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The Effect of the Project-Based Learning Model on Students' Learning Outcomes and Learning Activities

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Abstract
This study was motivated by the low level of students' learning outcomes and learning activities on electrolyte and non-electrolyte solution material. The study aimed to examine the effect of the Project Based Learning (PjBL) model on students' learning outcomes, to describe students' learning activities after its implementation, and to determine the relationship between learning activities and learning outcomes. This research employed a quasi-experimental method with a pretest-posttest control group design. The sample consisted of 55 students selected through cluster random sampling, divided into an experimental class taught using the PjBL model and a control class taught using the Direct Instruction model. The data were collected through learning outcome tests and observation sheets of students' learning activities, then analyzed using N-gain, correlation analysis, and an independent sample t-test. The results showed that the experimental class achieved a higher increase in learning outcomes (N-gain 0.75, high category) compared to the control class (N-gain 0.68, medium category). The hypothesis test indicated a statistically significant difference between the two groups ($p < 0.05$). In addition, students' learning activities in the experimental class were categorized as high (86.73%). Correlation analysis revealed a positive and significant relationship between learning activities and learning outcomes, with a contribution of 38.0%. In conclusion, the Project Based Learning model significantly improves students' learning outcomes and positively contributes to students' learning activities on electrolyte and non-electrolyte solution material.

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INTRODUCTION

The rapid advancement of technology in the twenty-first century has significantly transformed the educational landscape, requiring students to develop essential skills such as critical thinking, problem-solving, creativity, collaboration, and communication. In this context, the integration of technology into teaching and learning is not only a necessity but also a strategic approach to enhancing student engagement and improving their understanding of complex concepts, particularly in science education such as chemistry (Lubis et al., 2024).

Chemistry is one of the fundamental subjects that plays a crucial role in understanding molecular structures and interactions while fostering students' scientific literacy. Nevertheless, chemistry is often perceived as a difficult subject because many of its concepts are abstract and require visualization at the microscopic level. One of the most challenging topics in secondary school chemistry is electrolyte and non-electrolyte solutions, which demand a deep conceptual understanding as well as mastery of numerous related concepts (Raabi & Musta, 2022).

Observations and interviews conducted at MAN 2 Model Medan on October 15, 2025, revealed that teacher-centered instructional approaches are still predominantly employed in chemistry classrooms, resulting in limited student engagement during the learning process.

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Students' daily assessment scores on the topic of electrolyte and non-electrolyte solutions remained below the school's Minimum Learning Achievement Criteria (KKTP), which was set at 85. Grade XI students at MAN 2 Model Medan experienced difficulties distinguishing between strong and weak electrolytes, differentiating acids, bases, and salts, and writing ionization equations for electrolyte and non-electrolyte solutions.

Previous studies have explored various efforts to improve the quality of chemistry instruction through the implementation of the Project-Based Learning (PjBL) model. (Jannah et al., 2018) reported an increase in the proportion of actively engaged students from 67% in Cycle I to 80% in Cycle II, accompanied by an improvement in students' mastery of the subject matter from 53% to 77%. (Sulyantari, 2023) found that project-based practical activities improved students' conceptual mastery by approximately 12% and enhanced their practical skills assessment by 14%, achieving a "very good" category in learning electrolyte solutions among Grade X science students. (Panjaitan, 2023) confirmed that a PjBL-based learning module was effective in facilitating students' understanding of electrolyte and non-electrolyte solutions, with 28 out of 30 students rating the module as "very good." Furthermore, the reported success rate of PjBL implementation across various studies ranges from 60% to 95% (Chaniago & Dafit, 2024). These findings indicate that PjBL effectively promotes active student participation, enhances problem-solving skills, and strengthens conceptual understanding through meaningful, authentic project-based learning experiences (Lubis et al., 2024).

Despite the well-documented effectiveness of Project-Based Learning (PjBL) in chemistry education, most previous studies have focused on a single aspect of learning, such as learning achievement, learning activities, process skills, or instructional material development. Moreover, research on electrolyte and non-electrolyte solutions has generally evaluated the effectiveness of PjBL based solely on improvements in learning outcomes or students' responses to instruction, without examining the relationship between students' learning activities during the learning process and their learning outcomes. Consequently, empirical evidence explaining the extent to which learning activities fostered through PjBL contribute to improved learning outcomes on this topic remains limited.

