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Physics students' conceptual understanding of "*gravity and free fall*"

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ABSTRACT

The focus of this study is to ascertain the conceptual understanding students of Bolgatanga Girls Senior High School (BGSHS) have in "*gravity and free fall*". Descriptive research design (cross-sectional survey) was used in this study as a method of collecting information. Out of 183 second and third year students, 43 of them were randomly selected and involved in the study. Students were given 10 conceptual based test items relating to "*gravity and free fall*" to respond to. Students were required to respond true/false and provide reasons for their response. It was found that majority of the students had the misconception that gravity is selective and therefore acts more on heavier objects compared to lighter objects. As a result, they are of the opinion that larger object should hit the ground first before a light object dropped from the same height, which is not scientifically accurate. Based on the findings of the study, it was recommended that physics teachers in BGSHS should carefully pay attention to students' misconceptions and be guided by it when teaching.

Keywords: misconception, conceptual understanding, physics students, gravity, free fall

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INTRODUCTION

One of the first and most advanced of all the sciences is physics. It addresses most fundamental issues relating to the nature of the physical universe. It answers questions, as follows:

1. What is the nature of the universe, for example?
2. What does matter consist of?
3. Which natural forces are the essential ones?

Thus, the foundation for all other physical sciences is provided by physics (Keith, 2016). When students learn physics, they develop manipulation and processing abilities necessary to effectively forecast the results of many occurrences, including the occurrence of an eclipse, the impact of gravity and other forces, and the phases of the moon (Munene, 2014).

Despite its relevance, there seems to be a lack of interest in physics among students at Bolgatanga Girls Senior High School (BGSHS) probably because of their lack of understanding of some concepts in physics. It can be because there is little connection between what is taught in school and how it relates to real life situations (American Association of Physics Teachers, 2009). This lack of relationship between theoretical physics and application physics may contribute towards the several misconceptions that students of BGSHS carry to physics class hence their poor performance as well. Perhaps the misconceptions they have in physics work for them in linking what they have learnt in class to the real world, though they might not be scientifically accepted as they cannot answer all possible situations.

Preliminary study by the researchers shows that physics teachers in BGSHS in the Bolgatanga Municipality teach their physics concepts in abstract. Their illustrations and explanations, while teaching is without teaching-and-learning materials, which make the understanding of the subject matter difficult. A problem is therefore presented when what is being taught or learnt is only perceived rather than practiced. This situation had contributed to the development of some misconception in physics among science students at BGSHS. Misconceptions in physics is quite common among students (Halim et al., 2014; Pablico, 2010; Santyasa et al., 2018). Students of BGSHS physics are of no exception. For example, they are of the view that the initial force required to throw or shoot an object moves with it and diminishes as the object moves. Once the force pushing it wears off, the object comes to a stop. The misunderstandings that students bring to class might be attributed to a number of causes.

A significant one of these is the employment of the conventional lecture style to teach concepts. With this approach, students are not given enough information and interactions to come out with the proper understanding of concepts, hence they formulate concepts that suit them in few (but not all) situations thereby making them to carry several misconceptions. It is upon this background that the study seeks to ascertain the conceptual understanding students of BGSHS have in the concept "*gravity and free fall*".

Findings of the study would bring to bear misconceptions that students usually carry to class during physics lessons. The findings would serve as a guide for physics teachers so that they can do advance preparations before they meet their students. Findings of the study could be used by future researchers as a baseline for further studies especially in finding the appropriate teaching methods that will help erase such misconceptions.

LITERATURE REVIEW

Students' Misconceptions

Misconceptions are concepts created by students that deviate from scientific explanations (Halim et al., 2014). According to Eryilmaz (2002), misconceptions are ideas that contradicts widely accepted scientific theories but appear to be supported by certain real-world trials and experiences, or logical deductions. Simply put, misconception is a lack of comprehension of a concept that happens when students cultivate an incorrect idea rather than actual knowledge. The teaching of courses in the natural sciences such as biology, chemistry, mathematics, and physics is sometimes hampered by misconceptions (Stein et al., 2008).

