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Assessing the Effectiveness of Constructivist Teaching Approaches in Physics Education: Insights from Free Fall Motion Topics

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Abstract

Physics subjects encompass all aspects of nature on both the macroscopic and submicroscopic levels. It was reported that upper secondary school students in Malaysia have difficulties in some topics in Physics which lead to poor performance of students and a lack of interest in the Science, Technology, Engineering and Mathematics subjects. This research assessed the level of students' knowledge of Free Fall Motion, explored the difficulties faced by the students with Free Fall Motion's topics, measured the effectiveness of the constructivist teaching approach for students in learning Free Fall Motion, and collecting students' perception towards the constructivist teaching approach. This study used a pretest-posttest research design. The population was upper secondary school students from public secondary schools in Malaysia and 30 students were selected as a research sample in this study Using descriptive analysis and paired sample t-tests, it was revealed that majority of students preferred constructivist teaching approach in learning this topic as significant difference in effectiveness of two constructivist coping techniques, visual learning and contextual learning were observed while, assisting students in managing difficulties in learning Free Fall Motion. In conclusion, the constructivist teaching approach improved student`s understanding of the Free Fall Motion concept, however, because of different perspectives and having to adapt to various methods of learning, not all of the students were interested in applying it in their classroom.

Keywords: *Constructivist Teaching, Learning Physics Subjects, Upper Secondary School Students*

INTRODUCTION

Physics, as a fundamental branch of science, delves into the intricacies of matter, energy, and their interactions, encompassing both the macroscopic and submicroscopic levels of the natural world (Walker, 2013). This study of matter's structure and the fundamental principles governing the universe is not only essential for advancing technological growth but also for fostering a scientific mindset among students. The relevance of physics in various sectors such as transportation, medicine, and communications underscores its importance in contemporary education (Raymond A. Serway, 2018).

In Malaysia, the aspiration to become a developed nation hinges significantly on fostering a

progressive, scientific, and technologically adept society. The integration of Science, Technology, Engineering, and Mathematics (STEM) education into the curriculum is a pivotal step towards achieving this goal(Akademi Sains Malaysia, 2017). In order to fulfil these goals, Physics has been encompassed into the two-year curriculum in Malaysia, along with other scientific disciplines. This curriculum begins in Form Four and ends in Form Five. Nevertheless, despite the collective efforts, students often encounter significant obstacles in comprehending and achieving proficiency in Physics concepts.

It has been reported that the level of educational achievement in the subject of Physics is declining in Malaysia (Norezan et al., 2019). Students, in general, have struggled to flourish in the subject of Physics. To top it all off, a variety of studies done around the same time period revealed that the vast majority of student population are uninterested in studying Physics (Saleh, 2021). For most , physics appears as a difficult to comprehend and unpleasant subject. This perception is a worry not only in schools, but also in higher learning institutions such as colleges and universities where enrolment into STEM related programmes can be affected. Due to this reason, a startlingly large proportion of students have also been discovered to avoid studying any Physics-related courses at higher levels of school.

This research focuses on one such challenging topic: Free Fall Motion. Numerous studies have found that some misunderstandings persist among students. (Dognia et al., 2023) demonstrated that the misconception that gravity hampers motion is the most widespread misunderstandings among physics and physical science groups. The objective of the research is to assess the level of students' knowledge of Free Fall Motion, to explore the difficulties faced by the students with Free Fall Motion's topics, to measure the effectiveness of the constructivist teaching approach for students in learning Free Fall Motion, and to determine students' perception towards the constructivist teaching approach. This study aims to provide insights that can help improve the teaching and learning of Physics. The constructivist approach, which encourages active participation and contextual learning, is hypothesized to be particularly effective in addressing these challenges (Jajuri et al., 2019).