To address this research gap, the present study offers a novel contribution by comprehensively examining the effect of the Project-Based Learning model on students' learning outcomes, describing the development of students' learning activities throughout the instructional process, and investigating the relationship between learning activities and learning outcomes using correlation analysis. In addition, this study implements PjBL through contextualized projects on the topic of electrolyte and non-electrolyte solutions for Grade XI students at MAN 2 Model Medan. Therefore, this research not only provides empirical evidence regarding the effectiveness of PjBL in improving students' learning outcomes but also elucidates the role of learning activities as a factor associated with students' academic success. Accordingly, this study is expected to make a more comprehensive empirical contribution to the advancement of project-based chemistry education.

METHOD

This study employed a quasi-experimental approach with a *Pretest-Posttest Control Group Design*, selected because it allows comparison of learning outcomes between two groups without full randomization.

Table 1. Research Design

Class	*Pretest*	Treatment	*Posttest*
Experimental	T_1	X_1	T_2
Control	T_1	X_2	T_2

Note: X_1 *= Implementation of the* ***Project-Based Learning (PjBL)*** *model;* X_2 *= Implementation of the* ***Direct Instruction*** *model;* T_1 *= Pretest (before the treatment);* T_2 *= Posttest (after the treatment).*

The study was conducted at MAN 2 Model Medan during the even semester of the 2025/2026 academic year. The population comprised all 549 Grade XI students. Sampling was carried out using cluster random sampling a class-based random selection method because students in this school are already organized into fixed classes that cannot be restructured. This technique was chosen to preserve natural classroom conditions and avoid disruption to existing class structures. Two classes were selected: XI-F1C (28 students) as the experimental class receiving the PjBL model, and XI-F1G (27 students) as the control class receiving Direct Instruction, yielding a total sam-

ple of 55 students.

Research Instruments

The test instrument consisted of 20 multiple-choice items covering cognitive levels C2–C5 (Bloom's Taxonomy), selected from 40 pilot-tested items administered to 34 Grade XII students, based on item validity (Tpoint biserial, rtable = 0.339), reliability (KR-20, r_{11} = 0.884, very high category), difficulty index, and discriminating power. The non-test instrument was a learning activity observation sheet with five indicators (cooperation, sincerity, responsibility, asking questions, and answering questions), validated through expert judgement.

Before use, the test instrument was piloted on 34 Grade XII students. Of the 40 items, 27 were declared valid using point biserial correlation (rtable = 0.339; α = 0.05). From these valid items, 20 representative items were selected based on an appropriate balance of validity, discriminating power, and coverage of learning indicators. Reliability was measured using the Kuder-Richardson 20 (KR-20) formula, yielding r_{11} = 0.884, classified as very high. Instrumen non-tes divalidasi secara kualitatif melalui *expert judgement* oleh validator ahli.

Research Procedure

The study was conducted in three stages: (1) preparation, including field observation, development of learning materials, and instrument validation; (2) implementation, beginning with a pretest, followed by PjBL instruction (six syntaxes) in the experimental class and Direct Instruction in the control class both using Canva Presenter as a learning medium with learning activities observed by three observers; and (3) administration of a posttest after all learning sessions were completed. The research flowchart is presented in Figure 1.

Data Analysis

Improvement in learning outcomes was measured using normalized N-Gain. Prerequisite tests included the Shapiro-Wilk normality test and Levene's homogeneity test, conducted using SPSS 26. Hypotheses were tested using a one-tailed Independent Samples t-test (α = 0.05). Learning activity data were analyzed descriptively as a percentage per meeting. The relationship between learning activities and learning outcomes was examined using Pearson correlation and the coefficient of determination (R^2).

