

An Investigation of the Determinants of Engineering Aptitude Using Structural Equation Modeling

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ARTICLE INFO

Article history

Received 10 February 2026

Revised 02 June 2026

Accepted 09 June 2026

ABSTRACT

The urgency of this research is a follow-up to previous research that identified moderate engineering aptitude among engineering students at Universitas Islam Ogan Komering Ilir Kayuagung. Therefore, further analysis of the factors influencing engineering aptitudes is necessary. The results of this research will have implications for curriculum development, instructional design, and learning environments that can support engineering aptitude in engineering students and ensure success in the workforce. This study aims to determine a model of factors influencing engineering aptitude in engineering students. This research is a quantitative cross-sectional study. The sampling technique used was purposive sampling, involving 30 mechanical engineering students and 72 civil engineering students from the Faculty of Engineering at Universitas Islam Ogan Komering Ilir Kayuagung. The data were analyzed using Structural Equation Modelling (SEM). The SEM analysis included testing the measurement model and evaluating the structural model. Based on the research results, it can be concluded that engineering students' engineering aptitude is influenced by problem-solving and mechanical reasoning. Therefore, the study emphasizes the crucial role of mechanical reasoning and problem-solving processes in developing engineering aptitude among students. From a practical perspective, the findings suggest that engineering education should provide learning environments that actively encourage reasoning skills and real-world problem-solving experiences.

Keywords

Engineering Aptitude
Mechanical Reasoning
Problem Solving
SEM
Spatial Ability

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Introduction

Aptitude is a combination of characteristics that indicate an individual's capacity to acquire a certain amount of knowledge, skills, or a series of organized responses, such as the ability to master a language, become a musician, or perform mechanical work [1]. If students can follow an educational program that is relatively appropriate to their aptitude, their learning motivation tends to be better, the competencies achieved will be better and the learning time will be shorter, thus the allocated educational resources can be used more effectively and efficiently [2].

It is more accurate to think of aptitudes as prospective abilities. An individual's aptitudes indicate their likelihood of succeeding at a certain task [3]. If you don't naturally acquire aptitude, you may eventually discover that your propensity for a certain activity will diminish and that it will be difficult or impossible to further develop your abilities [4]. An aptitude test may assess a variety of skills, such as the capacity to learn new things and the potential to make a significant contribution to one's field of study. According to theories regarding aptitude as an innate or acquired skill, it can be measured to reveal a variety of skills essential for successful research [5].

The results of the study have shown that the engineering aptitude level of engineering students at the Universitas Islam Ogan Komering Ilir Kayuagung is predominantly at the moderate level [6]. In addition, the results of the study also show that there is no significant difference between the two engineering study programs, namely the civil engineering and mechanical engineering study programs [7]. This indicates that the type of study program does not affect the level of engineering aptitude.

In an effort to improve engineering aptitude, an analysis is needed to identify the influencing factors. There are several abilities or skills required by an engineer, including problem solving [8], [9], [10], mechanical reasoning [11], [12] dan spatial reasoning [13], [14], [15], [16]. Students' problem-solving abilities must be developed in higher education, especially in engineering subjects. Solving problems involves more than just technical expertise; it also involves successfully putting theoretical knowledge to use in real-world scenarios. This talent is essential since it shows that people are proficient in engineering and can convert theoretical knowledge into useful applications. As a result, it is a crucial sign of

students' capacity for persuasive reasoning and successful learning in both academic and professional contexts [17].

The goal of mechanical reasoning is to assess one's comprehension of the fundamental mechanical concepts underlying tools, machines, and motion. Each item includes basic inquiries that call for thinking rather than specialized knowledge, as well as a mechanical scenario that is illustrated. It is designed for machine operators, engineers, mechanics, and electricians, as well as those in occupations requiring sound mechanical thinking [18]. Furthermore, Spatial skills are essential for learning and developing expertise in engineering [19]. The complexity of engineering challenges has increased due to the nature of the engineering profession and technological improvements. It is suggested that spatial aptitude is crucial for problem solving and could help engineers and engineering students tackle challenging issues [20].

