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The Effect of Arithmetic Operation Ability and Emotional Intelligence on Physics Problem-Solving Ability among High School Students

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Abstract

The low achievement on the 2025 Physics Academic Competency Test, which reached only 31.34%, indicates that senior high school students still face difficulties in physics problem-solving, both in terms of mathematical-technical mastery and psychological readiness when confronting complex problems. This study aims to analyze the effect of arithmetic operation ability and emotional intelligence, both partially and simultaneously, on physics problem-solving ability among senior high school students. To achieve this objective, the study employed a quantitative approach with a multiple linear regression design. The population comprised eleventh-grade students with a total sample of 72 students. The sample was determined through three stages: purposive sampling to select the research schools, proportionate stratified sampling to determine the sample proportion from each school, and random sampling to select students from the designated classes. Data were collected using written essay-type tests to measure arithmetic operation ability and physics problem-solving ability (based on Polya's stages), as well as a Likert-scale questionnaire to measure emotional intelligence. Based on the hypothesis testing results, the findings are as follows: (1) arithmetic operation ability has a positive and significant effect on physics problem-solving ability ($t = 8.931$; $sig < 0.001$); (2) emotional intelligence has a positive and significant effect on physics problem-solving ability ($t = 6.618$; $sig < 0.001$); and (3) arithmetic operation ability and emotional intelligence jointly have a significant effect on physics problem-solving ability ($F = 53.542$; $sig < 0.001$), accounting for 60.8% of the variance. This study underscores the importance of an integrated approach that combines cognitive (arithmetic operation) and affective (emotional) aspects in physics learning to optimally enhance students' problem-solving skills.

Introduction

21st-century education demands that students not only master theoretical cognitive competencies but also apply knowledge in everyday life, with complex problem-solving and higher-order thinking as core competencies (Baihaqi et al., 2025; Yadav & Singh, 2026; Szabo et al., 2020), which are also reflected in the profile of Independent Curriculum graduates. Learning physics demands systematic observation and quantitative analysis, essentially a form of structured problem-solving (Kiraga, 2023; Kuswanto & Salim, 2025; Adams & Wieman, 2015). However, high school students' achievement remains low. The average absorption rate of 2025 TKA in Physics was only 31.34% of 262,559 participants, indicating students' difficulties in quantitative analysis and complex problem-solving.

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Polya formulated four stages of problem-solving: understanding the problem, developing a plan, implementing the plan, and reviewing it, with implementing the plan being the most challenging for students (Wahab et al., 2024; Thuan & Giang, 2023; Hidayah & Murti, 2025; Pratikno, H., & Retnowati, 2018; Yayuk & Husamah, 2020). Problem-solving leads to two key factors: arithmetic operation and emotional intelligence. Numerical ability (specifically, arithmetic operation), as one of the primary mental abilities, has been shown to contribute significantly to physics problem-solving (Berkowitz, M., & Stern, 2018; Badmus, O. T., & Jita, 2024; Reinhold et al., 2020; Kanderakis, 2016) and science learning outcomes (Yurita et al., 2025). Conversely, emotional intelligence Dewi et al., (2023) is also related to physics problem-solving ability (Kalsum et al., 2018), consistent with the finding that math anxiety influences quantitative performance through working memory (Finell et al., 2022).

These two variables have been widely studied separately, but research examining their simultaneous influence on physics problem-solving in high school students in Indonesia is still limited. Ramadhan et al. (2021) combined the two in junior high school mathematics, while studies in physics (Rivani et al., 2022; Silvianti et al., 2022) were still descriptive or partial. This gap underlies this study, which aims to analyze the influence of arithmetic operation ability and emotional intelligence, both partially and simultaneously, on high school students' physics problem-solving ability.

Method

Research Design and Variables

This study employed a quantitative correlational research design to examine the relationships among arithmetic operation ability, emotional intelligence, and physics problem-solving ability. Arithmetic operation ability was treated as the first independent variable (X_1), emotional intelligence as the second independent variable (X_2), and physics problem-solving ability as the dependent variable (Y). Simple and multiple correlation analyses were conducted using multiple linear regression to examine the relationships between the independent variables and physics problem-solving ability.

Population and Sample

The population consisted of all Grade 11 students enrolled in public high schools in Cilincing District. The sample size was determined using the Taro Yamane formula with a 10% precision level, resulting in a minimum sample of 72 students.

Sampling Technique

The sampling procedure was conducted in several stages. First, schools were selected purposively based on the predetermined research criteria. Second, proportionate stratified sampling was used to determine the number of students selected from each relevant group. Finally, students were selected randomly from the predetermined groups to obtain the required sample.

