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Effectiveness of Problem-Based Learning Assisted by Cleo Card to Improve Motivation and Learning Outcomes on the Periodic System of Elements Material

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ABSTRAK

Pemahaman konsep sistem periodik unsur (SPU) masih menjadi kendala bagi sebagian besar siswa, yang ditunjukkan oleh rendahnya hasil belajar. Salah satu faktor yang memengaruhi hasil belajar adalah motivasi belajar. Upaya perbaikan pembelajaran diperlukan untuk meningkatkan kedua aspek tersebut, salah satunya melalui pemanfaatan media dan model pembelajaran yang tepat. Penelitian ini bertujuan untuk menguji keefektifan model Problem Based Learning (PBL) berbantuan Cleo Card terhadap motivasi dan hasil belajar, serta menganalisis hubungan antara motivasi dan hasil belajar siswa pada materi SPU. Penelitian menggunakan desain quasi experiment dengan rancangan non-equivalent pretest-posttest control group. Hasil penelitian menunjukkan bahwa penerapan model PBL berbantuan Cleo Card secara signifikan meningkatkan motivasi belajar (%N-gain 64,14%, kategori cukup efektif) dan hasil belajar (%N-gain 68,84%, kategori cukup efektif) dibandingkan kelas kontrol. Motivasi dan hasil belajar siswa kelas eksperimen mencapai ketuntasan masing-masing sebesar 100% dan 97,22%, sementara kelas kontrol hanya sebesar 47,22% dan 8,33%. Uji t menunjukkan pengaruh signifikan model PBL berbantuan Cleo Card terhadap motivasi dan hasil belajar ($p < 0,05$). Selain itu, terdapat hubungan yang kuat dan signifikan antara motivasi belajar dan hasil belajar dengan koefisien korelasi sebesar 1,00 dan signifikansi 0,297.

ABSTRACT

Students still experience difficulties in understanding the concept of the periodic system of elements (PSE), as reflected in their low learning outcomes. One of the key factors influencing learning outcomes is learning motivation. Therefore, appropriate learning models and media are needed to improve both aspects. This study aims to examine the effectiveness of the Problem-Based Learning (PBL) model assisted by Cleo Card in enhancing students' learning motivation and learning outcomes, as well as to analyze the relationship between motivation and learning outcomes on PSE material. The research employed a quasi-experimental design with a non-equivalent pretest-posttest control group design. The results showed that the application of the PBL model assisted by Cleo Card significantly improved students' learning motivation (%N-gain 64.14%, moderately effective) and learning outcomes (%N-gain 68.84%, moderately effective) compared to the control class. Mastery of motivation and learning outcomes in the experimental class reached 100% and 97.22%, respectively, while the control class only reached 47.22% and 8.33%. The t-test confirmed a significant effect of the PBL model with Cleo Card on both motivation and learning outcomes ($p < 0.05$). Furthermore, a strong and significant relationship was found between learning motivation and learning outcomes, with a correlation coefficient of 1.00 and a significance value of 0.297.

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INTRODUCTION

The quality of a nation's education is one of the key indicators of its overall development. Poor educational quality can lead to a nation's stagnation and decline (Nur & Kurniawati, 2022). One indicator of learning difficulties among students is low academic achievement (Priliyanti *et al.*, 2021). Based on interviews with chemistry teachers at SMAN 1 Ungaran, it was found that many students scored below the minimum competency criteria (MCC). Teachers also reported that students struggle with topics in the periodic system of elements, particularly in classifying elements, visualizing electron configurations, and analyzing periodic trends. In addition to low academic performance, the interviews also highlighted the crucial role of learning motivation in chemistry education. High learning motivation significantly contributes to improved student performance (Romadhoni *et al.*, 2017). Students with higher motivation tend to be more engaged and achieve better results, while those with lower motivation show less persistence and learning gains. Enhancing learning motivation can be achieved by maximizing students' active participation in the learning process (Sanjiwani *et al.*, 2018).