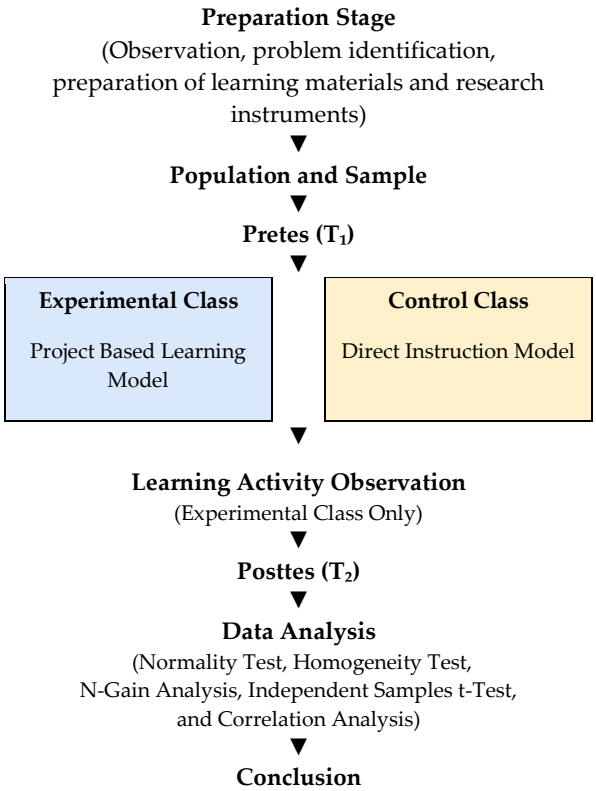


Figure 1. Research Flowchart

RESULTS AND DISCUSSION

Research Instrument Analysis

Prior to data collection, 40 multiple-choice items were piloted on 34 Grade XII students. Difficulty index analysis showed that 36 items were categorized as moderate, 2 as easy, and 2 as difficult. Discriminating power analysis yielded 13 items as good, 14 as adequate, and 13 as poor. Of the 40 items, 27 were declared valid using point biserial correlation (r_{table} = 0,339; α = 0,05). From these valid items, 20 representative items were selected based on a balanced distribution of cognitive levels (C2–C5), validity, and discriminating power. It is important to note that the 13 items with poor discriminating power were excluded from the final instrument, ensuring that only items capable of differentiating between higher- and lower-achieving students were retained. Reliability was calculated using the KR-20 formula and yielded r_{11} = 0.884, confirming very high internal consistency. The non-test instrument the learning activity observation sheet was validated qualitatively through expert judgement and deemed suitable for use.

Description of Mean Learning Outcomes

Descriptive statistics of pretest, posttest, and N-Gain scores for both classes are presented in Table 1.

Table 1. Description of Mean Learning Outcomes

Class	Pre-tes	Post-tes	N-Gain
Exsperimental	46,78 ± 11,96	87,14 ± 6,86	0,75 ± 0,11
Control	44,25 ± 8,40	82,59 ± 9,13	0,68 ± 0,14

As shown in Table 1, the mean pretest scores of the experimental class (46.78 ± 11.96) and the control class (44.25 ± 8.40) were comparable, confirming equivalent prior knowledge and validating the interpretation that posttest differences reflect treatment effects rather than pre-existing ability gaps. Notably, the larger standard deviation in the experimental class pretest (11.96 vs. 8.40) indicates greater initial heterogeneity. Against this backdrop, the PjBL model produced not only a higher mean posttest score (87.14 vs. 82.59) but also a considerably smaller standard deviation (6.86 vs. 9.13). This convergence of scores in the experimental class suggests that PjBL not only raised average achievement but also reduced learning outcome disparities among students a dimension of effectiveness rarely highlighted in prior studies.

N-Gain Test Results

Table 2. N-Gain Test Results of Learning Outcomes

Class	N-Gain	Categori
Experimental	0,75	Hight
Control	0,68	Medium

As presented in Table 2, the experimental class achieved an N-Gain of 0.75 (high category), while the control class obtained 0.68 (medium category). Although the numerical gap of 0.07 may appear modest, the categorical difference carries meaningful pedagogical implications: the experimental class realized approximately 75% of the maximum possible learning gain, compared to 68% in the control class. Furthermore, the higher standard deviation in the control class N-Gain (0.14 vs. 0.11) signals greater inconsistency in learning improvement under Direct Instruction — suggesting that while some students progressed substantially, others stagnated. This variability raises critical questions about Direct Instruction's capacity to accommodate diverse learning styles, particularly for abstract content such as electrolyte solutions that requires visualization and hands-on experimentation. According to the criteria proposed by Kurniawan & Hidayah (2021), PjBL is considered effective when N-Gain > 0.3, and the present findings clearly satisfy this threshold.

