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Project-Based Learning and Its Effect on Students' Engagement and Achievement in Acid–Base Chemistry: A Quantitative Study in Secondary Schools

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ABSTRACT

This study aims to examine the effect of the Project-Based Learning (PjBL) model on students' learning interest and learning outcomes in acid–base material among eleventh-grade students at SMAN 2 Makassar. A quantitative approach was employed using a pre-experimental design with a one-group pretest–posttest format. The results indicate that the average students' learning interest increased from 37.60% to 83.22%, reaching a high category, with the N-gain distribution predominantly in the high category (70%). Learning outcomes also improved, as evidenced by the N-gain distribution in the medium category (43.3%) and high category (56.7%). Furthermore, there was an increase in mastery across all indicators of acid–base material following the implementation of the PjBL model. In conclusion, the Project-Based Learning model is effective in improving both students' learning interest and learning outcomes. The model facilitates active, contextual, and meaningful learning experiences that support deeper conceptual understanding.

INTRODUCTION

Chemistry learning constitutes a fundamental domain within science education, characterized by a high level of complexity due to the abstract and multidimensional nature of its concepts. Chemical knowledge encompasses not only observable phenomena at the macroscopic level, but also microscopic representations and symbolic expressions that require advanced cognitive processing from students. This inherent complexity often leads to significant learning difficulties, particularly when students are expected to integrate multiple levels of representation simultaneously. As a consequence, many learners struggle to achieve a comprehensive understanding of chemical concepts, especially in topics that are highly conceptual in nature, such as acid–base chemistry. These challenges frequently result in low academic achievement and the persistence of misconceptions throughout the learning process.

Such conditions are further exacerbated by the predominance of traditional teacher-centered instructional approaches, which tend to limit students' opportunities to actively construct their own understanding. In these contexts, learners are often positioned as passive recipients of information, rather than active participants in the learning process. Previous studies in science education have emphasized that ineffective pedagogical strategies and insufficient student engagement contribute significantly to poor conceptual understanding and learning outcomes . Consequently, there is an increasing need to adopt instructional models that promote active learning and deeper cognitive engagement.

Among the various topics in chemistry, acid–base concepts have been consistently identified as particularly difficult for students to master. These difficulties are not only associated with the abstract nature of the content but also with the prevalence of recurring misconceptions across different educational levels. Moreover, the lack of contextualized learning experiences and limited opportunities for higher-order thinking further hinder students' ability to internalize these concepts effectively. In addition, affective factors such as learning interest play a crucial role in determining academic success, as students with low levels of engagement and motivation tend to exhibit lower learning outcomes.

To address these challenges, constructivist-based learning approaches have been widely advocated as effective alternatives to traditional instruction. Constructivism posits that knowledge is actively constructed by learners through interaction with their environment, rather than passively received. Within this framework, Project-Based Learning (PjBL) emerges as a pedagogical model that emphasizes student-centered learning through meaningful project activities. PjBL encourages learners to engage in exploration, investigation, and problem-solving in real-world contexts, thereby facilitating deeper conceptual understanding and knowledge retention.

Furthermore, PjBL promotes collaboration, reflection, and the development of critical and creative thinking skills, which are essential competencies in 21st-century education. Empirical evidence suggests that the implementation of PjBL has a positive impact on student engagement and learning outcomes across cognitive, affective, and behavioral domains. Active involvement in project-based activities enables students to connect theoretical knowledge with practical applications, resulting in more meaningful and authentic learning experiences. In addition, the integration of innovative approaches, such as digital technologies and simulations, has been shown to enhance the effectiveness of chemistry instruction by providing concrete visualizations of abstract concepts and fostering interactive learning environments.

Despite these promising findings, there remains a notable research gap in the literature. Most previous studies have examined the effects of PjBL on either student engagement or learning outcomes separately, rather than investigating both variables simultaneously within a robust quantitative framework. Moreover, empirical studies focusing on the implementation of PjBL in the context of acid–base learning at the secondary education level, particularly in developing countries such as Indonesia, are still limited. This highlights the need for further research to provide more comprehensive and generalizable evidence.