LITERATURE REVIEW

The primary theories of this research are Bloom's Taxonomy and John Dewey Theory, which aid in understanding the style of learning Physics. Bloom's taxonomy as shown in Figure 1, is an established framework for considering students' learning as a basis for teaching and learning. Bloom's taxonomy provides a hierarchical structure of cognitive skills and is utilized worldwide as guidance for effective teaching methods. The reason this research used Bloom's taxonomy is that it includes a hierarchy of progressive processes ranging from basic to complicated, where it is required to master those lower down the pyramid before mastering those higher up. The framework supports what Bloom referred to as mastery learning. It consists of 6 levels which are remembering, understanding, applying, analysing, evaluating, and creating (Prasad, 2021). By encouraging students to move through these levels, educators aim to develop not only knowledge but also critical thinking, problem-solving, and creativity in learners.

John Dewey, an American philosopher, educator, and social critic, on the other hand, thinks that progressive education should include lessons that are socially engaging and beneficial for young children's growth (Garalova, 2019). His concept that students, not curriculum, should be the focal point of the educational process has left a lasting impact on educators who align with his educational principles and views on effective student learning (Williams, 2017). This iterative approach guarantees that education is a dynamic and interactive experience that educates learners with the skills needed to face real- world situations, rather than a passive accumulation of data.

1. Diagnosing on Students' Perceived Difficulties Topic in Upper Secondary School

To ensure that the student is the primary focus of the educational process, educators must initially endeavour to comprehend the challenges that students encounter. In Free Fall Motion, the students frequently have problems in using scenarios such as the heavier object would fall quicker, gravity

decreases with height, and air resistance, temperature, and distance from the equator all have an influence on gravity. In a research conducted with high school students, using multiple-choice questions (Ziad et al., 2021), the students were asked to anticipate what would happen if one of the two weights, which were initially resting at the same height on Atwood's machine, was lowered to a different position and released. Because the weights had identical mass, most answers had assumed that the weight would move and seek' the same level.

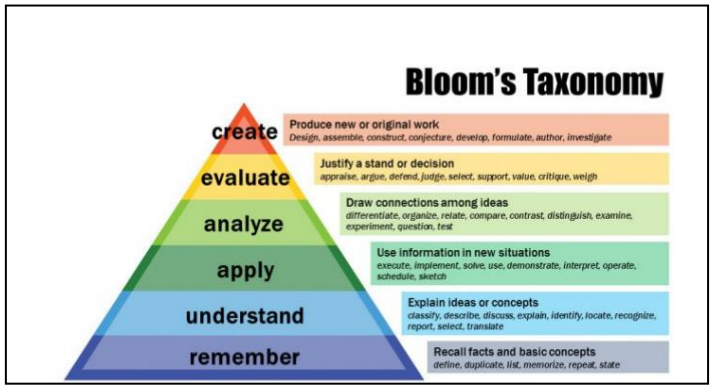

Figure 1 Bloom's Taxonomy Level for Learners (Dosmar et al., 2021)

The concept of object's acceleration due to gravitational force is frequently confused with the gravitational field. A past research also shown that in a case of a ball thrown upwards, the students recognised a negative acceleration (-*g*) as a ball was thrown up and a positive acceleration (+*g*) as it fell, and by simply combining these motions had concluded that the ball had zero acceleration but no gravitational force at the vertex of movement. The students also have misconceptions about the relationship between gravity and acceleration, such as (i) acceleration of an object is always constant in both upwards and downwards motions, and (ii) acceleration is the ~~a~~ result of gravity while going down and in moving up, it was because of an applied force.

2. Problems Faced by Students While Studying Physics During Their High School Years

Kaushal et. al investigated the major causes of students' difficulty in performing physics challenges in high schools(Kaushal, 2019). The objective of the research is to identify the problem-solving techniques that students utilized, as well as any approaches and stages that can assist students perform the work correctly. They expected that methodological materials with specific instructions for high school instructors and worksheets for students would be created on the basis of existing literature and the mentioned questionnaire survey. The students are the subjects of the research. Kaushal et.al reported that students experience difficulties when learning Physics since Physics is full of formulae, computations, graphs, conceptual explanations, and experiments, and students must convert pictorial to mathematical representations.

