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English Proficiency and Mathematical Ability as Cognitive Predictors of Critical Thinking Skill in Industrial Engineering Education

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Abstract. The rapid development of Industry 5.0 has raised the demand for higher-order thinking skills, especially critical thinking skill, among engineering students. This study was meant to evaluate the influence of English proficiency and mathematical competence on critical thinking capacity among Industrial Engineering students. This research used a quantitative approach utilizing survey method and multiple linear regression analysis. The population was 689 students of the second semester of Industrial Engineering and the sample was 104 individuals chosen by random sampling techniques. The research instrument for critical thinking capability was initially comprised of 10 items and 8 items were deemed valid with average validity value of 0.646 and reliability coefficient of 0.842. The results of the study showed that English proficiency and mathematics ability had positive and significant effect to analytical thinking capacity partially and simultaneously. The regression coefficient of English proficiency is 0.452 and the coefficient of mathematical ability is 0.318. English proficiency contributed more. Moreover, the simultaneous analysis showed that the two independent factors simultaneously contributed 54% to students' critical thinking skill. These results imply that linguistic competence and quantitative reasoning ability are significantly involved in the development of higher order thinking skills of Industrial Engineering students. English fluency and mathematical ability integration in engineering education is thus a key technique for preparing students to handle the complex problems of Industry 5.0.

Keyword: English Proficiency, Mathematical Ability, Critical Thinking Skill, Industrial Engineering Education, Industry 5.0

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INTRODUCTION

The rapid and significant advancement of globalisation, digital transformation, and intelligent technologies has fundamentally altered modern educational and industrial environments, necessitating individuals who possess not only technical skills but also the ability to analyse complex issues, evaluate information critically, and make informed decisions within dynamic systems (Kembau, 2025). In the current era of Industry 5.0, critical thinking is regarded not merely as a supplementary soft talent or an ancillary academic trait, but as an essential competency that higher education students, particularly in engineering fields, must possess (Jones, 2026; Nurhaliza, 2025). Industry 5.0 distinguishes itself from prior industrial paradigms that prioritised solely automation and efficiency. Industry 5.0 prioritises human-centric innovation, collaborative intelligence, ethical decision-making, and adaptive problem-solving, all of which necessitate robust critical thinking abilities from future engineers (Xu et al., 2021). Critical thinking is a complex skill that enables an individual to objectively assess information, rationally evaluate arguments, systematically interpret facts, and make reasoned choices in addressing challenging situations (Facione, 1990; Paul & Elder, 2019). The proficiency in critical thinking is essential for Industrial Engineering students, as their field focuses on the optimisation of integrated systems involving individuals, materials, information, technology, and organisational processes. Contemporary industrial systems are progressively in need of engineers capable of evaluating operational risks, critically analysing data, enhancing system efficiency, and providing strategic solutions for intricate industrial challenges. Recent academic literature reveals that university students frequently possess inadequate and highly variable critical thinking skills, failing to meet the demands of a competitive and innovative global workforce. This raises important questions regarding the internal cognitive and academic factors that affect students' critical thinking abilities (Sari, 2025).

To explain the variation in students' critical thinking skills, researchers must examine the cognitive tools employed in problem-solving, reasoning, and knowledge production processes. English proficiency and mathematical aptitude are fundamental academic factors posited to have significant and synergistic impacts on the enhancement of critical thinking skills. Proficiency in English serves as a means for accessing knowledge, engaging in global academic discourse, facilitating scientific communication, and appreciating diverse intellectual viewpoints. The majority of international scientific publications, technological advancements, engineering references, and educational resources are predominantly published and disseminated in English (Woo, 2026). Consequently, students with proficient English skills has a significant advantage in acquiring global knowledge, comprehending complex concepts, contrasting diverse viewpoints, and critically assessing arguments from many academic sources. Furthermore, proficiency in English enables engineering students to engage in analytical discussions, formulate logical arguments, articulate evidence-based reasoning, and actively partake in collaborative problem-solving settings, which are integral components of critical thinking skills (Novita, 2024; Liunokas, 2025). Students with advanced language proficiency frequently exhibit enhanced reflective thinking abilities, enabling them to synthesise information from a broader spectrum of academic materials and critically evaluate the validity, dependability, and utility of the content. The deficiency in English language proficiency may significantly restrict students' engagement with global scientific discourse, so diminishing their opportunities to cultivate critical reasoning and advanced cognitive skills.

