International Journal of Business Studies and Education (IJBSAE)
ISSN (Online):2735-0940
VOLUME:3
ISSUE: 1

Exploring Learning Transfer In Mathematical Competence And Physic Problem Solving: A TVET Perspective

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Abstract

Mathematical competency is a crucial skill for engineering students, as many concepts in physics rely on mathematical principles for understanding and application. However, transferring mathematical knowledge to physics problem-solving can be a significant challenge for some students, particularly in Technical and Vocational Education and Training (TVET) programs. This study explores the learning transfer in mathematical competence and physics problem-solving among first-semester engineering science students at Polytechnic Sultan Idris Shah. A quantitative research approach was utilized to analyse data from 240 students, which included final test scores in Engineering Mathematics 1 and Engineering Science, along with continuous assessment results. The findings revealed a strong positive correlation between students' performance in mathematics and physics, indicating that higher mathematical competency is associated with improved problem-solving skills in physics. Additionally, a statistically significant correlation was found between final exam scores and continuous assessment scores, supporting the idea of effective learning transfer between the two subjects. These results highlight the importance of developing strong mathematical skills to enhance physics problem-solving abilities and suggest the need for specialized instructional strategies to facilitate learning transfer between mathematics and physics in TVET education. This study contributes to the existing research on effective educational strategies that integrate mathematics and physics problem-solving in technical education.

***Keywords**: Competency; Formula; Mathematics; Problem; Physics; Skill*

I. INTRODUCTION

Transfer, the capacity to apply information across different contexts, is essential to engineering education. Engineers must be able to recall and apply fundamental knowledge across several contexts, including advanced coursework and practical professional settings [1]–[4]. Undergraduate engineering programs aim to establish a foundation in mathematics and science and thereafter use this base to instruct students in problem-solving and advanced engineering principles. Effective learning transfer is crucial for students to utilize their undergraduate knowledge in other contexts, including graduate education, professional environments, or other practical situations. The course structure in polytechnic institutions is crucial for facilitating successful learning transfer. Courses such as Engineering Mathematics 1 and Engineering Science are fundamental for first-semester students, establishing a foundation in mathematics and physics. Engineering Mathematics 1 encompasses algebra, trigonometry, matrices, vectors, and scalars, whilst Engineering Science presents fundamental physics principles such as measurement, linear motion, force, work, energy, power, fluid dynamics, and thermodynamics[5]–[8]. These courses necessitate a robust comprehension of mathematics and physics, providing several chances for knowledge transmission. Empirical research repeatedly demonstrates a robust correlation between students' mathematical competency and their effectiveness in solving physics problems[9]–[13]. Nonetheless, a substantial gap persists in comprehending how students assimilate mathematical knowledge into physics problem-solving, especially in polytechnic contexts. Many students encounter difficulties in using their mathematical skills within physics contexts, impeding their problem-solving efficacy[10], [14]–[17]. Although research has examined the correlation between mathematical proficiency and physics problem-solving at the university level, there is a paucity of studies

Received: 20 March 2025
Revised: 25 March 2025
Accepted: 08 April 2025

Publisher: ICBE Publication (NS0237611-W)

investigating this transfer in polytechnic or vocational education, particularly among first-semester students. As polytechnic students' progress from general education to specialized technical training, comprehending the transfer of mathematics skills to physics problem-solving is crucial for enhancing their academic success. This study seeks to address this gap by examining the transfer of learning between mathematical competency and physics problem-solving among first-semester engineering students at a polytechnic institution.

II. LITERATURE REVIEW

Technical and Vocational Education and Training (TVET) is essential for providing students with the practical skills and knowledge required to address the changing needs of the workforce, especially about the fourth industrial revolution[18]–[20]. The efficacy of TVET programs is enhanced by strong collaborations with industry stakeholders, guaranteeing that the curriculum stays linked with the evolving demands of the labour market Notwithstanding these endeavours, obstacles like the transfer of learning endure, as students frequently struggle to apply the abilities acquired in training environments to job situations[1], [3], [21]. In TVET, mathematics serves as an abstract discipline and a pragmatic instrument supporting technical comprehension and empowering students to address real-world problems. Instructing physics problem-solving in TVET enhances students' capacity to comprehend and interact with the physical environment. The interplay between mathematics and physics amplifies the significance of both fields in technical education, guaranteeing that students interact with both subjects practically and meaningfully. Effective learning transfer transpires when students cultivate a robust conceptual comprehension of mathematics and physics, allowing them to apply their knowledge to novel and unfamiliar contexts[4], [14], [22], [23]. Students frequently have considerable difficulties applying mathematical principles to physics problems, mainly because of the abstract character of mathematics and the challenge of translating mathematical equations into physical interpretations[24]–[27]. The issues are exacerbated by the necessity for many mathematical procedures, including calculus and differential equations, which may be unknown to students with inadequate mathematical grounding. Moreover, students' perceptions of mathematics and physics, coupled with conventional teaching techniques that prioritise rote memorisation, may impede the cultivation of a profound conceptual comprehension essential for effectively applying these disciplines in practical contexts[28]–[32]. Despite extensive study on the distinct elements of mathematical competence and physics problem-solving, a deficiency persists in comprehending the mechanisms of learning transfer between these domains, especially in engineering education. This gap is substantial as engineering necessitates a complex amalgamation of mathematical principles and physics problem-solving in practical applications[14], [33]–[38]. Therefore, this study seeks to address that gap by examining the learning transfer in mathematical competency through the role of assessments in forecasting the degree of learning transfer between these two fields.

