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Performance and Conceptual Understanding of Grade 11 Students in Physical Science

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Abstract— Albert Einstein's Theory of Special and General Relativity were some of the difficult topics in Physics encountered by the students. Moreover, these topics were taught purely by modular distance learning. This research used descriptive research design that aims to determine the performance and level of conceptual understanding of Grade 11 students of San Juan Bag-O High School along identified topics in Physical Science. The data were collected using a teacher-made conceptual understanding test (CUT) and were analyzed using the appropriate statistical tool. At the end of the analysis, the performance of the students on postulates and consequences of both the Special and General Theory of Relativity was satisfactory. For the level of conceptual understanding, it was determined to be complete understanding along consequences and postulates of General Theory of Relativity while partial understanding in consequences and postulates of Special Theory of Relativity. The findings obtained in this research indicate that Science teachers should make use of modern method of teaching to improve performance as well as utilized inquiry and interactive teaching to enhance the level of conceptual understanding of the students.

Keywords— conceptual understanding, education, performance, Special Theory of Relativity, General Theory of Relativity.

I. INTRODUCTION

The Theory of Relativity is one of the most influential theories in the history. The theories of special relativity and general relativity together represent one of mankind's greatest intellectual achievements. These theories overthrew many assumptions underlying earlier physical theories, redefining the fundamental concepts of space, time, matter, energy, and gravity (Perkowitz, 2023). This change in the learning of the basic concepts causes difficulties to the students in learning this theory. Moreover, the concepts of the theory of relativity are the concepts which cannot directly be observed in daily life. Therefore, determining and analyzing the students' performance and level of conceptual understanding along these concepts should be given focus.

The performance of the students academically is known to be crucial to education. It is the knowledge gained which is assessed by marks by a teacher and/or educational goals set by students and teachers to be achieved over a specific period of time and measured by using continuous assessment or examinations results (Narad & Abdullah, 2016). No wonder factors contributing to improvement in students 'performance have received much attention from educators and researchers (Artun & Özsevgec, 2018; Ibyatova et al, 2018; Naboya, 2019; Valencia, 2020). These researchers found out that the aid of modular approach to conventional teaching shows significant improvement on the performance of the students in different learning area.

Conceptual understanding is another area to look in addition with the performance. It is defined as the students' ability in recording and back transferring of some information from learning, which can be used in solving, analyzing, and interpreting the problem (Silaban, 2014). Significant efforts have also been made to determine the level of conceptual understanding of the students on topics in Science (Saricayir et al, 2016; Özcan, 2017). Saricayor et al (2016) revealed that students' understanding level in thermodynamics was from low level up to the lowest level of understanding although they have been studying these topics since primary school. Meanwhile, on the study of Özcan, (2017), the level of conceptual understanding of the students were from complete understanding to misunderstanding. It was found that putting together fragments of scientific and unscientific knowledge together put students at the lowest level. There are also several studies concerned with misconceptions in studying and learning the Theory of Relativity (Kersting et al, 2018; Özcan, 2017; Krijtenburg-Lewerissa, 2017). Magdalena et al (2018) found that students often mixed up classical and relativistic concepts, presented incoherent arguments or tried to argue with the relativity of observation to explain time dilation. Similarly, Özcan, (2017) found out that students; operational definition to questions about length contraction, time dilation and frame of references are not parallel to scientific definitions. Lastly, Krijtenburg-Lewerissa (2017) revealed that students struggle with relativity and quantum physics since phenomena being described cannot be visualized or experienced directly.

It is therefore probable that the abstract nature of the concepts of Theory of Relativity makes it difficult to the students to learn. That is to say, students may find it challenging to relate the principles in this topic to what they already know. This prevents genuine learning and makes other ideas about the issue emerge. This research aims to determine the performance and level of conceptual understanding of Grade 11 students along identified topics in Physical Science. For this reason, this research seeks answers to the following research questions so as to fill the gap in current literature and studies related to this subject and to make contributions to the research area of Physical Science:

1. What is the performance of the students in Physical Science along with the topics of Postulates of Special Theory of Relativity, Consequences of Special Theory of Relativity, Postulates of General Theory of Relativity and Consequences of General Theory of Relativity?
2. What is the level of conceptual understanding of the students along with the identified topics?