Mathematics is highly relevant to critical thinking skills both structurally and conceptually. It nurtures logical reasoning, analytical thinking, systematic evaluation and evidence-based problem-solving skills. Industrial Engineering students with a solid mathematical background tend to have better skills in determining the relationship between variables, analysing complex systems, evaluating alternative solutions, and making logical decisions based on quantitative data (Muhammad et al., 2025). Mathematical competence develops pupils' ability to think systematically and logically so that they may view events from a number of different perspectives rather than relying solely on intuitive conjectures. Students need to critically interpret the numerical data, evaluate operational restrictions, compare alternative results and develop efficient solutions using logical reasoning in order to solve industrial optimisation challenges. Mathematical ability is thus the cognitive foundation for the development of critical thinking skills, transforming youngsters from passive consumers of information into active decision makers capable of making reasoned and evidence based decisions.

The application of communication, analytical reasoning, and evidence-based decision-making in higher education and Industry 5.0 settings highlights the obvious connection between English competence, mathematical aptitude, and critical thinking skills. An Industrial Engineering student with good English skills and a good mathematics background is in a very good position to develop sophisticated critical thinking skills. Good English speaking skills enable you to analyse and critique many sources of knowledge and good maths skills help you develop analytical thinking, logical organization and systematic approaches to evaluation. These two abilities offer a dual cognitive foundation: language skill imparts conceptual grasp, intellectual engagement and argumentative reasoning; mathematical talent provides methodical analysis, objective evaluation and logical problem-solving. When an engineering student has deficiencies in any of these dimensions, their critical thinking skills are likely to be distorted either being able to express ideas without sufficient analytical rigour or having the logical rigour but lacking the communication and interpretative skills needed to evaluate complex real-world problems in global academic and industrial contexts.

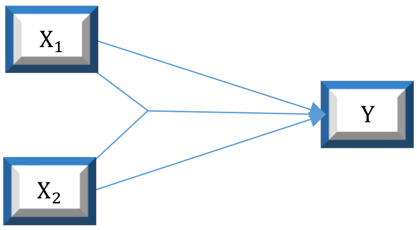
Although the literature on higher education competencies and technology adaptability has been growing, a notable research gap has been identified in the studies published in the recent decade. The majority of the previous studies have focused on technological literacy, academic achievement, or psychological aspects of learning motivation. The combined interaction of linguistic competence and quantitative reasoning in fostering students' critical thinking skills has received little empirical attention (Kembau, 2025; Nurhaliza, 2025). Moreover, the previous studies were mainly carried out with a subject with an education or computer science background excluding the non-computer engineering specialities such as Industrial Engineering. Students of Industrial Engineering are a unique academic population requiring a blend of communication skills, analytical reasoning, decision-making aptitude, and systematic problem-solving skills. This problem is more relevant in the context of Industry 5.0, where future engineers are expected to not only master technology but also to critically evaluate information, collaborate across multidisciplinary environments, and make ethical decisions in human-centered industrial systems (Xu et al., 2021). The present study attempts to fill this empirical gap. It focuses on a representative sample of 104 students of Industrial Engineering and identifies the role of English proficiency and mathematical aptitude as concurrent predictors of students' critical thinking skills.