Therefore, this study offers a novel contribution by simultaneously examining the effect of Project-Based Learning on both student engagement and learning outcomes within the context of acid–base chemistry using a quantitative approach. The aim of this research is to empirically investigate the influence of the Project-Based Learning model on students' engagement and learning outcomes. Accordingly, the research question addressed in this study is: Is there a significant effect of the Project-Based Learning model on students' engagement and learning outcomes in acid–base learning?

THEORETICAL REVIEW

Project-Based Learning (PjBL) in Instruction

Project-Based Learning (PjBL) is an instructional model grounded in constructivist theory, in which learners actively construct knowledge through meaningful and contextual learning experiences. This approach positions students at the center of the learning process by engaging them in project-based activities that require investigation, problem-solving, and collaboration. Within the PjBL framework, learning is not solely oriented toward final outcomes, but also emphasizes the processes of exploration and knowledge construction undertaken by students (Cocco, 2006; Blumenfeld et al., 2000).

PjBL is characterized by several key elements, including the presence of a *driving question*, constructive investigation, collaborative learning, and the production of a final artifact that represents students' understanding. The learning activities involve designing, collecting, analyzing, and presenting data, thereby fostering the development of critical and creative thinking skills. Furthermore, PjBL promotes contextual and problem-based learning, enabling students to connect theoretical concepts with real-life situations (Helle et al., 2006). Such characteristics align with contemporary perspectives in science education, which emphasize active learning and the development of higher-order thinking skills .

Learning Interest as a Component of Student Engagement

Learning interest constitutes a critical component of student engagement, reflecting students' inclination to participate actively in the learning process. It encompasses not only students' attraction to the subject matter, but also their attention, involvement, and sense of enjoyment during learning activities. In the context of science education, learning interest is closely associated with students' attitudes toward the subject and their academic achievement.

Empirical studies have demonstrated a positive relationship between learning interest and academic performance. Students with higher levels of interest tend to exhibit greater persistence, deeper engagement, and improved learning outcomes compared to those with lower levels of interest. Moreover, learning interest contributes to students' ability to achieve conceptual understanding, particularly in chemistry, where active engagement is essential for mastering complex and abstract concepts. This relationship highlights the importance of fostering affective engagement as a means to enhance overall learning effectiveness.

Learning Outcomes in Chemistry Education

Learning outcomes serve as a primary indicator of the effectiveness of the instructional process, particularly in chemistry education, which requires the comprehension of abstract and multi-representational concepts. Chemistry involves the integration of macroscopic, microscopic, and symbolic representations, making it inherently complex and challenging for students.

Difficulties in understanding chemical concepts are often attributed to their abstract nature, which cannot be directly observed, leading to low conceptual understanding and the persistence of misconceptions. Previous studies have emphasized that students frequently struggle to connect different levels of chemical representation, resulting in fragmented knowledge structures. Therefore, instructional approaches that facilitate the connection between abstract concepts and concrete experiences are essential to promote meaningful learning and improve learning outcomes.

The Effect of Project-Based Learning on Learning Interest and Outcomes

A growing body of research indicates that the implementation of Project-Based Learning has a positive impact on both learning interest and learning outcomes. PjBL engages students actively in the learning process through meaningful and relevant project activities, thereby increasing their motivation and engagement. This active involvement contributes to improved conceptual understanding and academic performance.

Studies have shown that PjBL enhances cognitive, affective, and behavioral domains of learning by promoting active participation and experiential learning. Additionally, PjBL has been found to significantly improve students' motivation and scientific process skills compared to conventional instructional methods. Through project-based activities, students are encouraged to explore concepts in depth, collaborate with peers, and apply their knowledge in practical contexts, which ultimately leads to improved learning outcomes.

