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Considering the Impact of Using Free-Body Diagram in Mechanics Problem-Solving on Improving Engineering Students' Performance in Physics at a Selected Public University in Rwanda

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Abstract

Background. Engineering students often struggle with physics problem-solving, especially mechanics problems, while teaching mechanics helps students predict motion and force impacts, enabling creative engineering design tasks. Problem-solving in mechanics involves using free-body diagrams, visual aids that identify objects and forces, determine appropriate approaches, and reduce information. The free-body diagram technique is crucial for understanding the principles of mechanics, as it helps distinguish between cause and effect, as well as focusing on the practical implementation of mechanics concepts.

Objectives. The current study aimed to examine the impact of free-body diagrams on engineering students' physics performance at a selected public university in Rwanda, highlighting cognitive load theory and constructivist learning theory's role in improving problem-solving abilities and understanding mechanics concepts.

Materials and methods. A sample of 68 students was purposively selected to participate in this study. Prior to the intervention, engineering students were given a pre-test to evaluate their ability to use free-body diagrams in solving mechanics problems. The experimental group underwent a four-week intervention, during which they were taught to draw free-body diagrams, identify external forces, and find force components. The data was collected through achievement tests and analyzed using Microsoft Excel and IBM SPSS Statistics 25.

Results. The study findings revealed that incorporating free-body diagrams into mechanics problem-solving improved significantly ($p < 0.001$) engineering students' performance in physics.

Conclusions. The study recommends incorporating free-body diagrams into the physics instructional curriculum to enhance student' understanding of basic subjects, practice problem-solving skills, and offer extra support for struggling students. Further research is needed to ascertain the impact of this approach on other physics fields.

Keywords: mechanics, engineering, problem-solving, free-body diagram.

Introduction

Engineering students frequently struggle with physics, particularly with mechanics problems, which necessitate a solid foundation in fundamental principles and problem-solving abilities (Niyomufasha et al., 2024a). Thabit et al. (2016) study shown that students who rely heavily on abstracted formulas struggle in mechanics tests due to a lack of understanding of physical concepts. The picture-like representations are more effective for understanding qualitative features of physics problems. Combining abstracted formulas and picture-like representations enhances students' learning skills and problem-solving abilities (Rosengrant et al., 2009).

Teaching and learning mechanics in physics serves a vital purpose in increasing engineering students' ability to predict the impact of motion and force, which allows students to perform creative engineering design tasks (Kraige & Meriam, 2012). Mechanics is also centered on problem-solving, and a suitable approach must be used to solve mechanics problems. Mechanics problem solving involves using representations like free-body diagrams, which are visual aids that help identify objects and forces, determine the appropriate approach, and reduce information (Taasoobshirazi et al., 2022).

The free-body diagram is the most significant single step in solving mechanics problems (Thabit et al., 2016). We consider both the physical aspects of the context and the appropriate mathematical representation. Every problem requires a shift from the physical to the mathematical. A free-body diagram also is a schematic of such an isolated object that

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displays all the external forces acting upon it (Mccarthy & Goldfinch, 2010). The free-body diagram technique is essential for comprehending mechanics. This is because the isolation of an object is a technique for clearly distinguishing cause and effect and focusing our attention on the practical implementation of a mechanics concept (Kraige & Meriam, 2012).

Procedures for Drawing a Free-Body Diagram

Due to the fact that we need to account for all of the forces that are acting on the particle when formulating equilibrium equations, constructing a free-body diagram is critical (Leipold & Ivancic, 2018). The three stages required for creating a free-body diagram are as follows:

Draw Outlined Shape

Isolate or separate the particle from the surrounding space. In this step, the particle's outline shape is drawn after removing all the supports.

↓

Show All Forces

It describes the active forces that set a particle in motion, as well as the reactive forces caused by constraints or supports. You can account for these forces by tracing around the particle's boundary and noting all the forces that act on it.