The study involved a total of 113 randomly selected individuals. Out of total responses, only 89 were able to be extracted. Consequently, 11% of participants reported that a lack of exposure to practical applications, 11% that a lack of conceptual knowledge, 20% that being an overburdened student, 23% that being an unprepared, deficient, and unmotivated teacher as a cause of dissatisfaction, and 33% pointed to insufficient prerequisite mathematical knowledge was a problem for them.

3. Ways to Overcome Difficulties in Learning Physics

Overcoming difficulties in learning Physics can be challenging but achievable with strategic approaches. Educators can implement active learning strategies such as hands-on experiments and interactive simulations to illustrate abstract concepts effectively (Fazio et al., 2021) (Karamustafaoglu, 2009). Other than that, promoting conceptual understanding through visual aids, analogies, and everyday examples helps clarify complex ideas (Diez, 2020). Ince et. al reported that teaching Physics

by systematic problem-solving techniques provides ample practice opportunities to build confidence and proficiency towards the students. Despite all the methods, the use of constructivist techniques such as idea mapping and project-based learning has been regarded as the most effective way to promote deeper learning and motivation in the field of Physics. Constructivist learning involves learners actively constructing their own knowledge (Tuwoso, 2016). They engage with a diverse range of educational materials and then decide what knowledge they will acquire.

METHODOLOGY

1. Research Approach and Design

A set of questions on Free Fall Motion's topic for investigation before and after examination was given. This research used a pretest-posttest research design to investigate the process and relationship of the participants' experiences before and after constructivist teaching approaches intervention.

The constructivist teaching approach includes two techniques, primarily emphasising visual learning and situated learning. Visual learning is the use of visual aids, such as videos, to improve the learning process. Participants were given sample videos that demonstrated free fall motion in a realistic and engaging manner by using channels such as YouTube. In the context of situated learning, which emphasises the application of knowledge in real-world situations, participants were required to apply their knowledge in activities that are related to free fall motion after observing the example video.

After the intervention, the same set of questions was administered to the participants as a posttest to measure any changes in their understanding of free fall motion. The pretest and posttest results were then compared to determine the effectiveness of the constructivist teaching approaches

2. Population and Sampling

The respondents for the pretest and posttest were chosen from six classes of science stream form 4 classes. Total population of the six Science Stream classes is 120 students. 30 respondents were chosen to participate in a pretest and posttest examination, forming the foundation for the research findings. Convenient sampling techniques were used to ensure the success of the study. The respondents are ready to cooperate with the researcher and agreed to join the study. During the data collection stage, 30 students were chosen randomly from six classes of science stream form 4 classes to avoid bias and other interference, in the conduct, marking and interpretation of the test results.

3. Method of Data Analysis

In this study, descriptive analysis was utilized to achieve the objectives of the study. Descriptive analysis is a statistical approach for summarizing and describing the basic characteristics of a dataset, such as the mean and standard deviation. The mean was the average value of a group of scores, and it provided an approximation of the data's central tendency. The standard deviation measured the variability or dispersion of the scores around the mean. This descriptive data, when combined, has given insights into the distribution and features of survey replies. The questionnaire's reliability and validity were initially assessed through pilot test analysis. The relationship was subsequently analysed using logistics regression analysis.

RESULT AND DISCUSSION

The results gathered are derived from the responses provided by participants in the pre-test and post-test, which included a sample of 30 students from six science stream form 4 classrooms. All data is analyzed using SPSS and the results are recorded. This includes demographic analysis, number of respondents, frequency, mean and standard deviation. The types of analysis that were used to analyze the research questions involved descriptive analysis and paired sample t-tests.

1. Demographic Details

Table 1 shows the distribution of gender of the respondents who were involved in this research. A total of 15 (50.0%) of the students are male while another 15 (50.0%) are females.