Relevance of PjBL in Chemistry Learning

In the context of chemistry education, the application of Project-Based Learning is particularly relevant due to its potential to address the challenges associated with abstract concepts. Through project-based activities, students can engage in experiments, observations, and data analysis, which facilitate the visualization and understanding of complex chemical phenomena. This approach enables students to bridge the gap between theory and practice, resulting in more meaningful learning experiences.

Furthermore, PjBL supports increased student engagement through collaborative and interactive learning environments. Active participation in group-based projects enhances students' communication and teamwork skills while fostering a deeper understanding of the subject matter. The integration of PjBL with technological tools and digital simulations has also been shown to further enhance conceptual understanding and student engagement in chemistry learning, providing innovative opportunities to visualize abstract processes and promote interactive learning environments.

Overall, the literature highlights the significant potential of Project-Based Learning as an effective instructional model for improving both affective and cognitive outcomes in chemistry education.

METHODOLOGY

This study employed a quantitative approach using a pre-experimental design to examine the effectiveness of the Project-Based Learning (PjBL) model in enhancing students' learning interest and learning outcomes in acid–base material. Specifically, the research adopted a one-group pretest–posttest design, in which a single group of participants received the instructional treatment through the implementation of PjBL. The comparison between pre-intervention and post-intervention performance was conducted through pretest and posttest measurements. The selection of this design was based on its suitability for identifying changes attributable to the instructional intervention, particularly within the context of chemistry learning that requires active student engagement and experiential understanding. The study was conducted during the second semester of the 2024/2025 academic year at SMAN 2 Makassar.

The population of this study consisted of all eleventh-grade students enrolled in the chemistry specialization program at SMAN 2 Makassar, comprising four classes in the 2024/2025 academic year. The sampling technique applied was simple random sampling, in which one class was randomly selected from the population assumed to be relatively homogeneous in characteristics. Based on this procedure, class XI Chemistry 2 was selected as the research sample and designated as the experimental group. This approach was intended to minimize sampling bias and ensure equal opportunity for each class to be selected as the study subject.

The research instruments consisted of two main components: a learning interest questionnaire and a learning outcomes test. The learning interest questionnaire was developed using a Likert-scale format in the form of a checklist to capture students' levels of agreement with a series of statements. The scale comprised four response categories: strongly agree, agree, disagree, and strongly disagree. The instrument was constructed based on indicators of learning interest, including attention, engagement, curiosity, and enjoyment during the learning process. A total of 20 items were included, consisting of both positively and negatively worded statements to reduce response bias. Meanwhile, students' learning outcomes were measured using an essay-based test aligned with the competency indicators of acid–base material. The test instrument underwent content validation by subject-matter experts and item analysis procedures, including difficulty index, discrimination power, validity, and reliability testing, to ensure its adequacy as a measurement tool.

The research procedure was conducted in three main stages: the preliminary stage, the implementation stage, and the final stage. During the preliminary stage, students were administered a pretest to assess their initial understanding of acid–base concepts, along with an initial questionnaire to determine their baseline level of learning interest. In the implementation stage, instruction was carried out using the Project-Based Learning model, which involved project planning, experimental activities, data collection and analysis, and the presentation of project outcomes by students. This model was designed to promote active student participation and facilitate deeper conceptual understanding through authentic learning experiences. In the final stage, students completed a posttest and a final questionnaire to measure changes in both learning outcomes and learning interest following the PjBL intervention.