Normality Test Results

The normality of the data was assessed using the Shapiro–Wilk test at a significance level of α = 0.05 with SPSS Statistics version 26. The test results are presented in Table 3.

Table 3. Shapiro-Wilk Normality Test Results

Class	Statistic	df	Sig.	Ket.
Experimental Pretest	0,937	28	0,095	Normally Distributed
Experimental Posttest	0,934	28	0,080	Normally Distributed
Control Pretest	0,952	27	0,238	Normally Distributed
Control Posttest	0,958	27	0,341	Normally Distributed

As shown in Table 3, all significance values exceeded α = 0.05, confirming that the data are normally distributed and that parametric analysis may proceed. It is worth noting, however, that the posttest significance value for the experimental class (0.080) approaches the α threshold. This is consistent with a ceiling effect: as many students achieved high scores, the distribution became left-skewed. Rather than being a methodological weakness, this pattern reflects the success of the PjBL intervention. Nonetheless, future studies should consider including a greater proportion of higher-order items (C4–C6) to achieve a more optimal score distribution and avoid ceiling-related constraints on statistical inference.

Homogeneity Test Results

Homogeneity of variance was assessed using Levene's test in SPSS. The test results are presented in Table 4.

Table 4. Homogeneity Test Results (Levene's Test)

Data	Levene Statistic	df1	df2	Sig.
Based on Mean	2,271	1	53	0,138
Based on Median	1,297	1	53	0,260

As shown in Table 4, the significance values for both Based on Mean (0.138) and Based on Median (0.260) exceeded α = 0.05, confirming that the variances of the two groups were homogeneous. The fulfillment of both normality and homogeneity assumptions validates the use of parametric hypothesis testing in the subsequent analysis.

Hypothesis Test Results

The hypothesis was tested using a one-tailed (right-tailed) Independent Samples t-test with the

assistance of SPSS. The results are presented in Table 5.

Table 5. Hypothesis Test Results: Independent Samples t-test

Data	Experi-mental	Control	t-value	Result
Mean Score	87,14	82,59	2,094 (df=53)	H_a accepted, H_0 rejected
Sig. (2-tailed)	–	–	0,041	–

As presented in Table 5, the independent samples t-test yielded t = 2.094 (df = 53) with a two-tailed significance value of 0.041 < 0.05, leading to the rejection of H_0 and acceptance of H_a. This confirms a statistically significant positive effect of PjBL on student learning outcomes. However, the p-value only slightly below the α threshold, combined with a mean difference of 4.55 points, indicates that while the effect is statistically significant, it is moderate in practical terms. The 95% confidence interval (0.192 to 8.909) is relatively wide, suggesting residual variability not fully explained by the treatment alone. To provide a more complete picture of the practical significance of PjBL, future studies should supplement significance testing with effect size measures such as Cohen's d reporting not only whether a difference exists, but how large that difference is in meaningful educational terms.

Development of Student Learning Activities

The learning activities of students in the experimental class were observed over three instructional sessions using an observation sheet consisting of five indicators: (1) collaboration, (2) learning engagement, (3) responsibility, (4) asking questions, and (5) answering questions. The observation results are presented in Table 6.

Table 6. Development of Student Learning Activities per Meeting

Meeting	Average Score	Percentage (%)	Category
Meeting 1	10,71	71,43	High
Meeting 2	13,21	88,10	High
Meeting 3	14,89	99,29	Very High
Final Average	–	**86,27**	**High**

As shown in Table 6, student learning activities increased consistently across three meetings, rising from 71.43% to 88.10% and reaching 99.29% a total gain of 27.86 percentage points. Critically, the largest single-session increase occurred between the first and second meetings (+16.67 points), not the second to third (+11.19 points). This pattern suggests that students overcame the PjBL adaptation barrier rapidly, challenging the assumption that extended orientation is required before productive project engagement can occur. It is worth noting, however, that learning activities were observed only in the experimental class, without a parallel observation group, limiting the extent to which this growth trajectory can be attributed exclusively to PjBL rather than general lesson familiarity over time. Furthermore, the near-perfect score at the third meeting (99.29%) likely reflects a ceiling effect in the observation instrument, signaling a need to develop more discriminative indicators in future research to capture finer gradations of high-level engagement. Overall, the final mean activity score was 86.27%, with all 28 students classified in the high category: 2 students (7.1%) in the 70–79% range, 18 students (64.3%) in the 80–89% range, and 8 students (28.6%) in the 90–100% range.