↓

Identify Each Force

The forces that are *known* should be labeled with their proper magnitudes and directions. Letters are used to represent the magnitudes and directions of forces that are unknown.

Fig. 1. Procedures for drawing free-body diagram

According to Lucas and Lewis (2019), the absence of a free-body diagram while solving mechanics problems was a common issue especially among students in engineering careers, leading to a number of analytical uncertainties. According to the theory, incorporating free-body diagrams into descriptions of problems might result in a rise, but also a decline in problem-solving challenges (Vanes et al., 2017), due to the fact that self-constructed instead of “pre-fabricated” free-body diagram are simple for students to implement as they appear to be more consistent with their own innate perceptions. It is imperative that students draw a free-body diagram correctly when trying to solve a mechanics problem because if the diagram is drawn correctly, they have a greater probability of solving the problem correctly than if the diagram is incorrect or if it is not used to solve (Rosengrant et al., 2006; Thabit et al., 2016). In order to understand mechanics, it is necessary to solve mechanics problems using free-body diagrams.

Rosengrant, Van Heuvelen, and Etkina (2009) study on physics majors found that only a small percentage of students correctly drew free-body diagrams with significant components. High-achieving students used diagrams to solve problems and evaluate their problem-solving approach, while low-achieving students drew diagrams without understanding components or checking accuracy. The study concluded that incorrect free-body diagrams led to more incorrect solutions.

Engineering and physics students have varying abilities in understanding free-body diagrams (FBDs) and solving mechanics problems. Some students understand FBDs, while others struggle due to visual or different learning levels (Davis & Lorimer, 2018).

Beyond the above studies described above, there is little research on how students are using free-body diagrams when studying or solving mechanics problems; there is a complete lack of research on engineering students’ impact on using free-body diagram in mechanics problem-solving at the University of Rwanda College of Science and Technology (UR-CST). Nguyen and Rebello (2011) found that students learn more if they understand the reason behind various pedagogical strategies such as using diagrams to solve problems. Understanding students’ free-body diagram use is an essential prerequisite to teaching students this reasoning. As a result, the purpose of this research is to explore the impact of using FBDs in mechanics problem-solving on students doing engineering for physics I’s performance. The study specifically investigated if the explicit instruction of FBDs leads to the improvement of problem-solving performance when compared to traditional approaches of teaching-learning mechanics. Finally, the findings of this study can be used to inform instructional approaches in physics education and help students improve their ability to solve mechanics problems.

FBDs, or force-based diagrams, are visual aids that help students break down complex problems into smaller parts and identify forces (Aviani et al., 2015). They also aid in understanding the connections between forces and system motions. Research shows that FBDs enhance engineering students’ understanding of physics concepts and problem-solving abilities (Mccarthy & Goldfinch, 2010; Aini, Sutopo, & Suyudi, 2021). Research has shown that employing Fundamental Differential Equations (FBDs) in mechanics problem-solving can significantly improve engineering students’ mechanics competencies. Studies by Kohl, Rosengrant and Finkelstein (2007) found that students trained in FBDs performed better on theoretical problems and numerical problems. Rosengrant et al. (2005a, 2005b) found that students taught using FBDs had a greater understanding of topics and better problem-solving abilities. Mccarthy and Goldfinch (2012) found that students using FBDs outperformed those not, and those given specific guidelines outperformed those not. Rosengrant et al. (2009) found that students using FBDs developed a stronger conceptual knowledge of physics and understood how forces interact to produce motion. Taasoobshirazi and Farley (2013) found that students using FBDs were more likely to identify the necessary information and use the right equations and principles to solve problems. Overall, the evidence suggests that incorporating FBDs into mechanics classes can enhance students’ problem-solving abilities.