The collected data were analyzed quantitatively using both descriptive and inferential statistical techniques. The improvement in students' learning interest and learning outcomes was calculated using the normalized gain (N-gain), derived from the difference between pretest and posttest scores normalized to the maximum possible score. The N-gain values were categorized into three levels: low ($g < 0.3$), medium ($0.3 \le g < 0.7$), and high ($g \ge 0.7$). The instructional model was considered effective if the resulting N-gain fell within the medium or high category. Furthermore, data normality was assessed using the Kolmogorov–Smirnov test at a significance level of 0.05 to determine the distribution characteristics. Given that pre-experimental data do not always meet the assumption of normality, hypothesis testing was conducted using the non-parametric Wilcoxon signed-rank test to examine significant differences between pretest and posttest scores. This analysis provided empirical evidence regarding the effectiveness of the Project-Based Learning model in significantly improving students' learning interest and learning outcomes.

RESULTS

This section presents the empirical findings regarding the changes in students' learning interest and learning outcomes following the implementation of the Project-Based Learning (PjBL) model in acid–base instruction for eleventh-grade students at SMAN 2 Makassar. A total of 30 students participated in this study as members of a single experimental group. The results include data on learning interest achievement, N-gain distribution, and learning outcome mastery across instructional indicators.

Students' Learning Interest

Table 1 presents the percentage of achievement for each indicator of learning interest in both the pretest and posttest phases.

Table 1. Percentage of Achievement of Learning Interest Indicators

No	Indicator	Pretest (%)	Category	Posttest (%)	Category
1	Enjoyment	38.34	Very low	83.19	High
2	Attention	36.87	Very low	83.95	High
3	Engagement	37.29	Very low	82.29	High
4	Interest	37.91	Very low	83.47	High
	Average	37.60	Very low	83.22	High

As shown in Table 1, all indicators of learning interest increased substantially from the *very low* category in the pretest to the *high* category in the posttest. The average score improved from 37.60% to 83.22%, indicating a notable shift in students' affective engagement during the learning process.

Improvement in Learning Interest (N-Gain)

The distribution of students' improvement in learning interest based on N-gain values is presented in Table 2.

Table 2. Distribution of N-Gain in Learning Interest

N-gain Value	Category	Frequency	Percentage (%)
$g < 0.3$	Low	1	3.33
$0.3 \leq g < 0.7$	Medium	8	26.67
$g \geq 0.7$	High	21	70.00
Total		30	100

Table 2 indicates that the majority of students (70%) achieved a high level of improvement in learning interest, while only one student (3.33%) remained in the low category.

Students' Learning Outcomes

Table 3 presents the percentage of learning mastery for each instructional indicator before and after the intervention.

Table 3. Percentage of Learning Mastery per Indicator

No	Indicator	Pretest (%)	Posttest (%)
1	Identifying acid–base properties	43.3	90.0
2	Calculating H^+ and OH^- concentration	33.3	73.3
3	Designing acid–base indicator experiments	20.0	63.3
4	Calculating pH values	33.3	73.3
5	Drawing conclusions from experiments	23.3	60.0

6	Analyzing pH transition ranges	23.3	60.0
7	Analyzing titration data	16.6	53.3
8	Interpreting titration curves	53.3	86.6
9	Designing titration experiments	20.0	63.3

As illustrated in Table 3, all indicators demonstrated an increase in mastery from pretest to posttest, reflecting improvements across both conceptual understanding and higher-order thinking skills.

Improvement in Learning Outcomes (N-Gain)

The distribution of N-gain scores for learning outcomes is presented in Table 4.

Table 4. Distribution of N-Gain in Learning Outcomes

N-gain Value	Category	Frequency	Percentage (%)
g < 0.3	Low	0	0
0.3 ≤ g < 0.7	Medium	13	43.3
g ≥ 0.7	High	17	56.7
Total		30	100

Table 4 shows that all students experienced improvement in learning outcomes, with 56.7% categorized as high and 43.3% as medium. No students were classified in the low category.

DISCUSSION

The findings of this study indicate that the implementation of the Project-Based Learning (PjBL) model resulted in observable improvements in both students' learning interest and learning outcomes in acid–base material. The increase in learning interest, reflected by the shift from a very low to a high category, suggests that project-based instruction is capable of creating more meaningful and engaging learning experiences. This outcome is consistent with the fundamental characteristics of PjBL, which position students as active agents in the learning process, enabling them to construct knowledge through contextualized project activities rather than passively receiving information. Such active engagement is widely recognized as a key factor in fostering students' interest, as it allows them to explore, discuss, and apply concepts in authentic situations.

