fills in the worksheet at the data collection stage. There are several questions at this stage. The questions on the worksheet are relevant to the questions in the stages in the e-module. The e-module display in the data collection stage can be seen in **Figure 4**.



Figure 4. E-module display at data collection stage

d. Stages of Testing a Hypothesis

The next stage in the worksheet is the hypothesis testing stage. After collecting data obtained from the electronic configuration e-module. The e-module display at the hypothesis testing stage can be seen in Figure 5.



Figure 5. E-module display at testing a hypothesis stage

e. Making Conclusions

The final stage of the worksheet is making conclusions, students discuss in groups to make conclusions and representatives of group members are required to explain the conclusions reached in front of the class.

During the learning process, students worked on worksheets with the results presented in Table 3. Data include the results of student worksheets, control class pretest-posttest results, and experimental class pretest-posttest results.

Table 3. Average Score of Student's Worksheet

Learning Steps	Average Score	Interpretation
Problem Analysis	84.25	Very Good
Making Hypothesis	82.50	Very Good
Data Collection	80.50	Very Good
Testing Hypothesis	100	Very Good
Making Conclusion	89.50	Very Good

Based on Table 3 it can be concluded that the ability of students to work on worksheets gets an average score with a predicate of excellent at each stage. So that by using the e-module, students' ability to

complete worksheets has a very positive impact. The next data obtained is about the learning outcomes of control class and experimental class students. The data is presented descriptively as shown in [Table 4](#).

Table 4. Average Score of Pre-test and Post-test

Class	Sum of sample	Average	
		pre-test	Post-test
Control	20	17.2	54.4
Experiment	20	11.6	40.2

The data was then processed by inferential statistics. Data normality was analyzed using the SPSS program. The results of the analysis can be seen in [Table 5](#).

Table 5. Result of the Normality Test

	Kolmogorov-Smirnova
	Sig.
Pre-test Control	0.000
Post-test Control	0.131
Pre-test Experiment	0.034
Post-test Experiment	0.020

Based on [Table 5](#), shows that the data has sig < 0.05 is not normally distributed. So the Mann-Whitney test is used. The test results can be seen in [Table 6](#).

Table 6. Result of Mann Withney Test

Test Statistics	Student's Outcome
Mann-Whitney U	110.000
Wilcoxon W	320.000
Z	-2.482
Asymp. Sig. (2-tailed)	0.013
Exact Sig. [2*(1-tailed Sig.)]	0.014

Based on the results of non-parametric statistical tests with SPSS software, the 2-tailed significance result shows a value of 0.013. According to [Table 6](#), the significant value obtained is <0.05. So, the decision taken is H_a accepted and H_0 rejected. So, it can be concluded that there is a significant difference in student learning outcomes after the application of a problem-solving-based electron configuration e-module compared to student learning outcomes without using an e-module.

Discussion

This segment will delve into student activities, their performance on worksheets, and the impact on their learning outcomes following the implementation of problem-solving-based electron configuration e-modules. The study centred on the application of these e-modules, which spanned three sessions in the experimental class and two sessions in the control class. The research objectives were formulated based on identified issues. Firstly, to delineate student engagement levels during the utilization of problem-solving-based electron configuration e-modules. Secondly, to assess students' proficiency in completing worksheets aligned with the stages of the problem-solving model, facilitated by e-module support.

The second objective encompasses the analysis of students' cognitive learning advancements after the application of the problem-solving model facilitated by e-modules. Additionally, it involves a comparative evaluation of learning outcomes between the experimental and control classes. Researchers employed pretest and posttest question sets alongside question grids as measurement tools. In the experimental class, instruction centred on problem-solving methodologies, while the control class adhered to the traditional lecture-based teaching method. The learning process comprised several stages: firstly, orienting students to real-world scenarios pertinent to electron configuration materials, designed to pique students' curiosity and prompt engagement with problem-solving ([Pusporini et al., 2012](#)). Following this, the organization stage aimed at fostering collaborative problem-solving skills among students to achieve

desired learning outcomes. Subsequently, the investigation stage involved guiding students through data collection from various sources including e-modules, internet resources, and textbooks. Students then progressed to the presentation stage, where they were tasked with elucidating findings derived from previous stages to the initial problem scenario. Finally, the evaluation stage required students to synthesize their findings and offer solutions to the identified problems.