Theoretical Framework

The study explores the impact of free-body diagrams on engineering students’ physics performance, based on the cognitive load theory (Sweller, 1988). Free-body diagrams help students lessen their cognitive burden by providing diagrammatic illustrations of forces acting on an item (Kirschner, 2002; Sweller, 2011). Interpreting the contents of a completed free-body diagram consumes more memory capacity than a student's step-by-step development. The intrinsic load is more noticeable in designs with force resolutions into components (Mešić, Mahmutović, Hasović, & Nataša, 2017). This study also follows the constructivist theory of learning, emphasizing active and reflective learning (Mccarthy & Goldfinch, 2012). Free-body diagrams help students become more involved with mechanics principles and gain a deeper understanding of forces' interaction with things. The research draws on physics education literature, revealing students often struggle with grasping and implementing mechanics principles. The study hypothesizes that engineering students' mechanics performance will be positively impacted by the use of free-body diagrams, particularly in improving problem-solving abilities and understanding of mechanics concepts.

Materials and methods

The primary objective of the current research is to evaluate the impact of employing free-body diagrams in mechanics problem-solving on engineering students' performance in physics. The study's goal is to see if introducing free-body diagrams into mechanics problem-solving may increase students' performance and strengthen their understanding of mechanics concepts.

Study Design and Participants

The study employed a quasi-experimental quantitative research design to assess the impact of using free-body diagram in mechanics problem-solving on engineering students' performance in physics for engineers. Prior the intervention the engineering students were give a pre-test to assess their abilities and the extent to which they were using free-body diagram in solving mechanics problems. Thereafter assessing their level in mechanics problem-solving, a four-week intervention were given to the experimental group on how to draw a free-body diagram, identifying and labeling the external forces acting on the body and affecting the motion, and finding the components of forces on x and y-axis. This intervention also included on how to apply the principles of equilibrium of forces (the sum of all forces acting on a body in equilibrium is zero, and the sum of all moments turning clockwise and sum of all moments turning counterclockwise is zero). The control group were taught using conventional method of solving physics problems without any training on how to solve mechanics problems using free-body diagram.

The study entailed assigning the same problem sets to two groups of students, with the experimental group being taught in utilizing free-body diagrams to solve mechanics problems. The experiment took place during regular classroom hours, with a final sample size of 68 pupils. The experimental group had 20 males and 14 females, whereas the control group included 24 males and 10 females. A selected sample was made by engineering students studying mechanics in year one of Electrical Power Engineering (EPE) and Electronics and Telecommunication Engineering (ETE) were selected purposively in this study based on their will to participate into this study, their common background in secondary schools because they did the same combinations, and also they had approximately the same performance in end senior secondary exams. The students were assigned randomly into experimental and control group for the purpose of the study. Each group was composed by 34 engineering students who signed the consent to participate in this study.

In the present research, the data was collected using achievement tests (pretest and posttest). The test was composed by four mechanics problems taken from a text-book (Schaum' Outlines of College Physics, McGraw-Hill, 9th edition) that must be solved using a free-body diagram. In the pretest, neither engineering students were asked to draw a free-body diagram; nor received the instructions on drawing the free-body diagrams. One instructor marked the test for consistency and all tests questions were marked out of 20 marks, and all copies of the pre-test were used to get the information on engineering students' abilities in drawing free-body diagrams using the following codes: (0) no free-body diagrams drawn in the test; (1) all free-body diagrams drawn by the students are incorrect; (2) many of the free-body diagrams were incorrect (drawn with many errors); (3) many of free-body diagrams were drawn correctly but lacking some information (with minor errors such as force label); (4) all free-body diagrams drawn by students in solving mechanics problems were correct with all required force labels. The post-test also was given to two groups under study after training the experimental group on how to use the free-body diagrams in solving mechanics problems. The test was also marked out of 20 marks by the same instructor for maintaining consistency. Descriptive and inferential statistics were used to assess the impact of using a free-body diagram in mechanics problem-solving on engineering students' performance in physics.

Statistical Analysis

All statistical analysis was done using Microsoft Excel and IBM SPSS Statistics 25 software.

