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Learners' Level of Conceptual Understanding and Misconceptions on the Special Theory of Relativity: Crafting Pedagogical Intervention in Teaching Complex Concepts in Science

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Abstract:- **This study focused on the non-STEM learners' level of conceptual understanding and misconceptions about the Special Theory of Relativity. The participants were the 89 non-STEM learners identified through convenience sampling. A higher percentage distribution revealed that non-STEM learners have less to no understanding of the concepts on STR reflective of the pre-test and post-test scores with several incorrect responses. This also showed that the learners lack understanding of the concept of mass-energy equivalence. A t-test for paired samples revealed that there is no significant difference in the pre-test and post-test scores of the learners which means that the conventional method of teaching and learning the concept may not be enough to address their conceptions. The researchers recommend exploring pedagogical interventions that promote interactive engagement coupled with a learning material that will simplify highly abstract scientific concepts for better student learning.**

Keywords:- *Level of Conceptual Understanding, Special Theory of Relativity (SRT), Non-STEM Learners.*

I. INTRODUCTION

Einstein's Special Theory of Relativity is one of the lessons found in the Physical Science subject of the senior high school curriculum in the Philippines. Since the onset of the pandemic, a shift in the educational system followed the change from learning competencies to the most essential learning competencies as a basis for the teaching and learning process. Physical Science subject is considered a core subject for non-STEM learners.

Based on the DepEd Order No. 012 s.2020 [1], also known as the adaptation of the Basic Education Learning Continuity Plan in light of the COVID-19 Public Health Emergency, SRT follows the competency in which learners need to explain the consequences of postulates of the Special Theory of Relativity (e.g. relativity of simultaneity, time dilation, length contraction, mass-energy equivalence, and cosmic speed limit). According to Dapitan & Caballes [2], science deals with complex, diverse concepts. Belen & Caballes [3] also mentioned that one important skill necessary would-be critical thinking which was based on the 21st-century skills of learners.

This research aimed to identify the non-STEM learners' level of conceptual understanding of the concepts of the special theory of relativity. Identify which concepts of SRT learners' have misconceptions and lastly, identify the significant difference between the learners' pre-test and post-test scores.

➢ *Learners' Level of Conceptual Understanding*

Science education aims for students to gain insights into the process of theory development, in addition to the aim for conceptual understanding [4]. Conceptual understanding is an important goal in learning in general but is particularly relevant in science education because such understanding is required to make sense of phenomena [5]. Conceptual understanding is the process of grasping ideas in a transferrable way which can facilitate learners to apply what they learn in class across domains [6]. Several researchers in science education are concerned by the lack of depth of conceptual understanding in science that students have exhibited for the past decades [7,8] Conceptual understanding is the ability of a person to be able to explain, differentiate, give examples and connect a concept of what he knows with new knowledge [9]. Conceptual understanding of various physics concepts that have been obtained at schools can use as an adequate basis for the advancement and development of science and technology in society [10]. Knowing the students' conceptual understanding level, teachers can determine the appropriate learning model so that learning indicators can be achieved [11]. According to Abenes & Caballes [12], content knowledge is an essential factor to consider in learners' learning process. According to Cabas & Caballes [13], a heuristic approach can improve non-STEM learners' conceptual understanding of science concepts.

➢ *Special Theory of Relativity*

The concepts of the special theory of relativity are the concepts that cannot directly be observed in daily life, they are difficult for students to learn [14]. The abstract and counterintuitive concepts and outcomes of SRT are difficult to learn [15]. SRT is a promising topic to familiarize students with physics as a process of scientific knowledge

development, a key element in the history and philosophy of science[16].

Sherr et al. [17] showed that students tend to treat observers at the same position as being in the same frame of reference, regardless of their relative motion. The body of student conceptions found by Scherr et al [18] regarding time and simultaneity, result in several learning difficulties about the relativity of simultaneity. Selcuk [19] found that students fail to recognize the symmetry of time dilation and length contraction, considering instead that they are unilateral phenomena that occur only in the moving frame of reference. Dimitriadi and Halkia [20] showed that the students have difficulties in realizing that the maximum speed is an intrinsic property of nature.

➢ *Non-STEM Learners*

Cotner, Thompson, and Wright [21], discussed in their study that NON-STEM learners tend to have a more flourished interest in arts and religion than Science. Mentioned also in their study saying that non-STEM students are most likely to display inaccurate information about scientific concepts. Nieberding, Buxner Elfring, and Imprey [22] revealed that non-Science students' scores on a given assessment about science concepts were lower than those of STEM majors. In the study of Adino & Caballes,[23] they have mentioned that misconception is a noticeable issue held by students which are not scientifically accepted.