In the problem-solving-based learning approach employed, worksheets serve as pivotal tools for assessing learning efficacy. The stages within these worksheets commence with problem orientation. Based on research data, students demonstrate commendable performance during this initial stage. They engage attentively and systematically with the problems posed by the instructor and those outlined within the worksheet. Each group adeptly summarizes the key points of discussion outlined in the worksheet and observes relevant phenomena within the e-module, thereby gaining insight into the topics to be covered during the learning process. This aligns with findings from (Astiti et al., 2021), highlighting educators' role in stimulating students' recognition of presented problems during the orientation stage.

Subsequently, students progress to the problem analysis stage. Here, they attain an average score of 81.25, categorized as very good performance. This indicates students' adeptness in formulating pertinent questions as required. These questions are directly related to the stated problems, serving as the foundation for hypothesis generation and subsequent conclusions. This finding resonates with Riyadi's assertion that questions in problem-solving-based learning should directly stem from the topic under discussion (Riyadi, 2015). The ability to pose questions effectively involves eliciting explanations regarding the what, why, and how, as well as interrogating topics based on hypothetical constructs (Farida, 2013).

The next stage is making a hypothesis. At the stage of making a hypothesis, the average score was 81.25 with a very good category. Most groups wrote the hypothesis completely and under the questions previously made. This is in line with the opinion that at this stage students are expected to be able to propose hypotheses or temporary conjectures to explain their ideas or ideas from the questions they ask. In this stage educators only accept the students' ideas and can't blame students's answers (Damayanti et al., 2016).

The subsequent phase involves data collection, during which students analyze the outcomes of previously encountered problems with assistance from e-modules and supplementary explanations provided by the researchers. At this juncture, the average score stands at 80.5.

Following this, students proceed to hypothesis testing. Here, students engage in guided discussions facilitated by questions in the worksheets, supplemented by instructional materials embedded within the e-module to enhance conceptual comprehension. The collaborative nature of these discussions encourages students to consult with their peers, fostering a deeper understanding of the studied concepts. Evaluation of the worksheet results reveals an impressive average score of 100 in the very good category, indicating students' adeptness in addressing previously encountered problems (Zakiah & Dwiningsih, 2022).

The last stage is making conclusions. At the stage of making conclusions, students are expected to be able to make temporary conclusions based on the learning that has been done, make a summary, and present the learning results orally. Students make conclusions in worksheets based on learning outcomes. In the process of collecting data, before and after students apply the problem-solving learning model assisted by an e-module on electron configuration material, students are directed to fill out pretest and posttest questions. The data from filling out the pretest and posttest questions are used to analyze the improvement of students' cognitive learning outcomes after the application of the problem-solving-based learning model assisted by the e-module. Analysis of the improvement of students' cognitive learning outcomes was carried out using the Mann-Whitney U test hypothesis test and determining N-Gain. Based on Table 6, the overall N-gain results of experimental class students' learning outcomes obtained an average pretest score of 17.2 and a posttest of 54.4 with an N-gain value of 0.445 with a moderate category. Enhanced cognitive learning outcomes are attributed to adherence to essential principles outlined in Piaget's constructivism theory, emphasizing the significance of student engagement and activity during the learning process (Zakiah & Dwiningsih, 2022). Achieving this objective necessitates leveraging advancements in technology to their fullest potential. The integration of technology-based media has been shown to amplify learning effectiveness, particularly when complemented by active learning methodologies (Zakiah & Dwiningsih, 2022; Asih et al., 2022).

In the control class, the average pretest result was 11.6 and posttest 40.2 with an N-gain value of 0.319. This value is much lower than the experimental class using e-module assistance. By using the same questions, the same material, and the same question indicator, there are significant differences. This shows that the use of e-modules can have a positive impact on students and improve student learning outcomes.