II. MATERIALS AND METHODS

This study determined the performance as well as the level of conceptual understanding of the students in Physical Science at San Juan Bag-O High School. The study employed a descriptive analysis wherein the performance and level of conceptual understanding was determined using a teacher-made test. The results were analyzed using frequency, percentage, and weighted mean.

The performance and level of conceptual understanding was determined using a conceptual understanding test (CUT) which was made by the researcher. The CUT was composed of 30-item test. This CUT was checked by two master teachers and panel members before the pilot testing and undergo steps for verification of validity and reliability. Each item consisted of four options and a space below for the students to explain their answer. The researcher used these explanations to verify the answer of the students.

The necessary permissions from the concerned heads starting from the school principal and district supervisor was secured before conducting the data gathering. Upon the approval of the request, permission was also asked to the participants for the utilization of the responses. Before the pilot testing, two master teachers in Physics check the quality of the test. Afterwards, the researcher conducted pilot testing first to check the validity of the test and another testing to verify the reliability of it. After the whole process, the final copy was given to the chosen respondents and was retrieved after.

The respondents of the study are composed of 30 students of Grade 11 at San Juan Bag-O High School who were randomly selected. Purposive method was used to determine the participants and a fishbowl technique was used to choose the sample size from a total population of 72 students from Grade 11 with two sections.

III. DATA ANALYSIS PROCEDURE

The answers from the respondents were computed, analyzed and interpreted using the necessary statistical tools. The statistical tools used in the study are frequency, percentage and weighted mean. The performance of the students was computed using frequency and percentage. The numbers obtained was interpreted using the following scale adapted from Deped Order No. 8 s. 2015.

Scale	Description
90 – 100	Outstanding (O)
85 – 89	Very Satisfactory (VS)
80 – 84	Satisfactory (S)
75 – 79	Fairly Satisfactory (FS)
Below – 74	Did not meet the Expectation

The level of conceptual understanding was determined using frequency, percentage and identifying the weighted mean. It was interpreted using the following scale.

Scale	Description
3	Complete Understanding
2	Partial Understanding
1	Faulty Understanding
0	No Understanding

Complete Understanding (CU) – students who were able to clarify their understanding of a science concept which is also consistent with the established scientific views. This included those students who have answered the question correctly and also explained their answers correctly.

Partial Understanding (PU) – Students who had acquired some understanding of a science concept although this understanding was not expressed in an integrated or unified way. Belonging to this category were those who answered the question correctly but could not fully explain their answer. The answer included at least one idea or concept in understanding level.

Faulty Understanding (FU) – Students whose explanation of the natural phenomenon was confused and contradictory. These were the students who could answer the questions correctly but could not explain their answer correctly.

No Understanding (NU) – Students who did not express their answer or idea about the phenomenon. They were those who could not answer the question correctly and those who refused to answer the question.

IV. RESULTS AND DISCUSSION

This part presents the performance and level of conceptual understanding of Grade 11 students along identified topics in Physical Science. The Table 1A presented the data about the performance of the students in postulates of Special Theory of Relativity. It can be obtained from the table that the overall performance of the students is 83.2 which can be interpreted as satisfactory. It also shows that 23 students or 77% are under the satisfactory category. Moreover, 3 or 10% got the very satisfactory performance and 1 or 3% got outstanding. However, 2 or 7% obtain fairly satisfactory and 1 or 3% who did not meet the expectation.