Results

The current study use a quantitative research design where pre-test were used prior the intervention and post-test after the intervention. The normality test, students' abilities in utilizing free-body diagram in mechanics problem-solving, pre-test and post-test results were presented below.

Normality test results

The normality test results by Shapiro-Wilk tests revealed that for pre-test, $p = 0.830$ and for post-test, $p = 0.782$ which were significant at the level of $p > 0.05$, means that the data were normally distributed. Therefore, the parametric test were conducted.

Students' free-body diagram abilities

Table 1 and Table 2 below represents the engineering students' abilities in drawing free-body diagram when solving mechanics problems for control and experimental group before the intervention.

Table 1. Comparison of students who drew a FBD and those did not in the control group (n = 34)

Case	Percentage
All free-body diagrams correct	8.5
All free-body diagrams incorrect	20.0
No free-body diagram drawn	55.6
Many of FBD correct	8.0
Many of FBD incorrect	7.9

In the control group, about 44.4 % drew the free-body diagram where 8.5 % of all free-body diagram were correct, 20.0 % were incorrect, 8.0 % of them, many were correct and 7.9 % many of them were incorrect. The reason behind of drawing free-body diagram for some students in control group was due to their prior knowledge in mechanics problems solving from high school.

Table 2. Comparison of students who drew a FBD and those did not in the experimental group (n = 34)

Case	Percentage
All free-body diagrams correct	71.5
All free-body diagrams incorrect	5.1
No free-body diagram drawn	5.3
Many of FBD correct	11.7
Many of FBD incorrect	6.4

In the experimental group, about 94.7 % drew the free-body diagram where 71.5 % of all free-body diagram were correct, 5.1 % were incorrect, 11.7 % of them, many were correct and 6.4 % many of them were incorrect. The reason behind of large number of students who was drawing free-body diagram in experimental group is due to the intervention where engineering students were trained to use free-body diagram in mechanics problems solving.

Descriptive pre- and post-test data analysis

Descriptive statistics were used to describe the characteristics of the sample. The mean and standard deviation were calculated for each group on the pre-test and post-test. The paired sample t-test was used to compare the mean scores of the pre-test and post-test within each group, and the independent samples t-test was used to compare the mean scores between the experimental and control groups. The pre-test and post-test scores of both groups were collected and analyzed using SPSS software. The descriptive statistics of the two groups are shown in Table 3.

Table 3. Descriptive Statistics of Pre-test and Post-test Scores

Group	n	Mean Pre-test	Mean Post-test	Mean Difference
Experimental	34	3.3	16.0	12.7
Control	34	2.9	7.8	4.9

Table 3 shown the mean pre-test scores of both groups had no significant difference, with experimental group scoring slightly higher (M=3.3) than control group (M=2.9). However, the mean post-test score of the experimental group (M = 16.0) was significantly higher than the control group (M = 7.8). The mean difference between the pre-test and post-test scores of the experimental group was 12.7, which indicates a substantial improvement in their performance in mechanics problem-solving. In contrast, the mean difference between the pre-test and post-test scores of the control group was only 4.9, indicating a significant improvement in mechanics problems solving but lower than that of experimental group due to the intervention.

A paired-sample t-test was used to compare the pre-test and post-test scores of each group separately. The results are shown in Table 4.

Table 4. Paired-Sample t-Test Results

Group	t-value	df	p-value
Experimental	-23.249	33	<0.001
Control	-10.700	33	<0.001

The paired-sample t-test results in Table 4 show that the post-test scores of the experimental group were significantly higher than their pre-test scores ($t_{(34)} = -23.249$, $p < 0.001$). This indicates that the training program on FBDs had a positive impact on the performance of the experimental group. In contrast, the paired-sample t-test results for the control group show a significant difference between their pre-test and post-test scores but lower than what was obtained in experimental group ($t_{(34)} = -10.700$, $p < 0.001$). This means that the use of traditional method could affect performance but at lower level compared to the use of free-body diagram.