Research Instruments

Three instruments were used to collect the research data: a physics problem-solving ability test, an arithmetic operation ability test, and an emotional intelligence questionnaire.

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Physics Problem-Solving Ability Test

Physics problem-solving ability was measured using a descriptive/essay test based on Polya's four stages of problem solving: understanding the problem, devising a plan, carrying out the plan, and reviewing the solution. The test focused on problems related to Newton's Laws of Dynamics.

Arithmetic Operation Ability Test

Arithmetic operation ability was measured using a numerical ability test based on Thurstone's numerical factor. The instrument consisted of four indicators: calculation speed, calculation accuracy, number manipulation, and understanding relationships among numbers.

Emotional Intelligence Questionnaire

Emotional intelligence was measured using a Likert-scale questionnaire based on Goleman's five dimensions of emotional intelligence: self-awareness, self-regulation, self-motivation, empathy, and social skills.

Instrument Validity and Reliability

The research instruments were validated by six experts consisting of three university lecturers and three physics teachers. The expert validation results ranged from 85.48% to 86.67%. Item validity was subsequently examined using the Pearson Product Moment correlation, while instrument reliability was assessed using Cronbach's Alpha. The reliability coefficients were 0.894 for the physics problem-solving ability instrument, 0.916 for the arithmetic operation ability instrument, and 0.942 for the emotional intelligence questionnaire.

Data Collection Procedure

Data were collected by administering the physics problem-solving ability test, arithmetic operation ability test, and emotional intelligence questionnaire to the selected Grade 11 students. The collected data were then scored and prepared for statistical analysis.

Data Analysis

The data were analyzed using SPSS version 30. Before conducting hypothesis testing, several prerequisite tests were performed, including the Kolmogorov–Smirnov normality test, multicollinearity test using the Variance Inflation Factor (VIF), heteroscedasticity test using a scatterplot, residual normality test, and linearity test.

Prerequisite Tests

The prerequisite analyses were conducted to determine whether the data met the assumptions required for multiple linear regression. Normality was assessed using the Kolmogorov–Smirnov test, multicollinearity was examined using VIF, heteroscedasticity was evaluated through a scatterplot, residual normality was examined, and linearity was tested between each independent variable and the dependent variable.

Hypothesis Testing

Multiple linear regression analysis was used to examine the contribution of arithmetic operation ability and emotional intelligence to physics problem-solving ability. The analysis included the regression equation, F-test for simultaneous significance, t-tests for partial significance, the coefficient of determination (R^2), and partial coefficients of determination to assess the contribution of each independent variable.

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Result and Discussion

The results of the analysis prerequisite tests show that all multiple linear regression assumptions have been met, as presented in Table 1.

Table 1. Summary of Prerequisite Test Results for Data Analysis

Assumption Test	Result	Conclusion
Normality (Kolmogorov–Smirnov Test)	Sig. > 0.05 for X_1, X_2, and Y	Data are normally distributed
Multicollinearity	VIF = 1.028 (< 10)	No multicollinearity detected
Heteroscedasticity	Data points are randomly scattered with no specific pattern	No heteroscedasticity detected
Residual Normality	Asymp. Sig. = 0.200 (> 0.05)	Residuals are normally distributed
Linearity of X_1 with Y	Sig. Deviation from Linearity = 0.512	Linear relationship
Linearity of X_2 with Y	Sig. Deviation from Linearity = 0.090	Linear relationship

The results of the multiple linear regression analysis yield the following regression line equation. A constant of 9.242 indicates the baseline value of physics problem-solving ability when arithmetic operation ability and emotional intelligence are zero. Positive regression coefficients of X_1 and X_2 indicate that increasing both numerical ability and emotional intelligence will improve students' physics problem-solving ability. A summary of the hypothesis testing results is presented in Tables 2 and 3.

Table 2. Results of the Simultaneous Significance Test (F Test) of the Effect of X_1 and X_2 on Y

Parameter	Value
Multiple Correlation Coefficient (R)	0.780
Coefficient of Determination (R^2)	0.608 (60.8%)
Adjusted R^2	0.597
F-statistic	53.542
Significance (Sig.)	< 0.001

Based on Table 2, the calculated F value of 53.542 with a significance level <0.001 (p <0.05) indicates that arithmetic operation ability and emotional intelligence jointly have a positive and significant effect on physics problem-solving ability, thus accepting hypothesis H3. The R^2 value of 0.608 indicates that 60.8% of the variation in physics problem-solving ability can be explained by the two independent variables, while the remaining 39.2% is influenced by other factors outside this research model. The partial contribution of arithmetic operation ability to physics problem-solving ability is 40.85%, while the partial contribution of emotional intelligence is 19.93%, which when added together corresponds to the total R^2 value.