Research on engineering aptitude analysis has been conducted in previous studies, such as Hapsari and Hidayat's (1) study, which used correlation analysis; and Balai Penelitian et al.'s (19) study, which used multinomial logistic regression. However, no study has yet developed and tested statistical models in the form of effect models. The novelty of this study is the use of Structural Equation Modeling (SEM). Determination of factors can use SEM analysis. The SEM approach appears to subvert the dominance of path analysis and multiple regression, which have been employed for decades in associative, multivariate-correlational, or causal-effect analyses. The advantage of the SEM approach over route analysis and multiple regression is that it can evaluate data more thoroughly [21]. PLS-SEM is particularly suitable for research in these domains since it offers a number of advantages over the more traditional covariance-based SEM (CB-SEM). One of these benefits is the ability to handle small sample sizes, which is crucial in educational settings where gathering a lot of data could be challenging. Furthermore, as data frequently deviates from normal distributions in social science research, PLS-SEM's resilience while handling non-normal data is beneficial [22].

The urgency of this research is as a follow-up step from previous research that has mapped the level of engineering aptitude of engineering students at UNISKI at a moderate level, so it is necessary to conduct further analysis regarding the factors that influence engineering aptitude, which then the results of this research will have implications for the development of curriculum/learning design/learning environment that can support engineering aptitude of engineering students to ensure academic success and in the world of work. Research on Engineering aptitude analysis has been conducted in previous studies, however, there has been no research that has built and tested statistical models in the form of causal models.

Therefore, based on the research background, the research problem is formulated as follows: What is the model of factors influencing engineering aptitude among engineering

students at the Islamic University of Ogan Komering Ilir, Kayuagung? Based on this research problem, the following are the research hypotheses:

H1: Problem solving has a significant influence on engineering aptitude

H2: Mechanical reasoning has a significant influence on engineering aptitude

H3: Spatial reasoning has a significant influence on engineering aptitude

Material and Methods

This research is a quantitative study with a cross-sectional study design. A cross-sectional study, also known as prevalence or transversal research, uses a description of the beliefs, behaviors, or other variables of participants in the study population at a specific point in time [23]. The sampling technique used was purposive sampling, involving 30 mechanical engineering students and 72 civil engineering students from the Faculty of Engineering at Universitas Islam Ogan Komering Ilir Kayuagung.

The research data were analyzed using Structural Equation Modeling (SEM) using the SmartPLS4 application. SEM analysis involves two stages: measurement model testing and structural model evaluation [24]. Measurement model testing was conducted to obtain the value of the reflective construct by measuring validity and reliability. Validity was measured by estimating the loading. Indicator loadings were in the range of 0.70 and statistically significant (sig) at 0.50 or below. Internal consistency reliability was also examined using Cronbach's alpha (α) and Composite Reliability (CR). The cutoff value for both measures was 0.70 [25]. The conceptual framework image to visually present the relationship between research variables is presented in the figure 1.

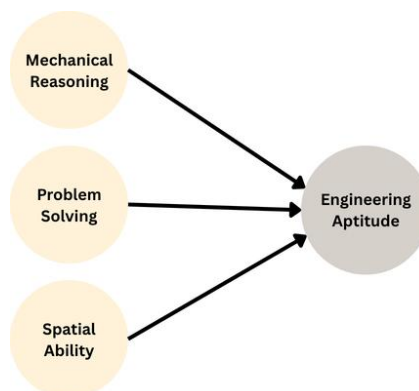


Fig 1. Conceptual Framework

Structural model evaluation is performed by determining the collinearity of the model. When two or more predictors measure the same underlying construct, they are said to be collinear [26]. The construct scores of the predictor constructs in each regression in the structural model are used to calculate the variance inflation factor (VIF) value (31). If all VIFs resulting from the full collinearity test are equal to or lower than 3.3, the model can be

considered free from common method bias [26]. Determine the coefficient of determination (R^2). R^2 indicates the variance explained in each predictor construct and is a measure of the explanatory power of the relationship between constructs in the model [25], [27]. And evaluate the size and significance of the path. This stage is carried out to see the strength of the effect and the meaningfulness of the path.

Results and Discussions

This study included four variables: engineering aptitude (EA), mechanical reasoning (MR), spatial ability (SA), and problem solving (PS). The data were analyzed using structural equation modeling (SEM) using the SmartPLS4 application. Two stages of PLS-SEM reporting techniques were explained. Reporting the suitability of the second-order construct in PLS-SEM is the initial step. In order to prevent biased outcomes, preliminary considerations include the use of repeated indicator techniques using Mode B and the path weighting scheme. Reporting the factors and general guidelines used to evaluate PLS-SEM is the second layer. The measurement model and the structural model were tested using an analytical process [28].