One instructional approach that addresses these challenges is the Problem-Based Learning (PBL) model. PBL begins with the presentation of a contextual problem, prompting students to independently acquire and integrate new knowledge (Aslan, 2021). This model encourages students to take an active role in their learning, resulting in a more effective learning experience. Providing opportunities for independent exploration and active engagement is expected to support students in understanding complex chemistry concepts (Harnitayasri & Irma, 2015). In a PBL environment, the teacher acts as a facilitator—posing problems, guiding discussion, stimulating inquiry, and providing necessary learning resources. This support helps to foster student intelligence and creativity (Hotimah, 2020).

In addition to learning models, instructional media play a vital role in enhancing the learning process. CLEO (Chemical Learning with Uno Card) is an educational card game designed by university students at Gadjah Mada University as a learning aid in chemistry, particularly for teaching the periodic system of elements. The Cleo Card is designed with vibrant visual animation and engaging gameplay rules to make chemistry learning more enjoyable. It features Augmented Reality (AR) and Voice Over (VO) technologies to enhance the user experience. Cleo Card aims to increase students' motivation by providing visual representations of abstract chemical concepts, enabling more efficient in-class learning, supporting independent learning outside the classroom, and improving student understanding through visual and auditory explanations of the periodic system. As such, the use of Cleo Card as a learning medium is considered a promising solution to overcome the challenges faced in chemistry instruction.

The novelty of this study lies in the integration of the Problem-Based Learning (PBL) model with the Cleo Card learning media, which incorporates both Augmented Reality (AR) and Voice Over (VO) features. While numerous studies have examined the individual effectiveness of PBL or educational card games in learning, research that specifically combines both elements within the context of the periodic

system remains limited. This study offers a new perspective in improving student motivation and learning outcomes through an approach that emphasizes problem-solving while leveraging visual and auditory technologies to bridge the gap between abstract concepts and concrete understanding. Thus, the findings of this research are expected to contribute to the development of more engaging and effective strategies in chemistry education, particularly for topics that are inherently challenging for students.

METHODS

This study employed a quasi-experimental design, specifically the non-equivalent pretest-posttest control group design. In this design, both the experimental and control groups were given a pretest prior to the intervention to assess their initial abilities and a posttest after the intervention to measure the learning outcomes. This approach was selected to examine the effectiveness of the treatment by comparing students' learning outcomes and motivation between two classes subjected to different instructional conditions.

Several statistical tests were conducted to analyze the data. First, the Kolmogorov–Smirnov normality test was used to determine whether the data from the sample followed a normal distribution. The Levene's test for homogeneity was applied to examine whether the sample groups had equal variances. To assess the effectiveness of the intervention, the N-Gain test was used to measure the relative improvement from pretest to posttest. An independent samples t-test was conducted to test the null hypothesis and determine whether there was a statistically significant difference between the means of the two groups. Lastly, a correlation analysis was performed to identify the direction and strength of the relationship between learning motivation and learning outcomes.

RESULT AND DISCUSSION

Result

The students' learning outcome data consisted of pretest and posttest scores collected from Grade XI MIPA 3 (experimental class) and Grade XI MIPA 4 (control class). In the experimental class, students received instruction using the Problem-Based Learning (PBL) model assisted by Cleo Card on the topic of the Periodic System of Elements (PSE), whereas the control class was taught using the PBL model without Cleo Card on the same topic. Cognitive learning outcomes related to the PSE material were measured in both groups.

Table 1 presents the interpretation of the N-Gain analysis results of students' learning outcomes in both the experimental and control classes. The N-Gain scores for both classes fall into the moderate category. However, in terms of effectiveness, the control class is categorized as ineffective, while the experimental class is categorized as moderately effective.

Table 1. N-Gain Analysis Results of Students' Learning Outcomes

Class	N-gain Score	N-gain Category	Effectiveness Category
Experimental	0,69 (68,84%)	Moderate	Moderately Effective
Control	0,37 (37,68%)	Moderate	Ineffective

Table 2 presents the results of the N-Gain analysis of students' learning motivation in both classes, which fall into the moderate category. However, in terms of effectiveness, the control class is categorized as ineffective, while the experimental class is categorized as moderately effective.