III. THEREOTICAL FRAMEWORK

The relationship between mathematics and physics has traditionally been a primary focus in educational studies, particularly in Technical and Vocational Education and Training (TVET)[2], [4], [39]. This exploration is grounded in Thorndike and Woodworth's Learning Transfer Theory which asserts that learning transfer occurs when there are shared elements or similarities between two activities or situations. The theory's premise of identical elements suggests that transfer is more likely when cognitive or procedural similarities between two domains enable learners to apply their prior knowledge to new contexts[1], [2], [40]. In TVET, students often use mathematical skills and problem-solving techniques to tackle physics challenges, especially in engineering education. This study investigates how these shared concepts facilitate knowledge transfer, including mathematical problem-solving procedures, formulas, and logical reasoning. The mathematical equations learned in mathematics can directly solve physics problems, establishing identical elements that link the two disciplines[13], [24], [40], [41]. Thorndike and Woodworth's approach highlights the importance of skill generalization, which occurs when competencies gained in one context are relevant in another, particularly when learners can recognize patterns or structures. Mathematical principles such as algebra, calculus, and geometry are vital for problem-solving in physics within TVET curriculum[3], [18], [42], [43]. This study examines how students generalize mathematical skills across different settings, revealing their application of mathematical competencies to physics problems and evaluating the effectiveness of this transfer. Additionally, the concepts of positive and negative transfer where transfer can either support or hinder learning offer further insights into

Received: 20 March 2025
Revised: 25 March 2025
Accepted: 08 April 2025
Publisher: ICBE Publication (NS0237611-W)

the connection between mathematics and physics in TVET programs. Figure 1 shows theoretical framework of the study.

Thorndike & Woodworth's Learning Transfer Theory

⬇

Principle of Identical Elements

Positive and Negative Transfer

Degree of Similarity Between Tasks

Contextual Factors

⬇

<u>Generalization of Skills</u>

Mathematical competency in TVET are applied to solve physics problems

⬇

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A solid foundation in mathematics may enhance a student's ability to solve physics problems, while difficulties in applying mathematical concepts to physical situations may indicate negative transfer. Such insights are crucial for understanding how the interplay between these subjects affects problem-solving skills in TVET students[17], [44], [45]. The extent of similarity among tasks is another vital aspect of Thorndike and Woodworth's theory. Transfer is more likely when the tasks in mathematics and physics exhibit significant cognitive and procedural similarities. In TVET education, analysing the curricula and task designs of both subjects allows for assessing the degree to which the cognitive skills needed for mathematics problem-solving align with those required for physics problem-solving. This analysis is essential for evaluating whether TVET programs are designed to support effective learning transfer[2], [46]. Thorndike and Woodworth acknowledged that contextual factors influence the efficacy of transfer, including motivation, instructional methods, and prior knowledge. In TVET programs, students' capacity to apply mathematical and physics concepts in diverse, real-world situations enhances learning transfer. Furthermore, the theory posits that learning transfer is more effective when students establish clear connections between their existing knowledge and new situations. A significant barrier for students, particularly in TVET education, is the difficulty of applying mathematical knowledge to physics problems[14], [47]–[49]. Despite their proficiency in abstract mathematical concepts, students often struggle to apply these skills in practical physics scenarios due to a lack of integration between mathematics instruction and its real-world applications in physics[48], [50], [51]. This challenge is especially relevant in TVET, where the emphasis on experiential learning requires students to merge theoretical knowledge with practical applications in fields such as engineering, manufacturing, and technology. The gap between abstract mathematics and its practical applications complicates the transfer process, making it difficult for students to establish the cognitive connections necessary for effective problem-solving[1], [12]. This difficulty can be elucidated through Thorndike and Woodworth's Transfer of Learning Theory, which posits that learning is most efficacious when knowledge acquired in one context applies to another environment with analogous elements. This theory posits that effective transfer of learning transpires when students identify correlations between the initial learning context and the new problem-solving situation[2], [21], [46]. Thorndike and Woodworth's Learning Transfer Theory provides a valuable framework for understanding the transfer of mathematical skills to physics problem-solving within TVET institution as represented by Figure 1. Thus, this study investigates the transfer of learning between mathematical skills and physics problem-solving, specifically among engineering students. The study aims to offer ideas for enhancing the integration of mathematics and physics instruction in TVET environments.