A. Measurement Model Testing

In testing the measurement model, the validity and reliability of the indicators on each variable and indicator are tested. The results of validity testing using factor loading indicate that the following indicators have been declared valid with factor loading > 0.7 . In the Mechanical reasoning variable, there are four valid indicators (MR1, MR3, MR5, and MR7) with outer values of 0.908 to 0.938. In the Problem-Solving variable, there are six valid indicators (PS1, PS4, PS12, PS14, and PS15) with outer loadings of 0.786 to 0.922. The Spatial Ability variable has two valid indicators (SA4 and SA8) with outer loadings of 0.983 and 0.979, respectively. The results of this factor modeling are shown in Fig. 1.

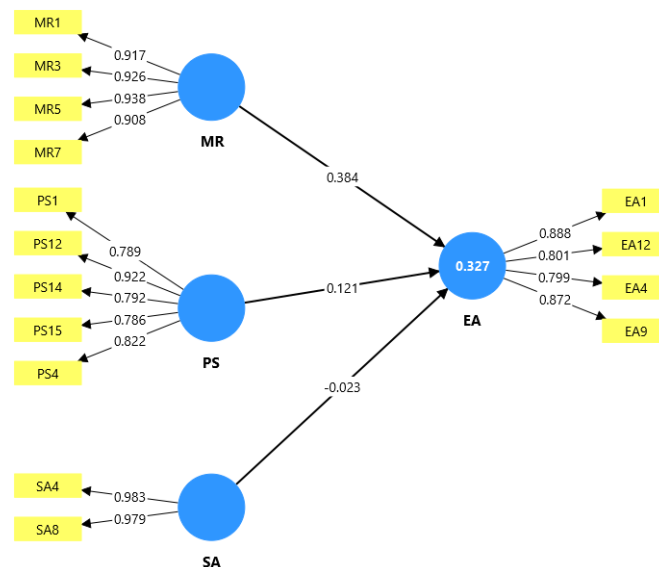


Fig 2. Factor model

In this study, two reliability tests were conducted: Cronbach's alpha and composite reliability. The cutoff value for both measures was 0.70. The reliability test results are shown in Table 1.

Table 1. Reliability test results

Variable	Cronbach's alpha	Composite reliability (rho_c)	Category
EA	0.867	0.890	Reliable
MR	0.943	0.970	Reliable
PS	0.885	0.968	Reliable
SA	0.961	0.972	Reliable

The results of the Cronbach's alpha and composite reliability tests show that all variables have a value of more than 0.7 so that all variables are declared reliable. The ability of a variable measurement to yield consistent outcomes and measurements under repeated circumstances is known as reliability. Research's consistency, accuracy, repeatability, and trustworthiness will all be measured by reliability, which also shows how impartial the study is. Generalization can be established by applying the results to a wider population and across a range of study settings once validity and reliability have been proven [29].

B. Structural Model Evaluation

1. Collinearity Test

Multicollinearity describes the extent to which other factors in the analysis correlate with or can be used to explain a particular variable. The presence of high levels of multicollinearity can affect the overall results. The presence of multicollinearity in this study was examined using the variance inflation factor (VIF) value [30]. Overall, the VIF values are shown in Table 2.

Table 2. Collinearity Test Results

Variable	VIF
MR -> EA	1.433
PS -> EA	1.625
SA -> EA	1.399

Based on Table 2, there were no collinearity problems in this study, which, in general, indicates that there is no correlation between the predictors in a statistical model, is seen as an issue for statistical analysis [31]. when two or more variables do not show collinearity, then the parameter estimates are stable and accurate [32].

2. Coefficient of Determination (R Square)

Based on the measurements, the model used in this study has a good fit, as shown in Table 3, with a high R-square value. Collinearity is also not a problem.

Table 3. R-square test results

Variabel	R-square	R-square adjusted
EA	0.412	0.381

Based on the coefficient of determination (R-square), the engineering aptitude variable has an R-square value of 0.412. This means that the predictor or explanatory power of the relationship between indicators in the model contributes 41,2% to the engineering aptitude variable, which is included in the moderate category.