Table 2. N-Gain Analysis Results of Learning Motivation

Class	N-gain Score	N-gain Category	Effectiveness Category
Experimental	0,64 (64,14%)	Moderate	Moderately Effective
Control	0,31 (31,20%)	Moderate	Ineffective

Based on the N-Gain scores of both classes, the experimental class demonstrated a significantly higher improvement in learning outcomes compared to the control class. This indicates that the treatment applied in the experimental class had a positive impact on students' learning achievement.

The basis for decision-making in the T-test is as follows: if the significance value is greater than 0.05, it indicates that there is no significant effect of the PBL model assisted by Cleo Card on students' learning outcomes. Conversely, if the significance value is less than 0.05, it indicates that the implementation of the PBL model with Cleo Card has a significant effect on students' learning outcomes.

Table 3. T-Test Results on Learning Outcomes and Learning Motivation

Criteria	*Sig*(2-*tailed*)	Conclusion
T-Test on Learning Outcomes	0,000	H_0 is rejected and H_1 is accepted
T-Test on Learning Motivation	0,000	H_0 is rejected and H_1 is accepted

Table 3 provides information that the significance value from the T-test is 0.000, which is less than 0.05. This indicates that H_0 is rejected and H_1 is accepted, meaning that there is a significant effect of the implementation of the PBL model assisted by Cleo Card on students' learning motivation and learning outcomes in the topic of the Periodic System of Elements (PSE).

Discussion

This study generated several sets of data, including students' pretest and posttest scores on the Periodic System of Elements (PSE) material, as well as their learning motivation scores before and after the implementation of the PBL model. The learning outcome data were collected from Grade XI MIPA 3 (experimental class) and Grade XI MIPA 4 (control class). In the experimental class, students received instruction using the Problem-Based Learning (PBL) model assisted by Cleo Card on the PSE topic, while the control class received instruction using the PBL model only, without the Cleo Card, on the same material.

The improvement in students' learning motivation was measured using the N-Gain score. Students were given a learning motivation questionnaire to complete both before and after the use of Cleo Card. This treatment was intended to compare the changes in students' motivation before and after instruction using the Cleo Card media. The average pretest motivation scores in the experimental and control classes were 65.16 and 62.40, respectively, indicating a relatively small difference. After the treatment, the average motivation scores in both classes increased. The average increase in learning motivation in the experimental class was 21.99, while the control class showed an increase of 12.43.

The improvement in motivation scores was analyzed using the N-Gain score. The average N-Gain scores in the experimental and control classes were categorized as moderate, with values of 0.64 and 0.31, respectively. The corresponding percentage N-Gain scores were 64.14% for the experimental class and 31.20% for the control class. The effectiveness of the PBL model assisted by Cleo Card in improving student motivation was confirmed by the T-test, which yielded a significance value of 0.000. Since this value is less than 0.05, H_0 is rejected and H_1 is accepted, indicating a significant effect of the Cleo Card-assisted PBL model on students' learning motivation in the topic of the Periodic System of Elements (PSE).

Learning motivation is considered satisfactory when posttest motivation scores exceed 75. A significant difference was observed between the two classes: in the experimental class, 100% of students scored above 75, while in the control class, only 47.22% achieved this level. Students' learning motivation was influenced by both intrinsic and extrinsic indicators, which are interrelated. These indicators include aspects such as enjoyment, interest, knowledge, achievement, attention, teacher influence, peer support, learning facilities, and parental involvement. The effectiveness of the PBL model assisted by Cleo Card was further supported by student response data. Students were highly engaged during the gameplay, indicating that Cleo Card was effective as a learning medium. This was reflected in the students' responses to indicators 1 and 3 on the questionnaire, which stated that learning chemistry with Cleo Card increased their enthusiasm and seriousness during lessons. The effectiveness was attributed to the engaging content of Cleo Card, which motivated students to learn.