IV. RESEARCH METHODOLOGY

The methodology for examining learning transfer in mathematical competence and physics problem-solving was structured as a quantitative research study. The study utilized a census sampling strategy, including the whole population of 240 students, to guarantee a comprehensive and representative sample[52]–[55]. This methodology was used as it facilitated the participation of all students in the research, guaranteeing that the results correctly represented the performance and experiences of the entire cohort, devoid of sampling bias or constraints. The census approach guaranteed that the study findings were applied to the entire student population, augmenting the conclusions' reliability and validity. The data collection occurred over a four-month research period, during which numerous tests were conducted to investigate the association between students' mathematical competencies and their effectiveness in answering physics problems.

Received: 20 March 2025
Revised: 25 March 2025
Accepted: 08 April 2025
Publisher: ICBE Publication (NS0237611-W)

This duration was adequate for collecting extensive and pertinent data on students' academic performance and advancement. The research instruments for data collection comprised the final examination results for Engineering Mathematics 1 and Engineering Science, in addition to continuous assessment scores accumulated during the term. These tools were selected for their close correspondence with the research aims. Final test results were significant since they offered a definitive, standardized assessment of students' comprehensive mathematics and physics abilities. Continuous assessment scores were gathered to evaluate students' sustained improvement and capacity to apply mathematical knowledge across various contexts[9], [26]. These evaluations were crucial in demonstrating both conceptual comprehension and practical implementation, rendering them optimal indicators of mathematical proficiency and knowledge transfer. The data collected from these instruments were subsequently analyzed using correlation analysis. Table 1 shows the range of the Pearson correlation coefficient was utilized to explore learning transfer in mathematical competency and physics problem-solving[56], [57].

Table 1

Range of Correlation Coefficient Values	Level of Coefficient
0.80-1.00	Very Strong Positive
0.60-0.79	Strong Positive
0.40-0.59	Moderate Positive
0.20-0.39	Weak Positive
0.00-0.19	Very Weak Positive

V. RESULT AND DISCUSSION

This study sought to investigate the transfer of learning in mathematical competency and problem-solving in Physics. Table 2 shows the strong positive Pearson correlation value of 0.744 between the Mathematics Final Exam scores and the Physics Final Exam scores of 240 students, which indicates a high positive correlation between the two variables. The result demonstrates that heightened mathematical competency is associated with improved success in physics problem-solving. This outcome provides additional evidence for learning transfer from Mathematics to Physics. The robust positive association indicates the mathematical skills and competencies acquired in mathematics. The results corresponded with the findings that demonstrated a high link, providing substantial evidence of learning transfer between Mathematics and Physics[14], [26], [58]–[60]. Students who excel in Mathematics employ analogous problem-solving and reasoning skills. Studies previously corroborated the existence of a significant correlation between mathematical competency and physical problem-solving.[11], [32], [46], [61]. The correlation data demonstrate an intersection in the abilities and knowledge necessary for both areas. Competency in Mathematics correlates positively with success in Physics, offering compelling evidence of interdisciplinary learning transfer. The results were further analysed using continuous assessment scores for both courses.

Table 2

		Engineering Mathematics 1 Final Exam Score	Engineering Science Final Exam Score
Engineering Mathematics 1 Final Exam Score	Pearson Correlation	1	.744**
	Sig. (2-tailed)		.000
	N	240	240
Engineering Science Final Exam Score	Pearson Correlation	.744**	1
	Sig. (2-tailed)	.000	
	N	240	240

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3 presents the correlation coefficient for the continuous assessment scores of Engineering Mathematics 1 and Engineering Science.

Table 3

		Continuous Assessment Scores of Engineering Mathematics 1	Continuous Assessment Scores of Engineering Science
Continuous Assessment Scores of Engineering Mathematics 1	Pearson Correlation	1	.427**
	Sig. (2-tailed)		.000
	N	240	240
Continuous Assessment Scores of Engineering Science	Pearson Correlation	.427**	1
	Sig. (2-tailed)	.000	
	N	240	240

**. Correlation is significant at the 0.01 level (2-tailed).

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Revised: 25 March 2025
Accepted: 08 April 2025
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A coefficient of 0.4727 indicates a moderate positive correlation between the continuous Assessment Scores of Engineering Mathematics 1 and Engineering Science Scores. The correlation of 0.4727 between Continuous Assessment Scores of Engineering Mathematics 1 and Engineering Science Scores indicates that mathematical competency favourably affects physics problem-solving. The moderate correlation indicates that although mathematical proficiency enhances problem-solving in physics, it is not the sole determinant of success in the discipline. Consequently, the subsequent analysis using the t-test and p-value demonstrates that the correlation between the two variables is statistically significant. Table 4 shows the t-test and p-value of 0.00 indicates that the correlation between Engineering Mathematics 1 Final Exam Score and Engineering Science Final Exam Score and Continuous Assessment Scores of Engineering Mathematics 1 with Continuous Assessment Scores of Engineering Science scores is statistically significant.