Table 3. Results of Partial Significance Test (t-Test) of the Effect of X_1 and X_2 on Y

Variable	Coefficient (b)	t-value	Sig.	Partial Correlation (r)

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Arithmetic Operation Ability (X_1)	0.654	8.931	< 0.001	0.732
Emotional Intelligence (X_2)	0.292	6.618	< 0.001	0.623

Based on Table 3, the calculated t value of arithmetic operation ability is 8.931 with a significance level <0.001, indicating a positive and significant effect on physics problem-solving ability, thus accepting hypothesis H3. Likewise, the calculated t value of emotional intelligence is 6.618 with a significance of <0.001, indicating a positive and significant influence, so H_1 is accepted.

The Influence of Arithmetic Operation on Physics Problem-Solving Ability

The results of this study indicate that arithmetic operation ability has a positive and significant effect on physics problem-solving ability, with a strong partial correlation (r = 0.732) after controlling for emotional intelligence (Tong et al., 2025; Cholifah et al., 2024). This finding aligns with Thurstone's theory of Primary Mental Abilities, which positions arithmetic operation factors as primary mental abilities that play a crucial role in quantitative processes (Lourenco et al., 2018; Aran & Richaud, 2017; Buckley et al., 2018). Within Polya's stage framework, arithmetic operation ability contributes across all stages: at the problem-understanding stage, students with strong arithmetic operation ability are able to accurately identify quantities; at the planning stage, the ability to understand number relationships helps select relevant formulas; at the plan-executing stage, arithmetic operations and algebraic manipulations are crucial in producing accurate answers; and at the reviewing stage, estimation skills help detect irregularities in results. This finding corroborates the research findings of Wahyuni (2018) which also found a significant contribution of arithmetic operation ability to physics problem-solving.

The Influence of Emotional Intelligence on Physics Problem-Solving Ability

Emotional intelligence has been shown to have a positive and significant effect on physics problem-solving ability, although its contribution (19.93%) is smaller than that of arithmetic operation ability (40.85%). This finding is consistent with the results of Kalsum et al. (2018), Gustiana et al. (2023), and Ramadina (2023), who also found a significant influence of emotional intelligence on problem-solving ability. Referring to Goleman's five dimensions, self-awareness plays a role in the problem-understanding stage by helping students recognize the limitations of their understanding; self-motivation encourages students to persist in developing a solution plan despite encountering obstacles; while self-regulation plays a significant role in the plan-execution stage, namely managing anxiety (physics anxiety) and maintaining concentration during lengthy calculations. At the reexamination stage, self-awareness and self-regulation encourage students to conduct critical self-evaluations rather than hastily concluding answers (Khoiriyah & Roberts, 2025).

Simultaneous Influence of Arithmetic Operation Ability and Emotional Intelligence

Simultaneous testing showed that arithmetic operation and emotional intelligence together contributed 60.8% to physics problem-solving ability, with a very strong multiple correlation (R = 0.780). This finding strengthens the integrative perspective of Thurstone, Goleman, and Polya's theories: arithmetic operation ability provides a procedural technical foundation, while emotional intelligence provides a motivational affective foundation, both of which are necessary at every stage of problem-solving. Students who excel in both dimensions simultaneously tend to demonstrate the best performance throughout the physics problem-

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solving process, from understanding the problem to verifying the final answer. This result is also in line with the findings of Ramadhan et al. (2021) in the mathematics context, which showed that the combination of cognitive and affective factors consistently makes a meaningful contribution to students' problem-solving ability, while extending the generalizability of these findings to the realm of high school physics learning in Indonesia.

Conclusion

Based on the results of data analysis and discussion, it can be concluded that: (1) arithmetic operation ability has a positive and significant effect on the physics problem-solving ability of high school students (b_1 = 0.654; t = 8.931; Sig. < 0.001; r-partial = 0.732); (2) emotional intelligence has a positive and significant effect on the physics problem-solving ability of high school students (b_2 = 0.292; t = 6.618; Sig. < 0.001; r-partial = 0.623); and (3) arithmetic operation ability and emotional intelligence together have a positive and significant effect on the physics problem-solving ability of high school students (F = 53.542; Sig. < 0.001; R^2 = 0.608). These findings emphasize the importance of a holistic approach to physics learning, combining arithmetic operation skills strengthening and emotional intelligence development in an integrated manner. Therefore, teachers and schools need to design learning strategies and mentoring programs that are not only oriented towards mastering cognitive content but also pay attention to students' psychological-affective readiness. Further research is recommended to explore other predictor variables, such as self-efficacy and spatial ability, and consider experimental designs to test the effectiveness of learning interventions that target both variables simultaneously.

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