Cleo Card, which integrates Augmented Reality (AR) and Voice Over (VO), helps foster students' spatial visualization skills—the ability to mentally visualize transformations. The 3D AR display enables students to better observe changes in electron paths, thus addressing the limitations of conventional media, such as drawing on the chalkboard. Learning media is considered something enjoyable, engaging, and entertaining. When instruction is both interesting and enjoyable, students' motivation to participate in learning tends to increase. This was evidenced in the current study by students being more active and enthusiastic during learning activities that involved the use of Cleo Card. Group-based learning also supported students in communicating and sharing knowledge with one another to solve problems collaboratively.

Figure 1. AR and VO Display of Cleo Card

These findings are consistent with those of Macariu et al. (2020), who investigated the effectiveness of the AR Chemistry application in enhancing students' motivation in chemistry learning. Their results showed a significant improvement in students' learning motivation. Learning with AR Chemistry stimulated students' curiosity and fostered logical thinking in a more interactive chemistry learning environment. The use of AR attracted more students in the classroom by offering visually appealing representations, which also helped them better retain new information. The motivation gained through such tools is expected to foster students' persistence and enthusiasm, encouraging active participation in learning activities such as discussions, and ultimately leading to improved learning outcomes and understanding.

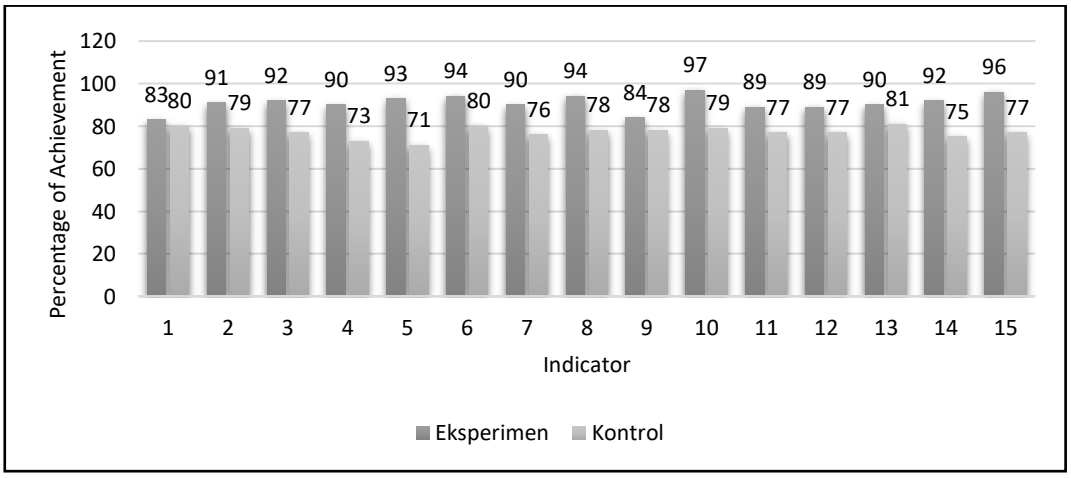

Figure 2. Achievement of Intrinsic Learning Motivation

To further evaluate the effectiveness of the PBL model assisted by Cleo Card in enhancing students' motivation, an analysis of the achievement levels across each learning motivation indicator was

conducted for both the experimental and control classes. The learning motivation indicators were categorized into two types: intrinsic motivation and extrinsic motivation. The level of achievement of each motivation indicator in the experimental and control classes is shown in Figure 2 for intrinsic motivation and in Figure 3 for extrinsic motivation.

Based on the data, the highest achievement in intrinsic learning motivation indicators in the experimental class was found in Indicator 10 (97%), which asked about students' feelings of boredom during chemistry lessons. This suggests that students in the experimental class, where Cleo Card was used as a learning medium, felt more interested and engaged compared to those in the control class (79%) where Cleo Card was not implemented. The lowest achievement in intrinsic motivation in the experimental class was observed in Indicator 1 (83%), which questioned students' efforts to complete chemistry assignments earlier and on time. This indicates that motivation related to punctuality and early task completion was still relatively lower compared to other intrinsic motivation indicators.