Pre-test results

Table 5. Independent Samples Test for pre-test results

Groups	n	Mean	SD	t	df	Sig. (2-tailed)
Control group	34	2.912	.949	-1.547	66	0.127
Experimental group	34	3.250	1.432			

Table 5 shows that the obtained p (0.127) exceeds 0.05, which implies the test does not show statistical significance at the 0.05 level, demonstrating that there were no differences that were significant between the two groups, and the null hypothesis was accepted for the pre-test. The experimental and control groups were equal before the intervention. With regards to the performance, there was no discernible difference between the experimental group (M = 3.25, SD = 1.432) and the control group (M = 2.91, SD = 0.949).

Post-test Results

Table 6. Independent Samples Test for post-test results

Groups	n	Mean	SD	t	df	Sig. (2-tailed)
Control group	34	7.809	2.7313	-11,89	66	<0.001
Experimental group	34	16.015	2.9571			

As shown in Table 6, the students who used free-body diagram in solving mechanics problems had higher achievement test scores (M = 16.015, SD = 2.957) compared to those who solved them using traditional methods of plugging number into formulas (M = 7.809, SD = 2.731). Since the obtained p-value (p0.001) is less than 0.05, there are significant differences between the groups at 0.05 level, indicating that the experimental group has a significant advantage over the control group. As a result of this test, it is concluded that using free-body diagram in solving mechanics problems in Physics courses for Engineering College students positively affects how well they perform in physics.

Discussion

The purpose of this study was to investigate the impact of using free-body diagrams in mechanics problem solving on the performance of engineering students in physics at a selected public university in Rwanda. The use of free-body diagrams is a fundamental concept in mechanics, and its effective application is crucial for solving physics problems (Mccarthy & Goldfinch, 2012). This results discussion aims to analyze and interpret the findings of the study, considering the implications for teaching and learning in physics education.

The findings of this study revealed that the use of free-body diagrams in solving mechanics problems had a significantly impacts on engineering students' performance in their first-year physics for engineers courses. During the course, students were engaged in various activities that emphasized the importance of using free-body diagram representation to enhance their understanding of the physical concepts. The experimental group (M = 16.015, SD = 2.957) results post-intervention shown that 94.7 % of students in this group drew the free-body diagram where 71.5 % of all free-body diagram were correct, 5.1 % were incorrect, 11.7 % of them, many were correct and 6.4 % many of them were incorrect. This indicates that engineering students post the intervention were aware of the importance of using free-body diagrams in solving mechanics problems, compared to the control group (M = 7.809, SD = 2.731) where 44.4 % drew the free-body diagram where 8.5 % of all free-body diagram were correct, 20.0 % were incorrect, 8.0 % of them, many were correct and 7.9 % many of them were incorrect. Those findings affirmed that students who drew correct free-body diagrams were more likely to solve problems correctly, while those who did not or drew wrong ones were unlikely to provide a correct solution (Thabit et al., 2016). This suggests that creating a correct free-body diagram would help students construct a suitable understanding of the problem, which in turn would enhance their problem-solving abilities. The current research results are consistent with other research on the impact of using free-body diagram in physics problem-solving (Mccarthy & Goldfinch, 2012; Mešić, Mahmutović, Hasović, & Erceg, 2017; Rosengrant et al., 2009; Sorby & Duffy, 2022). The employment of a free-body diagram considerably improves students' chances of answering mechanics problems when compared to inaccurate free-body diagram or no diagram, emphasizing the importance of this technique in studying and mastering the area of mechanics (Niyomufasha et al., 2024b). Cognitive load is reduced through step-by-step construction of the free-body diagram, and self-constructed external representations which is more consistent and easier to interpret than those externally provided diagrams which could increase the load because they requires a higher level of metacognitive thinking (Mešić, Mahmutović, Hasović, & Erceg, 2017). On the other hand, this study shown that the students' who did not draw free-body diagram, failed the course, which implies that students who have poor understanding of the course material are unlikely to draw free body diagrams. The success in drawing and appropriately using these diagrams is correlated to the success of a student in his/her entire course and further it indicates that the concept of drawing free-body diagrams is really fundamental. The existence of few students who could solve the test problem correctly without drawing the free-body diagram was a noticeable feature that should be considered for forthcoming research. This feature could be attributed to the fact that students who did not draw free-body diagrams may have done a correct diagram in their minds or they did it on an external draft paper which were not collected (Rosengrant et al., 2009). The analysis of the students' common mistakes in using free-body diagrams showed that students' mistakes were mainly either drawing one force (or more) in a wrong direction or wrong vector analysis of the gravitational force.