Table 4

	Engineering Mathematics 1 Final Exam Score and Engineering Science Final Exam Score	**Continuous Assessment Scores of Engineering Mathematics 1 and Engineering Science**
t-test	8.1175	16.8334
p-value	0.000*	0.000*

The results indicate a significant transfer of learning between Engineering Mathematics 1 and Engineering Science. The t-test value and p-value demonstrate a strong correlation between Engineering Mathematics 1 and Engineering Science. Both Engineering Mathematics 1 and Engineering Science often employ similar problem-solving methods, mathematical principles, and analytical skills. Solving engineering problems typically requires the application of mathematical concepts, including calculus, algebra, and differential equations[38], [47], [48], [62]. Therefore, the learning transfer is substantiated by the results of this study, which demonstrate that the skills and knowledge obtained in Engineering Mathematics 1 are directly applicable to the resolution of engineering science problems. The strong correlation between the two subjects underscores the significance of mathematical competency in engineering science problem-solving which suggests that students who excel in mathematics are likely to apply their mathematical skills to tackle challenges in engineering science. This exemplifies learning transfer where students' mathematical competency enhances their understanding and application of engineering concepts. This result is supported by previous findings, which demonstrate that mathematical competency is a key predictor of success in physics[2], [43], [46]. The p-value of 0.000 indicates that this transfer is reliable and unlikely to occur by mere chance. This reinforces the notion that the transfer of mathematical proficiency to engineering science is both substantial and dependable. Consequently, the findings support the idea that mathematical expertise is essential for engineering science problem-solving, and the transfer of knowledge from mathematics to engineering science is statistically significant and practically beneficial[16], [26]. Previous studies also found that strong mathematical skills are often associated with higher success in physics, as mathematical concepts are integral to understanding and solving physics problems[4], [26], [49], [63].

VI. CONCLUSION

The results of this investigation indicate a robust positive correlation between problem-solving abilities in physics and mathematical competency. This suggests that students who excel in mathematics also tend to achieve higher success in physics. The correlation was further supported by continuous assessment scores, which indicated that sustained performance in mathematics is positively associated with progress in physics. This reinforces the idea of learning transfer between the two subjects in the Technical and Vocational Education and Training (TVET) environment. These findings are consistent with prior research, which has demonstrated that mathematical mastery is essential for improving students' problem-solving skills in physics. This study contributes to the literature on learning transfer in TVET, emphasizing the importance of mathematical skills in preparing students for practical problem-solving in technical and vocational fields. The study offers valuable insights for TVET educators and curriculum developers by emphasizing the transfer of mathematical knowledge to physics, indicating that enhancing mathematical competencies can enhance students' technical skills and overall academic performance. Additionally, this investigation concentrated on the correlation between the two subjects, it points to the need for future studies that explore the specific mathematical skills most relevant for solving real-world technical problems. Investigating the impact of teaching strategies and integrating interdisciplinary learning in TVET institutions could enhance learning transfer even further. Ultimately, this study reinforces the idea that a strong foundation in mathematics is essential for improving problem-solving abilities in physics, which is crucial for students pursuing careers in technical and vocational fields.

Received: 20 March 2025
Revised: 25 March 2025
Accepted: 08 April 2025
Publisher: ICBE Publication (NS0237611-W)

ACKNOWLEDGMENT

We would like to express our deepest gratitude to the Director of Politeknik Sultan Idris Shah for granting permission and providing the necessary support for the completion of this research study. We are also deeply thankful to the Head of the Research and Innovation Unit of Politeknik Sultan Idris Shah, Dr. Naemah binti Md Yusof and Head of the Mathematics, Science, and Computer Department, Puan Siti Norzailina bt Md Som for their unwavering encouragement and support throughout the research process.

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Received: 20 March 2025
Revised: 25 March 2025
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Received: 20 March 2025
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Received: 20 March 2025
Revised: 25 March 2025
Accepted: 08 April 2025
Publisher: ICBE Publication (NS0237611-W)

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Received: 20 March 2025
Revised: 25 March 2025
Accepted: 08 April 2025
Publisher: ICBE Publication (NS0237611-W)

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Received: 20 March 2025
Revised: 25 March 2025
Accepted: 08 April 2025
Publisher: ICBE Publication (NS0237611-W)