Table 1A: *Performance of the Students along the Postulates of Special Theory of Relativity*

Grade Interval	F	%
90-100 (O)	3	10%
85-89 (VS)	7	23%
80-84 (S)	17	57%
75-79 (FS)	1	3%
74-below (DNME)	2	7%
Total	30	100%
Average: 83.6		Satisfactory

The result in the table means poor performance of the students on the postulates of Special Theory of Relativity. This may be due to the fact that the concepts counter to everyday experience making it counterintuitive and difficult to accept as discussed by the study of Miller (2010). Meanwhile, the study of Tuh (2016) found out that the utilization of space time diagrams is proven to enhance the student performance on concepts of Special Theory of Relativity. Thus, a numerous positive contributing element must be taken into consideration in order to create strategies that will further strengthen and improved the students' performance. The Table 1B shows the data on performance along the consequences of Special Theory of Relativity. It can be gleaned that students' overall performance is 82.8 under the satisfactory category. This also reveal that 16 or 53% got satisfactory which is the highest percentage obtained. In addition, 8 or 27% got very satisfactory and only 1 or 3% got outstanding. On the other hand, 2 or 7% just got fairly satisfactory performance and 3 or 10% did not even meet the expectation.

Table 1B: *Performance of the Students along the Consequences of Special Theory of Relativity*

Grade Interval	F	%
90-100 (O)	1	3%
85-89 (VS)	8	27%
80-84 (S)	16	53%
75-79 (FS)	2	7%
74-below (DNME)	3	10%
Total	30	100%
Average: 82.8		Satisfactory

The result reflects low performance of the students on the consequences of Special Theory of Relativity. This is clear evidence of the negative effect of COVID-19-related school closures on students' performance which was emphasized by the study of Hashemi (2021). Moreover, the topics are also an abstract concept wherein the described phenomena cannot be experienced directly. The study of Turgut et al, 2013 shows that most of the students had difficulty on concepts related Special Relativity such as the relativity of time and its reference frame. Most of them could not make the interpretation that the speed of light was the limit speed, and no other object could reach that speed. This poor accomplishment level in science disciplines calls for creative techniques to inspire students to study the subject even in abstract form. This may through the use of educational reconstruction discussed by the study of Kamphorst et al 2023 that shows as a fruitful approach to introduce the concepts of Special Relativity to secondary students.

The Table 1C reveals the performance of Grade 11 students in postulates of General Theory of Relativity. It can be observed from the table that the overall performance is 84.4 which is interpreted as satisfactory. Also, it shows that 12 or 40% got satisfactory and 10 or 33% got very satisfactory performance. Moreover, 3 or 10% got outstanding among other students. However, 3 or 10% are under fairly satisfactory and 2 or 7% did not meet the expectation.

Table 1C: *Performance of the Students along the Postulates of General Theory of Relativity*

Grade Interval	F	%
90-100 (O)	3	10%
85-89 (VS)	10	33%
80-84 (S)	12	40%
75-79 (FS)	3	10%
74-below (DNME)	2	7%
Total	30	100%
Average: 84.4		Satisfactory

It comes as no surprise that the performance of the students seemed to be in this category since historically, the general relativity has been considered prohibitively difficult. This topic also includes phenomena that is hard to visualized.

This low level of performance may be addressed by utilizing thought experiment (TE) in teaching the concepts of General Theory of Relativity. The study of Velentzas & Halkia (2013) reveals that the use of TEs in teaching the theory of relativity can help students realize situations which refer to a world beyond their everyday experience and develop syllogisms according to the theory. In this way, students can grasp physics laws and principles which demand a high degree of abstract thinking, such as the principle of equivalence

The Table 1D shows the performance of the students in consequences of General Theory of Relativity.

This reveals that the students' performance is 83.6 or satisfactory. It can also be observed that 17 or 57% got satisfactory performance. Moreover, 7 or 23% identified as very satisfactory and 3 or 10% got outstanding performance. Meanwhile, 1 or 3% is under fairly satisfactory and 2 or 7% did not meet the expectation.

Table 1D: *Performance of the Students along the Consequences of General Theory of Relativity*

Grade Interval	F	%
90-100 (O)	3	10%
85-89 (VS)	7	23%
80-84 (S)	17	57%
75-79 (FS)	1	3%
74-below (DNME)	2	7%
Total	30	100%
Average: 83.6		Satisfactory

The occurrence of students' performance like this is not surprising since the concepts on the consequences of General Theory of Relativity focus mainly on abstract phenomena that cannot be experienced in day-to-day life. That is why students may find difficulty in understanding the abstract principles of this topic as discussed by Henriksen et al, 2014.