We all hold false beliefs about how the world operates. Some of these are propagated through inaccurate textbooks and fictional films, while others are acquired early in life through poor observation and unfounded assumptions (Murphy & Alexander, 2013). However, results from earlier studies have shown that students typically cultivate knowledge of natural phenomena prior to formal instruction (Halim et al., 2014). The learning process, the curriculum, and the teacher's premise that teaching is the transmission of knowledge are some variables that could be suspected as the root of misconception in the formal teaching environment (Kurniawan, 2018; Santyasa et al., 2018; Üce & Ceyhan, 2019). Also, numerous studies have shown that some physics disciplines are challenging due to their abstract concepts (Kotluk & Kocakaya, 2016). This obstacle causes misconceptions. Kuczmann (2017), in his studies, seen that, based on the nature of students' errors, misconceptions among students reflect a particular knowledge deficit. This shortcoming could indicate a lack of factual information and understanding of how certain pieces of knowledge relate to one another. The learning of students can be seriously impacted by misconceptions.

These common misunderstandings prevent students from learning more complex concepts, and as they continue to gain information, it gets harder to correct the misunderstandings but revert to their preconceptions outside the classroom (Pablico, 2010). There is strong evidence that students' maintaining misunderstandings can inhibit them from understanding physics further. As a result, a fundamental element of teaching physics is determining students' current level of understanding and deciding how to proceed accordingly (Institute of Physics, 2021).

Although their existence has been made clear throughout time, several studies have found that some misconceptions are still common among students. (Halim et al., 2014; Santyasa et al., 2018). The same misconception occurs and exists at primary and up to university level. For instance, Pablico (2010) revealed that the assumption that gravity slows down motion is the most widespread misconception among physics and physical science groups. Among the middle school science group, the most common misconception was that the force used to speed up an object is still there. This demonstrates that the typical or regular teaching and learning process cannot dispel misconceptions (Halim et al., 2014). The eradication of misconceptions among students calls for a conceptual change. Kuczmann (2017) is of the opinion that misconceptions could be prevented if a student has all necessary knowledge and is aware of all connections between factual knowledge.

METHODOLOGY

Descriptive research design (cross-sectional survey) was used in this study as a method of collecting information. The focus of this study is to ascertain the conceptual understanding students of BGSHS have in "*gravity and free fall*". The population was, therefore, all science students in BGSHS in the Bolgatanga Municipal of the upper east region of Ghana. The entire population of science students in the school was 300 comprising 100 3rd year students, 83 2nd year students, and 117 students in the 1st year. 2nd and 3rd year students were purposely selected because they had treated topics related to "*gravity and free fall*". 3rd year students were however not involved in the study due to unavailability.

During the data collection stage, 3rd year students were engaged in examination in preparations towards their final examination (West African senior school certificate examination). Out of the 83 2nd year students, 40 of them were in one class and the other 43 were also in one class. One of these classes of students was taught by one of the authors. The class of 43 students, which was taught by another teacher was selected for the study. The class of 43 students was chosen for the study to avoid bias and other interference, in the conduct, marking and interpretation of the test results due to the author's familiarity with her students. Students were given 10 conceptual based test items relating to "*gravity and free fall*" to respond to. Students were required to respond true/false and provide reasons for their responds.

RESULTS AND FINDINGS

The study involved a total of 43 physics students in BGSHS. Out of the 43 female students, majority of them, 36 (83.7%), were aged between 16 and 18 years of age. Four of the students were aged between 13 and 15 years. Three (7.0%) were between 19 and 21years of age.

The answer to the research question was obtained using 10 diagnostic test questions. The questions consisted of conceptual based test items on the concepts of "*gravity and free fall*". Students' partial and full understanding of the various concepts were determined based their choice of answers as well as reasons they provided for their choice. Students with full understanding are those who responded accurately to an item and provided the scientifically appropriate explanation to support their choice. The results are presented in **Table 1** and discussed.