Table 1 The distribution of gender of the respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	15	50	50	50
	Female	15	50	50	100
	Total	30	100	100	

2. Level of student`s knowledge of Free Fall Motion

Students were given a pre-test to determine the level of students' knowledge of Free Fall Motion before attending the constructivist teaching approach. It can be seen from descriptive analysis shown in Table 2 that on average , students have lowest performance in Test 1 on Free Fall Motion (mean = 6.5667, SD = 1.45468). The 10 weakest students achieved 5 marks and only 5 students scored 9 marks.

Table 2 Descriptive for Performance in Pre-test

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Test 1	30	4.00	5.00	9.00	6.5667	1.45468	2.116
Valid N (listwise)	30						

3. The difficulties faced by the students for Free Fall Motion's topic

The second objective of the study is to identify the students' opinions about the challenges or difficulties that they faced when studying Free Fall Motion. A descriptive analysis was conducted based on the students' opinions about challenges in learning Free Fall Motion. The data presented in Table 3 reveals that the majority of students struggle with recalling the formula for Free Fall Motion (mean = 0.433, SD = 0.49827). Some students expressed their concern on the difficulty in doing calculations, represented a mean of 0.1000 and a standard deviation of 0.30513. Additionally, students expressing confusion about the meaning of claims in the textbook, has a mean of 0.0667 and a standard deviation of 0.25371. The average response rate for the students not answering the questions was 0.3333 with a standard deviation of 0.47946. Additionally, the average level of fluency in understanding the Malay Language among the students was 0.0333 with a standard deviation of 0.18257. Furthermore, only one student said that the topics lacked examples, with an average rating of 0.0333 and a standard deviation of 0.18257.

Table 3 Descriptive of Students' Opinions About The Difficulties When Studying Free Fall Motion

	N	Mean	Std. Deviation
Hard to remember the formula	13	.4333	.49827
Hard in calculation	3	.1000	.30513
Lack of example	1	.0333	.18257
Confusing meaning/statement	2	.0667	.25371
Lack in understanding Physic in Malay Language	1	.0333	.18257
No answers	10	.3333	.47946
Valid N (listwise)	30	1.0	

4. Improvement in students' performance after learning using the constructivist teaching approach for students in learning Free Fall Motion

Paired samples t-test was conducted to see if there was a significant improvement in students' performance after learning using the constructivist teaching approach for students in learning Free Fall Motion. Table 6 shows that t value = -8.618, df = 29, alpha = < 0.001. Since the p-value is lower than 0.05, it can be concluded that there is a significant difference between the pre-test and post-test in improving the students' performance after learning using the constructivist teaching approach for students in learning Free Fall Motion. Students scored more during the post-test (mean=9.0000, SD=1.17444) rather than the pre-test (mean=6.5667, SD=1.45468).

Table 4 Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-test	6.5667	30	1.45468	.26559
	Post-test	9.0000	30	1.17444	.21442

Table 5 Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre-test & Post-test	30	.323	.082

Table 6 Paired Samples T-Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Test 1 – Test 2	-2.43333	1.54659	.28237	-3.01084	-1.85583	-8.618	29	<.001

5. Students' perceptions towards the constructivist teaching approach

Table 7 shows the distribution of visual learning resources among respondents. 26 (86.7%) students found that visual learning resources (such as diagrams, graphs, and videos) helpful in understanding Free Fall Motion concepts and another 4 (13.3%) students are not sure about that.

Table 7 The distribution of visual learning resources among respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	26	86.7	86.7	86.7
	I am not sure	4	13.3	13.3	100.0
	Total	30	100.0	100.0	

According to Table 8, only 2 students (6.7%) believe that contextual learning, such as problem-solving activities and real-world applications, will effectively enhance their understanding of Free Fall Motion. In contrast, 7 students (23.3%) find it effective, and 21 students (70.0%) consider it moderately efficient.

Table 9 indicates that 21 students, which makes up 70.0% of the total, agreed that constructivist learning methods were very helpful in enhancing their understanding of Free Fall Motion. Additionally, 6 students (20.0%) expressed a preference for visual learning, while 3 students (10.0%) favoured situated learning.