➢ *Objectives of the Study*

This study aimed to identify non-STEM learners' level of conceptual understanding of the concepts of the special theory of relativity, the researchers specifically answered the following statement of the problems.

- What is the learners' level of conceptual understanding of the concepts of the special theory of relativity?
- What are the concepts that learners misunderstood about the concepts of the special theory of relativity?
- Is there a significant difference between learners' level of conceptual understanding pre-test and post-test scores?

II. METHODS

➢ *Research Design*

The researchers utilized a mixed method of research in identifying the learners' level of conceptual understanding through quantitative and qualitative perspectives [24]

➢ *Sample and Setting*

There were 89 learners who were considered for this study. They were the Grade 11 non-STEM learners who were currently taking Physical Science subjects in one private university in Angeles City, Pampanga for the second semester of the academic year 2021-2022. The sampling method that the researchers utilized was convenience sampling. Convenience sampling since the data collection procedure will be conducted online using google forms.

➢ *Instruments*

The researchers designed a pretest and posttest to identify the learners' level of conceptual understanding of the concepts of the special theory of relativity. The pretest and posttest consisted of 10 items based on the most essential learning competencies. The three experts in the field validated the pre-posttest before the actual assessment. After considering the comments and suggestions, the researchers conducted the pilot testing. Based on the Cronbach's alpha model, the reliability coefficient of the test questions was 0.72.

➢ *Data Collection and Procedure*

The answers and scores from the pre-test and post-test were collected through google forms. After the post-test was conducted, three (3) learners were randomly selected for an interview and were coded A to C. The pre-test was given on April 1, 2022, while the post-test was conducted on April 15, 2022, after the two weeks intervention using the conventional method of teaching and learning. After the time frame, the researcher extracted the answers and scores for data analysis.

➢ *Data Analysis*

The answers and scores gathered from the pre-posttest were utilized to answer the research questions. A percentage distribution was utilized to determine learners' level of conceptual understanding and concepts that learners misunderstand or lack of understanding and was investigated in three levels: 1- no understanding: the learners answered the pre-posttest question incorrectly, 2- partial understanding or misconceptions: the learners answered the pre-test question correctly but failed to answer the post-test question, 3- full understanding- the learners answered the pre-posttest question correctly. Furthermore, a t-test for paired samples was utilized to determine the significant difference between the learners' pre-test and post-test scores.

➢ *Ethical Consideration*

The researcher adhered to the ethical standard and data privacy of the University. Before the actual gathering of data, the researchers asked for the approval of the Basic Education principal thru the Assistant Principal, and informed consent was given to learners. The participants of the study were informed of their right to withdraw from this study.

III. RESULTS AND DISCUSSION

Based on Table 1, a higher percentage distribution revealed that non-STEM learners have less to no understanding of concepts on STR reflective of the pre-test and post-test scores with several incorrect responses after two weeks of intervention using the conventional method of teaching and learning.

For the first two items related to the concept of relativity of simultaneity, 70.79 % and 55.06 % of non-STEM learners have no understanding of the given concept which determines that they answered the pre-posttest questions incorrectly. 2.24 % and 11.24 % of learners have partial understanding or misconceptions which means that they correctly answered the pre-test but failed to answer the post-test questions. 26.96 %

and 33.7 % of the total population of non-STEM learners have a full understanding or have answered the pre-test and post-test correctly. The interviews with learners A, B, and C further support these findings: learners A and C mentioned that based on their conceptual understanding, the simultaneity of events described has a connection to the relative motion of the observers. It was mentioned in the study of Scherr et al.,[18] regarding time and simultaneity, resulting in several learning difficulties regarding the relativity of simultaneity.

The concept of time dilation refers to items number 3 and 4, which resulted in 21.35 % and 29.21 % of non-STEM learners who answered the questions correctly which means that they fully understand the concept. 5.62 % of non-STEM learners have answered items 3 and 4 partially which shows that they correctly answered the pre-test but failed to answer the post-test questions with misconceptions. The learners who have answered the pre-posttest incorrectly reveal that 73.03 % and 65.17 % have no understanding of the concept of time dilation. The interviews provided further evidence that learners misunderstood the concept of time dilation; learners A, B, and C mentioned that as long as the speed is constant, the observer does not perceive a state of rest despite the high speed. For items 5 and 6 which refer to the concept of length contraction, 58.93 %, and 83.15 % showed that non-STEM learners answered the pre-posttest incorrectly which resulted in no understanding level of concepts. 4.49 and 1.12 % indicate partial understanding or misconception of the concept. 41.57 % and 11.23 % of the total population exhibit a full understanding of the items. In the interview with learners, C and B they understood that distance from one point to another must be equal to 1 since the whole space is moving at light speed. The study of Selcuk [19] found that students fail to recognize the symmetry of time dilation and length contraction, considering instead that they are unilateral phenomena that occur only in the moving frame of reference.