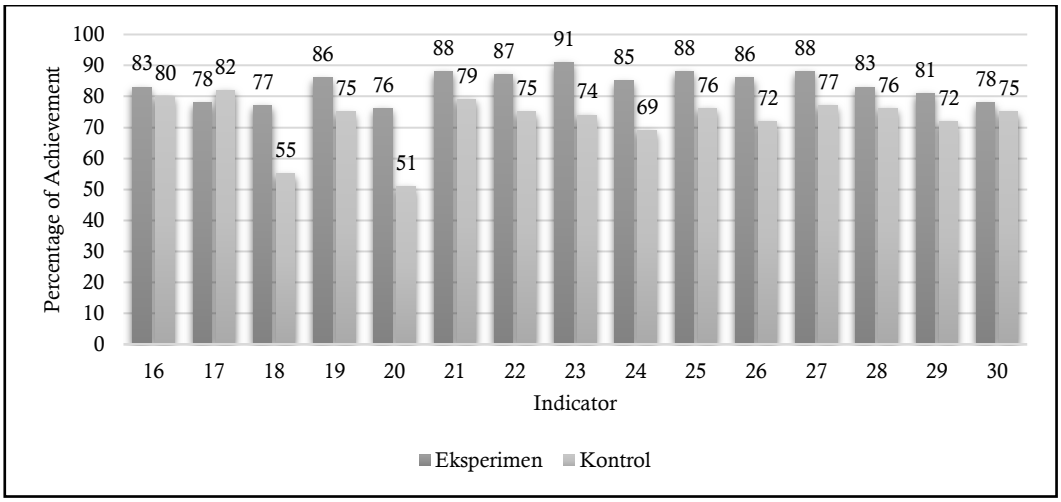

Figure 3. Achievement of Extrinsic Learning Motivation

Extrinsic learning motivation is closely related to intrinsic motivation. The highest achievement in extrinsic motivation was observed in Indicator 23 (91%), which asked about students' preferred learning environment for better comprehension. This suggests that students in the experimental class preferred a quiet learning environment, as it allowed them to better understand the material. In contrast, the lowest achievement in extrinsic motivation was found in Indicator 20 (76%), which addressed students' enthusiasm based on the classroom atmosphere. This indicates that students' motivation to learn in a clean and orderly classroom was relatively lower compared to other extrinsic motivation indicators.

In Indicator 29, which asked about students' interest in learning chemistry through game-based media, the experimental class showed a high response of 81%, whereas the control class, which did not use game-based media, showed an achievement of only 72%. This result is supported by intrinsic

motivation indicators 8 and 15, which addressed students' enthusiasm and participation throughout the entire lesson. In Indicator 8, the experimental class reached 94%, while the control class reached 78%. In Indicator 15, the achievement in the experimental class was 96%, while in the control class it was only 77%. These results demonstrate that the use of Cleo Card as a game-based learning medium increased students' interest and enthusiasm during chemistry lessons and helped reduce off-task behavior such as leaving the class or skipping lessons.

When comparing the two graphs, it is evident that the achievement of each learning motivation indicator was higher in the experimental class than in the control class. These findings confirm that students' learning motivation in the experimental group was stronger than that in the control group. Furthermore, both intrinsic and extrinsic motivation are interrelated, with intrinsic motivation playing a more significant role in enhancing overall learning motivation. This aligns with Emda's (2018) study, which concluded that improving motivation through intrinsic factors is more effective than relying on extrinsic factors. Intrinsic motivation leads students to engage in learning more sincerely, resulting in more meaningful and positive learning outcomes.

The effectiveness of students' learning outcomes was measured using the N-Gain score. The increase in students' learning performance was calculated by comparing pretest and posttest scores. The average N-Gain scores for the experimental and control classes were 0.69 and 0.37, respectively, both falling into the moderate category. In terms of percentage, the N-Gain scores were 68.84% for the experimental class and 37.68% for the control class. These results classify the experimental class as moderately effective, while the control class is considered ineffective.