In this sense, this study has several specific and interrelated goals regarding the clarification of these cognitive and empirical links within the framework of higher engineering education. The purpose of this research is to examine the partial effect of English proficiency on the level of critical thinking skill of the students of Industrial Engineering to find out how language competence becomes a facilitator of analytical reasoning, argumentative evaluation and evidence-based communication. Moreover, this study attempts to quantify the partial impact of mathematical aptitude on the critical thinking skills of students, stressing the special function of quantitative reasoning and logical analysis in the development of higher-order thinking capacity. Finally, the objective of this study is to examine the combined and interactive impacts of English language and mathematical ability on the critical thinking skills of a sample of 100 Industrial Engineering students. The research is expected to offer useful empirical insights that are needed to develop integrative engineering curricula that effectively connect linguistic competence, quantitative reasoning, and higher-order thinking skills, ensuring that future industrial engineers are fully prepared to face the growing complexity, collaboration, and innovation-driven demands of the Industry 5.0 era.

METHOD

The study used a quantitative approach with an ex-post facto research design and survey method. The aim of this research was to explore the effect of students' mathematical aptitude and English proficiency as cognitive predictors of critical thinking skills in the industrial engineering program. Multiple linear regression analysis was used to determine the partial and simultaneous effects of the independent variables on the dependent variable.

The research framework included two independent variables and one dependent variable:



X_1 : English Proficiency
X_2 : Mathematical Ability
Y : Critical Thinking Skill

The population in this study were 689 students of the Industrial Engineering Study Program in the second semester. The sample size was determined based on Arikunto's premise that if the population reaches 100 persons, the sample size is 10-25% of the total. Therefore, this study utilized 15% of the entire population from which 104 students were randomly selected.

The research instruments consisted of the following:
1. An English competency test,
2. A test of mathematical ability,
3. Critical thinking skills assessment

The critical thinking instrument was developed based on critical thinking markers of interpretation, analysis, evaluation, inference, explanation and self-regulation. Before the instrument was utilized in the main study it was pilot tested to make sure the instrument was valid and reliable. Pilot test results revealed that eight of the ten items provided were valid, with an average validity score of 0.646. The reliability test had a reliability coefficient of 0.842. It was indicated that the instrument was dependable and suitable for this study.

Testing and documentation were part of the methodology. The data obtained were analysed by descriptive and inferential statistical methods. The tests required were normality, linearity and multicollinearity. The hypotheses were also tested by multiple linear regression analysis using SPSS software.

This result is supported by previous research by Plaza Gálvez et al. (2023) who discovered that mathematical competence and analytical skills show a significant relationship with the development of critical thinking skills in engineering students. The study states that the students' critical thinking skills in engineering education can be improved through the numerical aptitude, problem solving abilities and the ability to grasp the academic knowledge. Hence, in the present study, English proficiency and mathematics ability are salient cognitive characteristics.

RESULTS AND DISCUSSION

Instrument Testing Results

Before beginning the primary data analysis, the study instrument was checked to ensure its validity and reliability. The critical thinking skill instrument was initially composed of ten items given to students outside the research sample. Table 1 presents an overview of the instrument testing results.

Table 1 Instrument Testing Results.

No	Variable	Number of Instrument Before Testing	Number of Instrument After Testing	Reability	Avarage of Validity
1	Critical Thinking Skill	10	8	0,842	0,646

Based on the criteria for interpretation of reliability, an instrument is regarded as reliable if the reliability coefficient is more than 0.70. Therefore, the coefficient obtained shows that the instrument was reliable and consistent enough to measure the critical thinking ability of students of Industrial Engineering. Hence, the 8 eligible items were given to the total sample size of 104 students.

Instrument testing results demonstrate that the evaluation items provided can effectively reflect the signs of analytical thinking. This research has important implications for critical thinking skills as such skills involve higher-order cognitive processes including logical reasoning, systematic evaluation, problem identification and evidence-based decisions. Therefore, the validity and reliability of the instrument should be verified before doing the regression analysis.

Data Assumption Testing

Prior to doing multiple linear regression analysis, prerequisite assumption tests were performed to confirm that the study data met the statistical assumptions needed for regression analysis. Normality and linearity tests were among the prerequisites. The results are summarised in Table 2.

Table 2 Data Assumption Testing Result.