The findings of this study have important implications for teaching and learning in the context of engineering education at the University of Rwanda. Incorporating the use of free-body diagrams into physics instruction can enhance students' performance by promoting a more systematic and organized approach to problem solving. By visualizing and analyzing forces acting on an object, students develop a clearer understanding of the underlying physics concepts and principles.

Conclusion and recommendation

In conclusion, the current research aimed to evaluate the impact of using free-body diagrams in mechanics problem-solving on engineering students' performance in physics at a selected public university in Rwanda. The study discovered that students who used free-body diagrams for solving mechanics problems, not only understanding the problem statement but also creating mathematical descriptions and assessing their outcomes. This might be credited to the learning approach, which taught students how to utilize diagrams to help them comprehend concepts and solve problems. The current research also revealed that the engineering students who draw accurate free-body diagrams are more likely to answer problems properly than those who do not or draw them incorrectly. The findings show that engineering students in the experimental group are more likely to draw correct free-body diagrams as a result of the intervention, implying that these diagrams are essential for comprehending mechanics problems. In this group 94.4 % of students employed the free-body diagram approach to answer mechanics problems, even though they were not given marks for it. This indicates that students are aware of the relevance of these diagrams and have a habit of employing them to solve problems. The study found that the use of free-body diagrams in classroom work and achievement tests in the first-year engineering mechanics course greatly improves concept understanding, problem-solving abilities and their performance in physics. The study suggests the physics tutors to add free-body diagrams into their curriculum to help students comprehend basic physics subject matters. They should also provide students opportunity to practice problem-solving by utilizing free-body diagrams to develop their problem-solving abilities and expertise. For some students who struggle with using free-body diagrams should be given extra help, such as mentoring or being given supplemental educational resources. To get greater insights, more study should be conducted into the influence of free-body diagrams on other physics fields, such as electrostatics or electromagnetism.

Data availability statement

The findings of this research are supported by the data available openly at the following DOI: 10.17632/56xjk7v545.1

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Conflict of interest

The authors declare no conflict of interest.

Ethical Considerations

The study adhered to ethical guidelines set by the college Research Screening and Ethics Clearance Committee (RSEC-C). The participants were informed about the purpose of the study, the data collection procedures, and their rights as participants. Participation will be voluntary, and participants were signing the consent form to approve their participation and they had the right to withdraw at any time without penalty. All data collected were kept confidential and anonymous and used for the purpose of the study only.

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APPENDIX

We provide below the four-problem assessment questions that had been solved by engineering students from the experimental and control group during pre-test and post-test. The assessment questions were the same for both pre- and post-test, the only difference was the ordering.

Problem 1

Suppose that a year one engineering student is pulling a 70kg box on a rough surface using a 400N force at an angle of 30o to the horizontal. The coefficient of kinetic friction of the box is 0.50. Find the acceleration of the box.

Problem 2

Consider the situation shown in the figure below. The uniform 0.60kN beam is hinged at P. Find the tension in the tie rope and the components of the reaction force exerted by the hinge on the beam. Given your answers to two significant figures.