Relationship Between Learning Activities and Learning Outcomes

To examine the relationship between students' learning activities and learning outcomes, Pearson's correlation test was conducted. The correlation test results and the coefficient of determination are presented in Table 7.

Table 7. Pearson Correlation and Coefficient of Determination

Data	Activity	Learning Results
Pearson Correlation	1	0,616**
Sig. (1-tailed)	–	0,000
R Square (Koef. Det.)	–	0,380

As shown in Table 7, the Pearson correlation coefficient of 0.616 (Sig. 1-tailed = 0.000 < 0.05) confirms a significant positive association between learning activities and learning outcomes, classified as strong (r = 0.61–0.80) according to Silitonga (2014). The coefficient of determination R^2 = 0.380 indicates that learning activities account for 38.0% of the variance in learning outcomes. Critically, the remaining 62.0% remains unexplained by this variable alone raising the question of which factors dominate the residual variance. Plausible candidates include students' prior cognitive ability, the quality of

teacher scaffolding during PjBL, project complexity, and intrinsic motivation, none of which were measured in this study. It is equally important to emphasize that the relationship identified here is associational, not causal: high learning activity does not necessarily cause better learning outcomes. Both variables may instead be comanifestations of a third factor, such as student motivation or self-efficacy. Future research should consider mediation or moderation designs to map these mechanisms more precisely for instance, testing whether intrinsic motivation mediates the relationship between PjBL engagement and academic achievement.

Discussion

Effect of the Project-Based Learning Model on Learning Outcomes

The findings of this study indicate that the implementation of the Project-Based Learning (PjBL) model had a positive and significant effect on students' learning outcomes in the topic of electrolyte and non-electrolyte solutions. This finding is evidenced by the higher mean posttest score achieved by the experimental group (87.14) compared to the control group (82.59), the higher N-gain score of the experimental group (0.75; high category) compared to that of the control group (0.68; moderate category), and the independent samples *t*-test results, which revealed a statistically significant difference (t = 2.094, p = 0.041 < 0.05).

The effectiveness of PjBL in improving learning outcomes can be attributed to its learner-centered characteristics, which position students as active participants in the learning process. Through the six phases of the PjBL model, particularly during the design and construction of an electrical conductivity testing device, students directly connected theoretical concepts of ionization, electrical conductivity, and the differences between ionic and covalent compounds with authentic hands-on experiences. This finding is consistent with constructivist learning theory, which posits that meaningful conceptual understanding develops through students' active engagement in constructing their own knowledge (Sari & Angreni, 2018). The results are also in agreement with the findings of (Simangunsong et al., 2022) who reported that PjBL is highly effective in improving students' learning outcomes by promoting engagement, conceptual understanding, and creativity. Furthermore,(Setiawan et al., 2021) emphasized that PjBL, as an educational approach that encourages students to take initiative in addressing real-world challenges, effectively enhances cognitive achievement and creative thinking skills.

In contrast, although the Direct Instruction model implemented in the control group also improved students' learning outcomes, it primarily positioned students as passive recipients of information. Consequently, this approach was less effective in facilitating a deep conceptual understanding of abstract concepts such as ion movement in solutions and ionization processes, which are better understood through direct visualization and experiential learning (Wardani et al., 2025).

Development of Students' Learning Activities through the Project-Based Learning Model

Students' learning activities improved significantly and progressively throughout the implementation of the PjBL model, increasing from 71.43% in the first meeting to 88.10% in the second meeting and reaching 99.29% in the third meeting. The overall increase of 27.86 percentage points demonstrates the effectiveness of PjBL in promoting sustained student engagement.