No	Variable	Normality Test	Linearity Test	Conclusion
1	English Proficiency	0,182	0,000	Normal and Linear
2	Mathematical Ability	0,125	0,001	Normal and Linear
3	Critical Thinking Skill	0,094	-	Normal

The results of the normality test in Table 2 reveal that all research variables are normally distributed. A significant value of 0.182 was obtained for English proficiency, 0.125 for mathematical aptitude, and 0.094 for analytical thinking competency. All significance values were more than 0.05, indicating that the data were normally distributed.

These results indicate that the data were not significantly deviated from a normal distribution. So the variables can be analysed by parametric statistical methods, that is multiple linear regression analysis.

The results of linearity test showed that the relationship between both independent variables and analytical thinking ability was linear. The significance threshold was 0.000 for English proficiency and 0.001 for mathematical ability. Both significance levels were less than 0.05, which means that the relationships between the independent variables and analytical thinking competence were linear.

The evidence for the linearity assumption indicates that changes in English proficiency and mathematical ability were consistently related to changes in analytical thinking capacity. The result further strengthens the appropriateness of using regression analysis to explore the predictive effect of the two independent variables on students' analytical thinking skills.

Multiple Regression Analysis Results

Multiple linear regression analysis was conducted to investigate the partial influence of English proficiency and mathematical ability on students' analytical thinking skill. The summary of the regression analysis is presented in Table 3.

Table 3 Multiple Regression Analysis Results

No	Variable	Regression Coefficient (B)	T Value	sig	Description
1	Constant	12,436	2,185	0,032	Significant
2	Mathematical Ability	0,318	3,012	0,004	Significant Influence
3	English Proficiency	0,452	4,736	0,000	Significant Influence

The regression analysis results showed that both English proficiency and mathematics ability had a positive and statistically significant effect on critical thinking skills among Industrial Engineering students.

The regression constant value was 12.436, with a significance level of 0.032, indicating that the regression model was both feasible and significant. Mathematical ability had a regression coefficient (B) of 0.318, a t-value of 3.012, and a significance level of 0.004. Because the p-value was less than 0.05, mathematics competence had a substantial influence on analytical thinking skills.

This research implies that pupils with higher mathematical aptitude tended to have superior critical thinking skills. Mathematical ability enhances pupils' capacity to evaluate problems logically, discover patterns systematically, comprehend quantitative data, and develop reasonable solutions. Mathematical reasoning is particularly crucial in Industrial Engineering education since engineering students are regularly asked to analyse operational systems, evaluate efficiency, and solve complicated industrial problems using structured logic and quantitative data.

Meanwhile, English proficiency had a regression coefficient (B) of 0.452, a t-value of 4.736, and a significance level of 0.000. Because the significance level was less than 0.05, English proficiency had a substantial influence on analytical thinking ability.

The larger regression coefficient implies that English competence was more strongly related to analytical thinking capacity than mathematical aptitude. This finding suggests that linguistic competency plays an important role in assisting pupils' higher-order thought processes. Students with higher levels of English proficiency are often better equipped to access foreign academic resources, read scientific references, interpret complicated information, critically evaluate arguments, and participate in analytical conversations.

Furthermore, English literacy improves pupils' capacity to analyse diverse viewpoints and evaluate information objectively. Students in higher education, particularly in engineering disciplines, are routinely exposed to scientific journals, technical manuals, and global technological breakthroughs that are primarily written in English. As a result, children with higher levels of English proficiency have more intellectual exposure, which helps them develop critical thinking skills.

The findings also show that students' communication and interpretative abilities shape their analytical thinking skills in addition to their quantitative reasoning ability. This lends credence to the notion that higher-order thinking skills emerge from the interaction of logical reasoning and knowledge accessibility.

Simultaneous Influence of English Proficiency and Mathematical Ability

To examine the simultaneous influence of English proficiency and mathematical ability on analytical thinking skill, the coefficient of determination and F-test analyses were conducted. The results are summarized in Table 4.

Table 4 Regression Model Summary

R	Coefficient of Determination (KD)	F- Value	Sig. F	Description
0,736	54%	38,415	0,000	Simultaneously Significant

Based on Table 4, the regression model produced a correlation coefficient (R) of 0.736, indicating a strong relationship between the independent variables and analytical thinking skill.