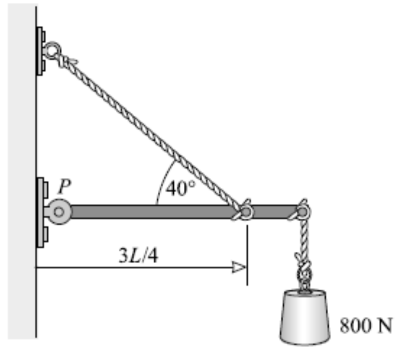

Fig 2. Illustration of Problem 2

Problem 3

A uniform, 0.20kN board of length has two objects hanging from it: 300N at exactly from one end, and 400N at exactly from the same end. What single additional force acting on the board will cause the board to be in equilibrium?

Problem 4

Approximately what magnitude of force, F_M, must the extensor muscle in the upper arm exert on the lower arm to hold a 7.3 kg shot put? Assume the lower arm has a mass of 2.8 kg and its CG is 12 cm from the elbow-joint pivot.

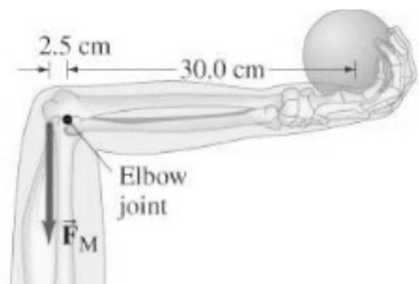

Fig 2. Illustration of Problem 4

Розгляд впливу використання діаграми вільного тіла при розв'язуванні задач з механіки на покращення показників успішності з фізики студентів інженерних спеціальностей окремого державного університету в Руанді

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Статья: 8 с., 6 табл., 3 рис., 26 джерел.

Історія питання. Студенти інженерних спеціальностей часто стикаються з труднощами в процесі розв'язування задач з фізики, особливо з механіки, тоді як вивчення механіки допомагає студентам прогнозувати рух і силові впливи, що сприяє виконанню творчих завдань з інженерного проектування. Розв'язування задач з механіки передбачає використання діаграм вільного тіла, візуальних засобів, які ідентифікують об'єкти та сили, визначають відповідні підходи та зменшують обсяг інформації. Техніка діаграми вільного тіла має ключове значення в контексті розуміння принципів механіки, оскільки допомагає розрізняти причину і наслідок, а також зосередитися на практичному застосуванні механічних концепцій.

Мета дослідження. Мета цього дослідження полягала у вивченні впливу використання діаграм вільного тіла на показники успішності з фізики студентів інженерних спеціальностей окремого державного університету в Руанді, підкреслюючи роль теорії когнітивного навантаження та конструктивістської теорії навчання щодо поліпшення здатності застосовувати набуті знання і вміння до розв'язування задач та розуміння концепцій механіки.

Матеріали та методи. До участі в дослідженні було цілеспрямовано залучено вибірку із 68 студентів. Перед початком інтервенції студенти інженерних спеціальностей пройшли попередній тест з метою оцінки їхньої здатності використовувати діаграми вільного тіла при розв'язуванні задач з механіки. Експериментальна група проходила чотиритижневий курс інтервенції, під час якого їх вчили креслити діаграми вільного тіла, визначати зовнішні сили та знаходити силові компоненти. Збір даних здійснено за допомогою тестів досягнень та проаналізовано із застосуванням програмного забезпечення Microsoft Excel та IBM SPSS Statistics 25.

Результати. За результатами дослідження встановлено, що включення діаграм вільного тіла до розв'язування задач з механіки сприяло суттєвому ($p < 0,001$) покращенню показників успішності студентів інженерних спеціальностей з фізики.

Висновки. Дослідження рекомендує включати використання діаграм вільного тіла до навчальної програми з фізики задля підвищення розуміння студентами базових тем, відпрацювання навичок розв'язування задач і надання додаткової підтримки студентам, які мають труднощі з навчанням. Проведення подальших досліджень слід спрямувати на з'ясування впливу зазначеного підходу на інші галузі фізики.

Ключові слова: механіка, інженерія, розв'язування задач, діаграма вільного тіла.

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