Majority of the physics students, 30 (69.8%), acknowledge the fact that weight of an object is the product of its mass and acceleration due to gravity. As such, weightlessness means there is no gravity. Some students supported their view with the explanation that weight depends on or is directly proportional to gravity hence the weight of an object decreases when gravity decreases. About one-fourth representing 30.2% of the students had misconception. Most of the students believe

Table 1. Physics students' understanding of concept of "*gravity and free fall*"

	Items	Full understanding: n (%)	Partial understanding: n (%)
1	Weightlessness means there is no gravity?	30 (69.8)	13 (30.2)
2	There is no gravity (gravitational force) in outer space?	32 (74.4)	11 (25.6)
3	Gravity works only on the people standing on the earth?	39 (90.7)	4 (9.3)
4	A larger object should hit the ground first before a light object dropped from the same height.	11 (25.6)	32 (74.4)
5	Constant gravity does not imply constant acceleration?	27 (62.8)	16 (37.2)
6	Gravity is selective; it acts differently or not at all on some matter?	10 (23.3)	33 (76.7)
7	Gravity increases with height?	34 (79.1)	9 (20.9)
8	Gravity requires a medium (air) to act through?	31 (72.1)	12 (27.9)
9	Heavier objects fall faster than lighter ones?	16 (37.2)	27 (62.8)
10	As a freely falling object speeds up, what is happening to its acceleration due to gravity does it increase, decrease, or stay the same?	31 (72.1)	12 (27.9)

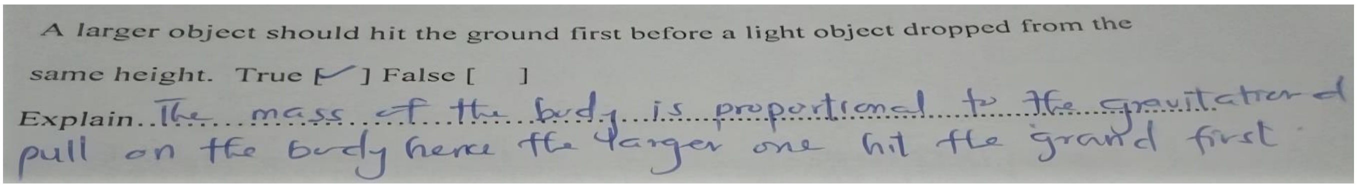

Figure 1. Example of scientific interpretations-1 (Field data, 2023)

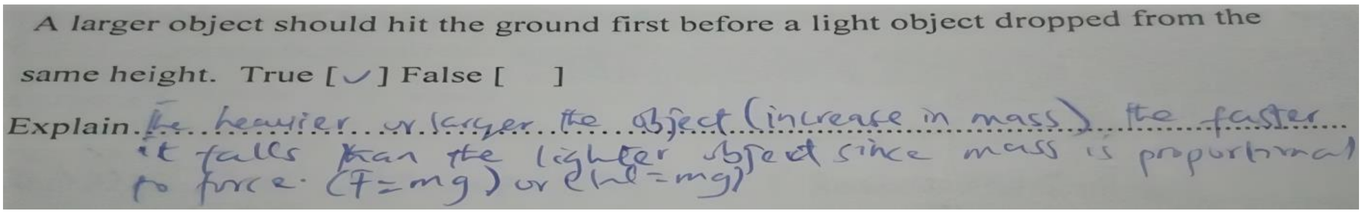

Figure 2. Example of scientific interpretations-2 (Field data, 2023)

that for weightlessness only occurs when the mass of an object is neglected. Only a few of the students, four (9.3%), had the misconception that gravity only act on objects on the earth surface.

The results presented in **Table 1** indicates that majority of the pupils have full understanding on items 1, 2, 3, 5, 7, 8, and 10. Students having full understanding of these items in as indication that, apart from choosing the right choice, they also give appropriate reasons for their choice. Meanwhile, majority of the students had partial understanding of the items 4, 6, and 9. Their partial understanding of these concepts is interpreted to mean that, students either selected the wrong choice or provided the right choice but supported their answer with wrong concept or idea. Students partial understanding is as result of their inability to properly interpret scientific ideas, concepts, definition, principles, laws, etc.