The coefficient of determination (R^2) demonstrated that English proficiency and mathematical ability jointly contributed 54% toward students' analytical thinking skill, while the remaining 46% was influenced by other factors outside the scope of this study.

The contribution value of 54% indicates that both variables played substantial roles in shaping students' analytical thinking capacities. Nevertheless, the remaining unexplained percentage suggests that analytical thinking skill may also be influenced by additional variables such as learning motivation, problem-solving experience, digital literacy, self-regulated learning, cognitive style, classroom interaction, and instructional strategies.

Furthermore, the F-test yielded an F-value of 38.415 and a significance level of 0.000. Because the significance level was less than 0.05, it can be stated that English proficiency and mathematical competence both had a substantial impact on analytical thinking skills among Industrial Engineering students.

These findings are particularly pertinent to the educational needs of the Industry 5.0 age. Human-centered innovation, complex decision-making, interdisciplinary cooperation, and adaptable problem-solving skills are all priorities in Industry 5.0. Future engineers are expected to not only have technical skills, but also to analyse information critically, evaluate industrial processes systematically, communicate effectively across global contexts, and make evidence-based judgements.

As a result, enhancing English proficiency and mathematical ability may be an effective educational technique for improving students' critical thinking skills in Industrial Engineering education. Integrating linguistic competency and mathematical thinking into engineering curricula may better prepare students for increasingly complex industrial environments marked by fast technology innovation and worldwide collaboration.

Figure 1 Comparative Contribution of Independent Variables toward Analytical Thinking Skill

Figure 1 depicts the relative contributions of English proficiency and mathematics aptitude to analytical thinking skills. English proficiency exhibited a higher regression coefficient than mathematics aptitude, indicating that linguistic competence was a better predictor of students' critical thinking capacities.

This study implies that critical thinking growth in engineering education is significantly linked not just to logical and mathematical reasoning, but also to students' capacity to obtain, analyse, evaluate, and communicate knowledge successfully. As a result, boosting English proficiency might indirectly improve students' analytical reasoning by increasing their exposure to scientific material, academic debate, and worldwide technology breakthroughs.

CONCLUSION

The purpose of this research was to explore the influence of English proficiency and mathematical competence on the critical thinking skills of students in Industrial Engineering. The result of multiple regression analysis showed that English proficiency and mathematics ability had positive and substantial effect on students' critical thinking capability, both partially and simultaneously.

The results revealed that English competence was more contributory to analytical thinking capacity than mathematics aptitude. This means that pupils with a higher level of English proficiency are better able to interpret information, evaluate arguments, recognize scientific references and engage in analytical thinking processes. Language proficiency is a key feature in aiding the students' higher order thinking growth, given that most academic and technology resources are distributed in English worldwide.

Meanwhile, mathematics skills also contributed greatly to critical thinking capacity. Students with higher mathematical proficiency exhibited more robust logical thinking, methodical evaluation and evidence based problem solving skills. A mathematical skill enables students to analyze relationships between variables, evaluate quantitative information and generate reasonable solutions to complicated engineering issues.

Similarly, English proficiency and mathematical ability explained 54% of the variance in students' critical thinking capacity. This signifies that the two factors have significant roles in influencing higher order cognitive capabilities among Industrial

Engineering students. The results indicate that analytical thinking capacity is a result of the interaction between linguistic competency and quantitative reasoning ability.

Industry 5.0 demands the future engineer to be equipped with analytical reasoning, multidisciplinary communication, critical assessment and adaptive problem solving skills. Hence, enhancing the students' English language and mathematical competence is of paramount importance. Higher education institutions, especially in engineering education, are therefore encouraged to better integrate language competence and quantitative reasoning into learning processes in order to improve students' critical thinking capacities and prepare them for increasingly complex global industrial challenges.

Finally, this study is confined to two predictor factors and one particular educational situation. Future researchers are encouraged to explore other variables that affect critical thinking skills, such as digital literacy, learning motivation, cognitive style, problem-solving experience, and technological readiness, to gain a more complete picture of higher-order thinking development in engineering education.

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