Meanwhile, Kersting & Steier, 2018 found out that Science teachers can utilize models, analogies, animations, simulations, role plays, or other analogical strategies to help students understand abstract concepts easier in General Relativity. In fact, in the Einstein-First Project, essential ideas related to general relativity such as the ideas that mass causes curvature in space-time, that freely falling bodies follow the shortest paths in space-time, and that geometry on curved space are introduced using models and analogies that use a space-time simulator, marbles, toy cars, billiard balls, woks, etc. (Kaur et al., 2017)

The Table 2 presents the level of conceptual understanding of the students on identified topics in Physical Science. It can be obtained from the table that the weighted mean for the postulates of Special Theory of Relativity is 2 which is interpreted under the level of partial understanding.

Same result is also obtained from the consequences of Special Theory of Relativity with weighted mean of 2 under the partial understanding level. Meanwhile, both the postulates and consequences of General Theory of Relativity garnered weighted mean of 3 which is categorize as the highest level which is complete understanding.

Table 2: *Level of Conceptual Understanding of the Students along the identified topics*

Topics	**Level of Conceptual Understanding of the Students**								
	CU		PU		FU		NU		WM
	f	%	f	%	f	%	f	%	
Postulates of Special Theory of Relativity	96	25%	152	40%	15	4%	117	31%	2
Consequences of Special Theory of Relativity	27	7%	272	75%	11	3%	54	15%	2
Postulates of General Theory of Relativity	225	41%	152	27%	51	9%	127	23%	3
Consequences of General Theory of Relativity	390	65%	80	13%	27	5%	105	17%	3
Average	185	35%	164	39%	26	5%	100	22%	

Legend:
CU –Complete Understanding
PU –Partial Understanding
FU –Faulty Understanding
NU –No Understanding
f –frequency
WM –Weighted Mean

This result reveals that the students have a basic understanding of the concepts of postulates and consequences of Special Theory of Relativity but are unable to express their answer to the questions clearly. This also implies that the students may not fully grasped the concept along these topics.

The students' answer on the question shows alternative conceptions like time does not vary, speed of light can vary as well as length of a body is not related with its speed. These alternative conceptions are similar with the alternative conceptions determined by the study of Alvarado et al. (2019) which found out to hinder full understanding of the concepts as well as the teaching-learning process.

On the other hand, the students acquired the knowledge and complete level of understanding along the concepts of postulates and consequences of General Theory of Relativity.

This suggests that the students fully understand and gave appropriate response to questions that is parallel to a scientific knowledge related to the concept.

This result can be retained by also trying to use the activity-based learning model and analogies utilized in the study of Dua et al, 2020 which reveals a significant improvement in students' conceptual understanding before and after the utilization.

The students' explanations in some of the questions included on the test questionnaire are presented below based on the level of conceptual understanding:

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a. 17. One of General Relativity's key components is the idea that space and time are part of a single, four-dimensional continuum. What is this continuum called?
(a.) spacetime c. gravity
b. interstellar medium d. all of these
Reason: Einstein concluded that space and time, rather than separate and unrelated phenomena, are actually interwoven into a single continuum (called space-time) that spans multipe dimensions.

Plate 1: *Student's Sample Answer for Complete Understanding*

The sample explanation above shows a detailed answer in the given question about the continuum by describing the spacetime as single continuum and its multiple dimensions.

A 13. Based on mass-energy equivalence, total amount of mass and energy together in a system is
a. constant
b. increasing
c. decreasing
d. zero
Reason: All object have mass or massive object because have, a corresponding intrinsic energy even they are stationary.

Plate 2: *Student's Sample Answer for Partial Understanding*

As can be glimpsed from the sample explanation, the student was unable to articulate the solution effectively. The student simply mentions the energy an object has when it is stationary, failing to explain why the overall amount of mass and energy is constant.