Mass-Energy equivalence as the fourth concept under the special theory of relativity discussed with non-STEM learners, 87.64 % and 51.69 % of the 89 learners answered items 7 and 8 of the pre-post tests incorrectly which revealed a no understanding. Partial understanding or misconceptions of the items given on the concept of mass-energy equivalence revealed 1.12 % and 3.37 % of the total population of participants. 11.23 % and 44.94 % of non-STEM learners showed full understanding which determines they have answered the items correctly. These further elaborated from the interviews with the learners; learners B and C understood that the mass-energy equivalence equation of Albert Einstein indicates that an object contains energy if it is moving and also learners A mentioned that when the sun releases a maximum amount of solar energy per second, it results to the gain of the significant amount of mass. Lastly, on the concept of the cosmic speed limit, items 9 and 10 revealed that 65.17 % and 67.42 % of learners have no understanding or incorrectly answered the pre-posttest questions. 2.25 % and 6.74 % of non-STEM learners were identified to have misconceptions of the concept. With full understanding, 32.58 % and 25.84 % of learners appeared to answer the items correctly. Based on the interviews, learners B and C understood that the speed of light is not the ultimate cosmic limit in the universe, also learner C stated that only massless electromagnetic radiation cannot travel at the light speed. . Dimitriadi and Halkia [20] showed that the students have difficulties in realizing that the maximum speed is an intrinsic property of nature.

Mass-energy equivalence as one of the concepts of the special theory of relativity revealed that learners lack understanding which appeared on item 7 or 87.64 % of non-STEM learners have a misunderstanding. Cotner, Thompson, and Wright [21] say that non-STEM students are most likely to display inaccurate information about scientific concepts. This lack of conceptual understanding is also found in the study of learning science concepts by teaching peers in cooperative learning [7,8]

Table 1 Concepts, item number, and level of conceptual understanding according to percentages

Concepts	Item Number	Level of conceptual understanding		
		1-No understanding	2-partial understanding	3-full understanding
Relativity of Simultaneity	1	70.79 %	2.24 %	26.96 %
	2	55.06 %	11.24 %	33.7 %
Time Dilation	3	73.03 %	5.62 %	21.35 %
	4	65.17 %	5.62 %	29.21 %
Length Contraction	5	53.93 %	4.49 %	41.57 %
	6	83.15 %	1.12 %	11.23 %
Mass-Energy Equivalence	7	87.64 %	1.12 %	11.23 %
	8	51.69 %	3.37 %	44.94 %
Comic speed limit	9	65.17 %	2.25 %	32.58 %
	10	67.42 %	6.74 %	25.84 %

Table 2 exhibits the significant difference between the pre-test and post-test scores of non-STEM learners. The non-STEM learners' pre-test score mean was 3.04 ± 1.46 and the post-test score with a mean value of 3.07 ± 1.59 compared using a t-test for paired samples, resulting in a t-value of -.092 α .927 which indicated that it is not significant hence, the null hypothesis was accepted. This reflected that the conventional method of teaching and learning the concept may not be enough to address their conceptions of the special theory of relativity.

Table 2 Significant difference between pretest and posttest scores

Test Type	Mean	SD	t-value	Sig. value	Interpretation	Decision
Pretest	3.04	1.46	-.092	.927	Not significant	Accept
Posttest	3.07	1.59				

IV. CONCLUSION

The following are the conclusion of the study.

1. The non-STEM learners' level of conceptual understanding revealed a higher percentage in all items on the level of no understanding.
2. Mass-energy equivalence concept of the special theory of relativity appeared as the concept learners lacked.
3. There is no significant difference in the learners' level of conceptual understanding between the pre-test and post-test scores.

RECOMMENDATION

The researchers recommend the following.

1. Future researchers should consider qualitative cross-sectional survey questions in identifying the non-STEM level of conceptual understanding.
2. A learning material should be developed and evaluated to increase non-STEM learners' level of conceptual understanding of the concepts of the special theory of relativity.
3. Explore pedagogical interventions that promote interactive engagement coupled with learning material that will simplify highly abstract scientific concepts for better student learning.

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