The improvement observed across all indicators of learning interest—namely enjoyment, attention, engagement, and curiosity—demonstrates that PjBL influences not only the cognitive domain but also the affective and behavioral dimensions of learning. This finding aligns with previous research indicating that PjBL enhances multiple aspects of student engagement, including emotional involvement and active participation in classroom activities. When students experience enjoyment and interest in the learning process, they are more likely to demonstrate sustained attention and active involvement, which in turn supports deeper learning. Therefore, the increase in learning interest observed in this study can be interpreted as the result of meaningful project activities combined with active student participation.

Furthermore, the distribution of N-gain scores in learning interest, which is dominated by the high category, reinforces the effectiveness of the PjBL model in enhancing students' affective engagement. The majority of students experienced substantial improvement, indicating that project-based instruction can accommodate diverse learner characteristics. This can be attributed to the flexible and adaptive nature of PjBL, which allows students to engage according to their individual learning styles while collaborating with peers to complete project tasks. Such a learning environment promotes inclusivity and participation, as supported by prior studies highlighting the role of social interaction and collaborative work in increasing student engagement.

In addition to learning interest, the results also reveal improvements in learning outcomes across all instructional indicators. The increased percentage of students achieving mastery in each indicator suggests that PjBL contributes to a deeper understanding of acid–base concepts. This is consistent with the nature of project-based learning, which emphasizes experiential learning through experimentation, observation, and problem-solving activities. These processes enable students to connect abstract concepts with real-world experiences, which is particularly important in chemistry education, where many concepts are inherently abstract .

The improvement in learning outcomes can also be explained by the knowledge construction processes embedded in PjBL. Students are actively involved in investigation, data collection, and analysis, allowing them to develop more integrated and robust conceptual understanding. Previous studies have demonstrated that PjBL positively affects cognitive achievement by increasing student engagement in learning activities and by utilizing diverse assessment methods, including tests, observations, and project artifacts. Thus, the enhanced learning outcomes observed in this study can be attributed to the active and meaningful learning processes facilitated by PjBL.

Moreover, the N-gain distribution for learning outcomes indicates that all students achieved improvement within the medium and high categories, with no students classified as low. This finding suggests that PjBL is effective in promoting learning gains across the entire group of participants. The absence of low-category improvement implies that the model provides equitable learning opportunities, supporting all students regardless of their initial abilities. This result is consistent with previous research demonstrating that PjBL significantly improves academic achievement compared to conventional instructional methods.

The findings also reveal a relationship between learning interest and learning outcomes. Students who demonstrated higher levels of interest tended to show greater improvement in learning outcomes. This relationship can be explained by the interaction between affective and cognitive domains, where increased interest motivates students to engage more actively in the learning process, leading to better understanding and performance. Previous studies have similarly reported a positive correlation between students' attitudes or interest and their academic achievement, highlighting the importance of affective factors in learning.

From a theoretical perspective, these findings reinforce the relevance of constructivist approaches in chemistry education. PjBL, as an implementation of constructivist theory, provides opportunities for students to construct knowledge through direct experience and social interaction. In this context, learning shifts from a teacher-centered paradigm to a student-centered process, where learners actively build their understanding based on prior knowledge and new experiences. Meaningful learning occurs when students are actively involved and able to relate new information to existing cognitive structures, which is a central principle of constructivism.

In addition to its theoretical contributions, this study offers practical implications for chemistry instruction. The application of PjBL can serve as an effective alternative strategy to improve the quality of learning, particularly for abstract topics such as acid–base chemistry. Teachers are encouraged to design projects that are relevant to students' daily lives, thereby enhancing the contextualization and meaningfulness of learning. Furthermore, PjBL supports the development of essential 21st-century skills, including critical thinking, creativity, and collaboration.