3. Significance of Path Coefficient

To assess the significance of the path coefficients and test the moderator's moderating effect, bootstrapping was performed with a resample of 5000. The t-value should be considered to determine the significance of the relationship. The standardized beta (β) value and the corresponding t-value were examined. A significant relationship was determined using a t-value greater than 1.96 or a p-value less than 0.05 [30].

Table 4. Results of the path coefficient significance test

Variabel	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P values
PS -> EA	0.121	0.129	0.059	2.046	0.041
MR -> EA	0.384	0.386	0.089	4.308	0.000
SA -> EA	-0.023	-0.020	0.138	0.168	0.867

Table 4 shows several relationships between variables with t-values greater than 1.96 and p-values less than 0.05, indicating a positive and significant relationship. These positive and significant relationships include those between mechanical reasoning and engineering aptitude (MR-> EA), and between Problem solving and engineering aptitude (PS -> EA). Based on the path coefficient significance test results, it can be concluded that engineering aptitude is influenced by mechanical reasoning and problem solving. The results show that mastery of concepts or technical knowledge is not the only factor determining student success in engineering. Students' ability to analyze problems, identify relationships between elements, and use logical reasoning to make decisions is also crucial.

The results of the hypothesis test on the problem-solving variable show that positively and significantly influences engineering aptitude (H1, p value 0.041). The significant influence of problem solving on engineering aptitude reinforces the view that problem-solving ability is a core competency that prospective engineers must possess. This view is reinforced by the fact that in professional practice, engineers are required to face unstructured problems and often require the integration of multiple sources of information before producing a correct solution. Therefore, students who have better problem-solving abilities will perform better. We need a deeper knowledge of students' thought processes, especially in relation to problem-solving, in order to better assist their learning outcomes and processes [33]. Problem-solving skills are 21st century skills needed by society and the world of work, which is the ability to identify problems, find and select various alternative solutions, and make decisions in solving all problems faced [34]. Any engineer must be able to solve problems, and this competency is

important for all other professional roles. As a result, cultivating a critical thinking propensity is seen as crucial to the growth of the thought process and the method of problem-solving that develops into expertise. Emphasizing problem-solving abilities has been revealed at all educational levels [35].

The results of the hypothesis test on the mechanical reasoning variable show that mechanical reasoning positively and significantly influences engineering aptitude (H2, p value 0.000). The positive relationship between mechanical thinking and engineering ability suggests that mechanical thinking enables students to construct mental representations of how a mechanism works so they can predict system behavior and evaluate possible solutions. Having an understanding of mechanical principles, cause-and-effect relationships, and the function of a system is an important foundation in developing engineering competency. It is often acknowledged that the ability to reason is a crucial component in enhancing professional effectiveness. Research on engineering students reveals that that these pupils' thinking skills and engineering aptitude appear to be highly and significantly correlated [36].

The results of this study are in line with research stating that reasoning will help students form accurate mental representations of relationships in problems, improving their understanding of problem situations (problem solving) [37]. recommended that engineering teachers specifically instruct students on the relationship between the issue solver and the problem structure in various industrial situations, in addition to discipline knowledge [38].

Conclusion

Based on the research results, it can be concluded that engineering students' engineering aptitude is influenced by problem-solving and mechanical reasoning. This can serve as a reference for future research in developing learning aimed at improving engineering aptitude through engaging, problem-solving learning and reasoning learning. Therefore, the study emphasizes the crucial role of mechanical reasoning and problem-solving processes in developing engineering aptitude among students. From a practical perspective, the findings suggest that engineering education should provide learning environments that actively encourage reasoning skills and real-world problem-solving experiences.

Limitation and Suggestions

Several limitations should be considered when interpreting these findings. The study's relatively small sample size and single-institution design may have limited the results' applicability in different settings. Future studies must look into engineering aptitude, according to Broader.

Acknowledgment

This research was funded by the Ministry of Higher Education, Science, and Technology under Decree No. 0419/C3/DT.05.00/2025 dated May 22, 2025, and Contract No. 123/C3/DT.05.00/PL/2025 dated May 28, 2025.

Conflict of Interest

The authors declare no conflict of interest

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