Significant disparities in learning outcomes were observed between the experimental and control classes. Despite the experimental class attaining a marginally higher average learning outcome compared to the control class, the achieved scores fell short of desired expectations, with the experimental class

securing an overall average of 54.4. This discrepancy may stem from students encountering considerable difficulty comprehending electron configuration material. This finding resonates with research conducted by Rahman et al. (2016), which identified challenges among students in grasping electron configuration concepts, particularly in understanding the correlation between the electron configuration of an ion and its respective position within the periodic table (Rahman et al., 2016). The study highlighted those students encountered considerable challenges with electron configuration material, with an overall difficulty rate of 71.12%. The pretest-posttest assessment featured numerous inquiries of various sub-materials within electron configuration. Consequently, the limiting factor contributing to students' relatively modest scores is the inherent complexity and abstract nature of electron configuration concepts, rendering them challenging to grasp (Fitriana, 2015; Fitriana & Gazali, 2017).

The data presented in Table 6 indicates a significant difference, with a 2-tailed value of 0.013. This discrepancy underscores higher improvements in learning outcomes within the experimental class compared to the control group, attributable to differing instructional approaches. While the experimental class utilized electron configuration e-modules, the control group relied solely on teacher explanation for instruction. The utilization of interactive learning media, such as e-modules, has been shown to enhance student learning outcomes due to their succinct content, ease of comprehension, and multimedia support, including videos and images. These features facilitate a more accessible learning experience for students (Abdullah et al., 2021). This perspective is further corroborated by Asih et al. (2022), whose findings indicate that students find e-modules more comprehensible compared to conventional learning. Consequently, these advantages contribute to increased student engagement and active participation in learning activities, thereby enhancing overall learning outcomes (Asih et al., 2022).

Based on the researchers' observations during the learning sessions, noticeable discrepancies were observed in the enthusiasm levels of students between the control and experimental classes. The control class, engaged in conventional learning methods, exhibited relatively low motivation towards learning, whereas the experimental class, implementing problem-based learning models, demonstrated remarkable levels of activity and motivation. The integration of technology-based media has been shown to enhance learning effectiveness, particularly when complemented by active learning methodologies (Zakiyah & Dwiningsih, 2022). Active learning, as defined by Kemendikbud (2014), entails interactive, inspiring, enjoyable, and motivating learning experiences for students. However, not all existing learning media in chemistry are conducive to fostering active learning. Interactive e-modules, on the other hand, offer an ideal platform for cultivating active learning environments, especially within the domain of chemistry (Salsabila & Nurjayadi, 2019). Research suggests a positive correlation between student motivation and learning outcomes, emphasizing the pivotal role of high learning motivation in achieving favourable educational outcomes (Oknaryana & Irfani, 2022). Furthermore, the interface of e-modules plays a crucial role in shaping student outcomes. Interactive and engaging interfaces mitigate student fatigue and boredom, resembling the experience of using mobile games. Leveraging game-like interfaces effectively introduces topics and complements traditional lectures, offering a more stimulating learning experience compared to conventional memorization-based approaches (Mariscal et al., 2012).

Following the non-parametric statistical analysis conducted with SPSS, the 2-tailed significance value is recorded as 0.013. Referring to Table 6, when the significance value is less than 0.05, the decision is to accept the alternative hypothesis (H_a) and reject the null hypothesis (H_0). Accordingly, the accepted hypothesis indicates a significant disparity in student learning outcomes when utilizing problem-solving-based learning e-modules compared to instances where no learning media is employed.

4. CONCLUSION

The use of electronic configuration e-modules can provide a significant increase in learning outcomes compared to those that do not use learning media. The 2-tailed value of 0.013 shows a significant difference between the control class and the experimental class. The utilization of e-modules has been shown to enhance student learning outcomes due to their succinct content, ease of comprehension, and multimedia support, including videos and images. These features facilitate a more accessible learning experience for students.

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