Students' chemistry learning outcomes improved in both classes after the implementation of the PBL model. In the experimental class, the average score increased from 33.25 to 79.60, while in the control class, it increased from 33.89 to 58.89. The improvement in the experimental class was significant, demonstrating that the PBL model assisted by Cleo Card helped students achieve better learning outcomes compared to traditional methods. The effectiveness of this model is further supported by the T-test results, which yielded a significance value of 0.000. Since this value is less than 0.05, H_0 is rejected and H_1 is accepted, indicating that the implementation of the Cleo Card-assisted PBL model had a significant effect on students' learning outcomes in the Periodic System of Elements (PSE) topic.

Mastery learning is defined as students achieving a posttest score greater than 70. The percentage of students who met this criterion differed significantly between the two classes: 97.22% of students in the experimental class achieved scores above 70, compared to only 8.33% in the control class. These findings are consistent with the study by Abanikannda (2016), which found that the implementation of the PBL model effectively improved student learning outcomes and helped develop essential skills such as communication, analysis, collaboration, and problem-solving. Similarly, Sari et al. (2018) reported that students who learned using UNO card-based media achieved higher learning outcomes than those

who received direct instruction. Game-based media also provided a more enjoyable learning experience and fostered student motivation, making the learning process more memorable.

The relationship between students' learning motivation and learning outcomes was also examined through a correlation test. At the end of the learning process, students were given a post-test, which was then analyzed to measure the improvement in critical thinking skills. To determine the relationship between two variables, the correlation coefficient must fall within the range of -1 to 1. Based on the analyzed data, the correlation coefficient between learning motivation and learning outcomes was found to be 1.00, indicating a perfect correlation. The two-tailed significance value (sig. (2-tailed)) for the correlation between motivation and learning outcomes was 0.297, which is considered significant. Therefore, it can be concluded that the relationship between students' learning motivation and their learning outcomes is both strong and significant.

The results of this study are in line with previous research by Dewi (2019), which found that both intrinsic and extrinsic motivation are correlated with student learning outcomes, with intrinsic motivation having a stronger influence. The higher level of learning motivation observed among students in the experimental class may have contributed to their superior academic performance compared to those in the control class. A related study by Sari (2020) also emphasized that learning motivation serves as a critical indicator of student achievement.

Furthermore, a study by Lestari et al. (2025) revealed that chemistry teachers in vocational high schools face significant challenges in implementing interdisciplinary learning projects such as IPAS. These challenges stem primarily from limited interdisciplinary knowledge and a lack of integrated training. This finding underscores the need for innovative and contextualized chemistry teaching strategies. One promising approach involves combining problem-based learning (PBL) with interactive educational media such as the Cleo Card. This integration not only enhances student motivation but also facilitates a deeper understanding of abstract chemical concepts through engaging and tangible learning experiences.

These findings align with Dewi (2019), who reported that both intrinsic and extrinsic motivation are correlated with academic achievement, with intrinsic motivation having a stronger influence on learning outcomes. The higher motivation levels among students in the experimental class may explain their better performance compared to the control class. Similar results were reported by Sari (2020), who confirmed that learning motivation is one of the key indicators of students' academic success.

CONCLUSION

The PBL model assisted by Cleo Card was found to improve students' learning motivation, as evidenced by a percentage N-Gain of 64.14% in the experimental class (categorized as moderately effective) compared to 31.20% in the control class (less effective). Mastery of learning motivation in the

experimental class reached 100%, while only 47.22% of students in the control class achieved mastery. The implementation of the PBL model assisted by Cleo Card also had an impact on students' learning outcomes, as shown by a percentage N-Gain of 68.84% in the experimental class (moderately effective) and 37.36% in the control class (less effective). Mastery learning in the experimental class reached 97.22%, while in the control class only 8.33% of students met the minimum standard.

The results of the T-test showed a significance value of 0.000, indicating a significant effect of the PBL model assisted by Cleo Card on both students' learning motivation and learning outcomes. Furthermore, motivation was found to influence learning outcomes, as indicated by the correlation test. The correlation coefficient was 1.00, categorized as perfect, with a significance value of 0.297, confirming that the relationship between learning motivation and learning outcomes is both strong and statistically significant.

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