Nevertheless, several limitations should be acknowledged. The use of a pre-experimental design without a control group limits the ability to directly compare the effectiveness of PjBL with other instructional approaches. Additionally, the study was conducted in a single class with a relatively small sample size, which may affect the generalizability of the findings. Future research is therefore recommended to employ more rigorous experimental designs and larger, more diverse samples to strengthen the validity and applicability of the results.

Overall, the findings of this study demonstrate that the Project-Based Learning model holds substantial potential in enhancing both learning interest and learning outcomes in chemistry education. These results contribute to the growing body of empirical evidence supporting innovative and student-centered instructional strategies, and further establish PjBL as a relevant and effective approach in 21st-century education.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this study, it can be concluded that the implementation of the Project-Based Learning (PjBL) model has a positive effect on students' learning interest and learning outcomes in acid–base material among eleventh-grade students at SMAN 2 Makassar. The improvement in learning interest is evidenced by the shift in the average achievement from the very low category to the high category following the implementation of project-based instruction. All indicators of learning interest, including enjoyment, attention, engagement, and curiosity, demonstrated consistent improvement, supported by the distribution of N-gain values predominantly in the high category. These results indicate that PjBL is effective in creating a more engaging, participatory, and student-centered learning environment.

In addition, students' learning outcomes showed significant improvement, as reflected in the increased percentage of mastery across all instructional indicators and the distribution of N-gain values within the medium and high categories. The absence of students in the low improvement category suggests that the PjBL model provides a uniformly positive impact across all participants. This improvement indicates that project-based learning facilitates a deeper understanding of acid–base concepts through direct, contextual, and problem-based learning experiences.

Overall, the findings of this study contribute to the advancement of chemistry education by supporting the use of Project-Based Learning as an effective instructional strategy to enhance both affective and cognitive learning domains. The model not only improves academic achievement but also fosters students' interest, which plays a critical role in the overall success of the learning process.

For future research, it is recommended to employ more robust research designs, such as quasi-experimental or true experimental designs with control groups, in order to provide more comprehensive comparisons regarding instructional effectiveness. Furthermore, future studies should involve larger and more diverse samples, as well as explore additional variables such as critical thinking skills, creativity, and self-regulated learning, to broaden the scope and contribution of research in chemistry education.

FURTHER STUDY

This study employed a pre-experimental design using a one-group pretest–posttest approach, which did not involve a control group for comparison. Consequently, this design limits the ability to isolate the effect of the Project-Based Learning (PjBL) model more rigorously in comparison with other instructional approaches. Without a control group, the observed improvements in learning interest and learning outcomes cannot be exclusively attributed to the intervention, as other external or uncontrolled factors may have influenced the results.

In addition, the relatively small sample size, consisting of a single class within one school, constrains the generalizability of the findings to broader populations with different characteristics. Variations in institutional context, student background, and instructional conditions may influence the applicability of the results in other educational settings.

Another limitation lies in the scope of the variables examined in this study. The research focused solely on learning interest and learning outcomes, without incorporating other essential competencies relevant to 21st-century learning, such as critical thinking skills, creativity, and self-regulated learning. Furthermore, the relatively short duration of the study did not allow for the observation of the long-term effects of the Project-Based Learning model on students' academic and personal development.

Based on these limitations, several recommendations can be proposed for future research. It is suggested that subsequent studies employ more rigorous experimental designs, such as quasi-experimental or true experimental designs with control groups, to enable more comprehensive comparisons of instructional effectiveness. Additionally, future research should involve larger and more diverse samples drawn from multiple educational contexts to enhance external validity. Further investigations are also encouraged to incorporate additional variables, including higher-order thinking skills, collaboration, and scientific literacy, as well as to examine the long-term impact of Project-Based Learning in chemistry education.

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