Table 8 The distribution of contextual learning among respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Moderately efficient	21	70.0	70.0	70.0
	Effective	7	23.3	23.3	93.3
	Very efficient	2	6.7	6.7	100.0
	Total	30	100.0	100.0	

Table 9 The distribution of constructive learning among respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Visual Learning	6	20.0	20.0	20.0
	Situated Learning	3	10.0	10.0	30.0
	Both are equally advantageous	21	70.0	70.0	100.0
	Total	30	100.0	100.0	

DISCUSSION

This study were based on four research objectives. First, the level of students' knowledge of Free Fall Motion. Second, the difficulties faced by the students for Free Fall Motion's topics. Third, the effectiveness of the constructivist teaching approach for students' in learning Free Fall Motion. Lastly, the students' perception towards the constructivist teaching approach.

The study began with a pre-test designed to assess upper secondary school students' understanding of Free Fall Motion before introducing them to the constructivist teaching method. Based on Table 2 it's clear that the ten lowest students received at least 5 marks, indicating that they were struggling with the fundamentals of Free Fall Motion. On the other hand, only 5 students received a score of 9, indicating a significant discrepancy in performance among the students. The result of low average score and unequal distribution of marks in pre-test raise queries concerning how well students initially understood Free Fall Motion. This shows a potential gap in basic understanding or misconceptions that need to be addressed. To address these challenges, an effective teaching strategy, such as the constructivist teaching approach used in this research which is critical for closing gaps and improving knowledge. (Garalova, 2019) identified similar issues in physics education, emphasizing the need for new teaching methodologies.

Students' perspectives on the challenges they experienced throughout the study of Free Fall Motion provide useful insights into the learning process. The results indicate that a large proportion of students had difficulties remembering the formula related to Free Fall Motion. This highlights an important point in which memorizing appears to be a significant barrier for students, potentially impeding their understanding and implementation of the principles involved. Another noticeable challenge was the difficulty of performing calculations relating to Free Fall Motion. It shows that a subgroup of students struggles with the mathematical parts of the subject(Ziad et al., 2021). Next, the students' confusion about the meaning or statements in the textbook emphasizes the significance of teaching materials and argues that improvements in content delivery clarity may reduce student confusion and improve overall understanding(Ibrahim et al., 2022). Moreover, students' fluency in understanding Malay and the perception that topics lack examples also result in low mean values. This highlights the importance of language proficiency and illustrative examples in facilitating effective learning experiences(Syaharudin et al., 2015).

The results of the paired samples t-test provide strong insights into the efficacy of the constructivist teaching strategy in improving students' performance in learning Free Fall Motion. The p-value is less than 0.001 suggesting a very significant difference between the pre-test and post-test results. This statistical significance demonstrates the effectiveness of the constructivist teaching technique in boosting students' understanding of Free Fall Motion.

Students' perspectives of the constructivist teaching technique in the context of grasping Free Fall Motion concepts provide insights into the effectiveness of different educational techniques by highlighting the diverse attitudes of students. The findings show that a higher percentage of the students

prefer visual learning tools such as diagrams, graphs, and movies to help them understand Free Fall Motion topics. This is in line with constructivist teaching ideas, which emphasize the need of engaging visual stimuli to facilitate learning(Fazio et al., 2021). A few of students who indicated confusion may necessitate more inquiry into their individual learning preferences or potential difficulties with using visual aids.

CONCLUSION

Based on all of the findings, educators should consider using constructivist teaching approaches while tackling Free Fall Motion challenges. This technique not only bridges knowledge gaps, but it also connects with students, resulting in a more interesting and successful learning experience. This study's nuanced findings contribute to the ongoing discussion about novel pedagogical approaches in scientific education. As education evolves, the incorporation of such tactics becomes increasingly important for assuring upper secondary school students' success and grasp of complicated physics concepts such as Free Fall Motion.

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DATA AVAILABILITY STATEMENT

Data will be made available on request.

CONFLICT OF INTEREST

The authors declare no conflicts of interest

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