B 10. Renz and Rose are twins. Suppose Renz left in a spaceship and travelled at 90% the speed of light and was sent on a space mission for 10 (Earth) years. How would you compare the age of the astronaut to his twin sister here on Earth when he returns?
a. He would be older than his twin sister.
b. He would be younger than his twin sister.
c. He would be of the same age as his twin sister.
d. He would be twice as old as his twin sister.
Reason: because in the outer space we don't have a oxigen because also of esist of gravity its revolution around the sun is rejected.

Plate 3: *Student's Sample Answer for Faulty Understanding*

The given reason in the sample answer was not even related from the concept since oxygen was not even mentioned from the lesson. The student failed to cite the principle of time dilation which is behind the phenomenon.

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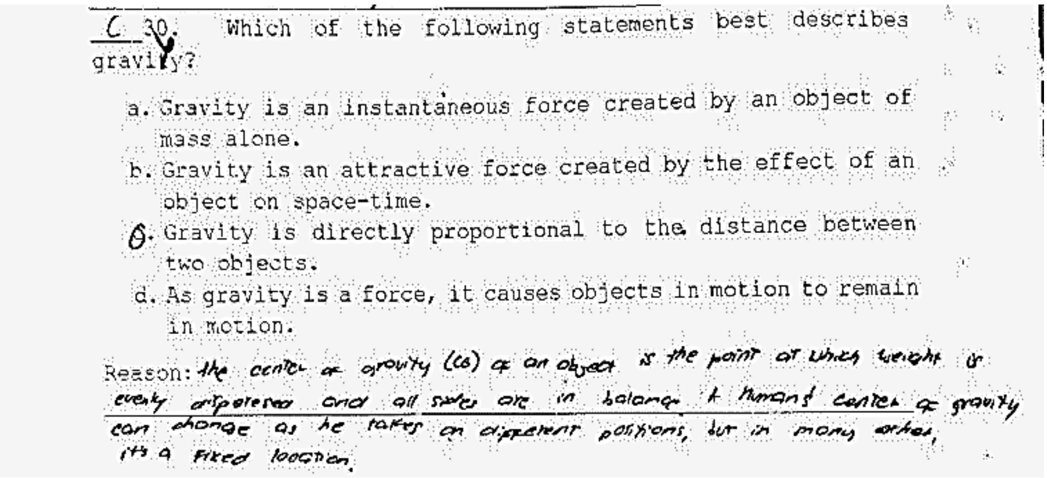

C 30. Which of the following statements best describes gravity?

a. Gravity is an instantaneous force created by an object of mass alone.
b. Gravity is an attractive force created by the effect of an object on space-time.
c. Gravity is directly proportional to the distance between two objects.
d. As gravity is a force, it causes objects in motion to remain in motion.

Reason: the center of gravity (CG) of an object is the point at which weight is evenly dispersed and all sides are in balance. A human's center of gravity can change as he takes on different positions, but in many others, it's a fixed location.

Plate 4: *Student's Sample Answer for No Understanding*

The sample answer above was incorrect. Instead of addressing gravity itself, the student's response focused on determining the center of gravity. It's possible that people don't understand or have the wrong understanding of gravity. So, it's critical to dispel misunderstandings before proceeding to the next topic.

V. CONCLUSION AND RECOMMENDATION

Based on the findings, the main conclusions drawn from this study are: the overall performance level of the students along the identified four topics in Physical Science is found to be Satisfactory. Meanwhile, the students' level of conceptual understanding based on the weighted mean is partial understanding for Postulates and Consequences of Special Theory of Relativity while complete understanding for Postulates and Consequences of General Theory of Relativity. It is therefore recommended that in this study teachers should use modern methods of teaching incorporating the use of different teaching methods and strategies in order to motivate and sustain the student's interest in learning topics in Physical Science to be able to improve the students' performance. In addition, teacher should also be more innovative in modifying teaching approaches that will better suit the level of the students. Inquiry and interactive teaching may be utilized that is proven beneficial for longer and increased students' conceptual understanding.

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