The relatively lower level of learning activity during the first meeting (71.43%) may be attributed to the students' adaptation to the PjBL approach, which differed substantially from the conventional teacher-centered instruction with which they were familiar. This finding supports (Shakti et al., 2026) who argued that the initial stage of PjBL plays a crucial role in fostering students' intrinsic motivation to actively participate in learning. During the second meeting, the most notable improvements were observed in collaboration and responsibility, indicating that PjBL successfully cultivated positive interdependence among group members, as reported by (Sitorus et al., 2025). In the third meeting, the project presentation stage served as a strong motivator for students to demonstrate their best performance. Overall, these findings are consistent with (Ibrahim & Sutiani, 2025) ho concluded that PjBL provides students with meaningful opportunities to explore subject matter more deeply through active participation in authentic real-world projects. Consequently, this deep involvement builds essential critical thinking skills.

Correlation between Learning Activities and Learning Outcomes

A positive and statistically significant correlation was found between students' learning activities and learning outcomes, with a correlation coefficient of r = 0.616, indicating a strong relationship, and a coefficient of determination (R^2) of 0.380. These findings suggest that higher levels of student learning activity are associated with better learning outcomes. Learning activities accounted for 38.0% of the variance in students' learning outcomes, while the remaining 62.0% was explained by other factors, including intrinsic motivation, intellectual ability, family environment, and the quality of instructional media.

These findings reinforce the view that active learning is an important predictor of students' academic achievement. Through active participation in observing, discussing, experimenting, and presenting project outcomes, students develop not only cognitive competencies but also affective and psychomotor skills, which ultimately contribute to improved academic performance. The results are consistent with the findings of (Fatmawati, 2023) who reported a positive relationship between learning activities and learning outcomes, indicating that increased student engagement is generally accompanied by improved academic achievement. Therefore, the Project-Based Learning model can be regarded as an effective catalyst for simultaneously enhancing students' learning activities and learning outcomes in the topic of electrolyte and non-electrolyte solutions among Grade XI students at MAN 2 Model Medan.

CONCLUSION

Based on the research findings, the implementation of the *Project Based Learning* (PjBL) model exerted a significant positive effect on student learning outcomes in electrolyte and non-electrolyte solution material, as evidenced by a higher mean posttest score in the experimental class (87.14 vs. 82.59), a high-category N-Gain (0.75 vs. 0.68), and a statistically significant group difference at the 95% confidence level ($p < 0.05$). Furthermore, PjBL effectively fostered the development of student learning activities, with a mean activity score of 86.27% (high category). A significant positive correlation was also confirmed between learning activities and learning outcomes (r = 0.616), with learning activities contributing 38.0% to the variance in outcomes.

These findings carry direct practical implications for teachers and schools. For chemistry teachers, the results confirm that PjBL is well-suited as a primary instructional approach not merely a supplementary strategy for topics requiring deep conceptual understanding and process visualization, such as electrolyte and non-electrolyte solutions. Teachers are encouraged to design authentic, contextual projects, for instance the construction of a simple electrical conductivity testing device, so that students can directly connect ionization concepts to real-world phenomena. Teachers also need to prepare themselves as active facilitators who provide targeted scaffolding, particularly during the first meeting when students are still adapting to PjBL syntax. For school institutions, these findings provide an empirical basis for systematically integrating PjBL into the chemistry curriculum, including through the provision of adequate laboratory facilities, procurement of consumable materials for student projects, and professional development programs that equip teachers with the competencies needed to design and manage project-based learning effectively.

RECOMMENDATION

Based on the findings and limitations of this study, the following specific and operational recommendations are proposed. First, chemistry teachers are advised to implement PjBL in a structured manner by consistently applying all six syntaxes: starting with the formulation of a fundamental question relevant to students' daily lives, followed by collaborative project planning, realistic scheduling, periodic teacher monitoring of project progress, in-class project testing, and evaluation of the learning experience. Second, to improve the measurement quality of learning activities, future researchers are encouraged to develop more discriminative observation sheets with indicators capable of differentiating engagement levels among high-performing students, thereby avoiding the ceiling effect identified in this study. Third, future studies should involve larger samples (at least three classes per group) drawn from multiple schools to enhance the generalizability of findings. Fourth, researchers are advised to complement

significance testing with *effect size* calculations (e.g., Cohen's d) to provide a more comprehensive picture of the practical magnitude of PjBL's effects. Fifth, to better understand the mechanisms underlying the relationship between learning activities and outcomes, future research should employ mediation or moderation designs by incorporating variables such as intrinsic motivation, *self-efficacy*, or prior cognitive ability as potential mediating or moderating factors.

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