It could be inferred from the result that majority of the students have the misconception that gravity is selective and therefore acts more on heavier objects compared to lighter objects. As a result, they are of the opinion that larger object should hit the ground first before a light object dropped from the same height. It is also worth noting that a significant number of students had misconceptions in all the 10 items presented aside the majority having misconception in item 4, 6 and 9.

DISCUSSION

It is not surprising that most of the physics students are of the view that *heavier objects fall faster than lighter ones.* Even though that is not the case scientifically, it is often observed that when two objects of different mass are dropped from the same height, the more massive one tend to hit the ground first before the less massive one. This observation from daily occurrences led to the explanations provided by students and has resulted in students' misconception and conclusion that *a larger object should hit the ground first before a light object dropped from the same height.* **Figure 1** and **Figure 2** shows some specific scientific interpretations students provided by two of the students, which confirms their misconception.

Contrary to students' understanding and interpretation, the scientific truth is that all objects irrespective of their mass will fall from the same height to the earth surface at the same acceleration. This acceleration due to gravity is not selective but rather acts equally on all objects. However, the motion of lighter objects tends to be influenced more by air resistance compared to heavier objects. This explains why lighter objects are often observed to take a longer time to fall from a height compared with a heavier object dropped from the same height. Scientifically, the reality is that gravity in any given place, accelerate everything downwards *at the same rate* but in the case of light objects with large surface areas, air resistance is opposing this. All objects moving through air, and hence, all falling objects, experience air resistance. This force is proportional to the area of the object in the direction of motion. Usually, this force is negligible, but for light objects with weight comparable to the air resistance, like a feather and a piece of paper, it will have a big effect.

CONCLUSIONS

It is obvious that when students are not adequately equipped with enough information on certain scientific occurrences, they rely on previous knowledge to explain such occurrences. Unfortunately, it does not always work and hence results in students having alternative conception. This was the case of majority of students of BGSHS who relied on the equation $w=mg$ (w is weight, m is mass, and g is acceleration due to gravity) to explain why heavier objects fall first before lighter ones when dropped from the same height. According to students, mass of an object is proportional to gravitational pull. But g is acceleration due to gravity is a constant and same for all falling objects.

Recommendations

Physics teachers in BGSHS and other schools should carefully pay attention to students' misconceptions and be guided by it to select appropriate teaching methodologies and pedagogical skills that would address students' misconceptions. Physics students of BGSHS should be exposed to lots of practical examples on scientific concepts for better understanding. To help students better understand why the rate at which objects fall is independent of their mass or weigh, a number of practical experiments could help teachers guide their students. One of such experiments is "Falling physics: Teacher's guide" an article written by APS Advancing Physics (n. d.) (https://youtu.be/EZxHOEsqVtc).

In the article, a number of practical ways of making students conclude that mass is not a factor that affects the falling of objects. The simplest among the experiments is asking students to take two pieces of paper of the same size and mass. One of the papers is crumpled into a ball. The two papers are then dropped from the same height at the same time. Students will then reflect on why the masses of the two pieces of paper were the same, yet the crumpled piece hit the ground first. The experiment can also be carried out by changing the direction in which the paper is dropped. An article by Anni (2021) in which "quantitative comparison between smartphone based experiment for gravity acceleration measurement at home" was carried out could also be a helpful guide to students and teachers. In the paper, smartphone-based methods and other apparatus were used to determine the falling time of steel sphere with 16 mm diameter with a temporal sensitivity of 0.1 ms in a height range between two cm and 96 cm in steps of one cm. Teachers and students can also refer to a similar publication "measuring the acceleration of gravity using a smartphone, A4-papers, and a pencil" by Kittiravechote and Sujarittham (2020).

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Data availability: Data generated or analyzed during this study are available from the authors on request.

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