Appraisal of STEM Students' Misconceptions of Heat and Temperature

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Abstract

This study was designed to determine the common misconceptions about heat and temperature among one hundred fifty-one (151) Grade 12 STEM students of Luis Palad Integrated High School in the Philippines. In the research process, an adapted 30-item multiple-choice Heat and Temperature Concepts Questionnaire (HTCQ) was administered to appraise the misconceptions among the student-respondents. It was followed by an in-depth interview with 20 students who had the most incorrect responses. This was done in order to determine the factors that affect the formation of misconceptions. Findings showed that the majority of these students have alternative concepts of heat and temperature that were greatly affected by experiences, prior learning, and, their attitude towards the subject. As an implication, it is suggested that these misconceptions must be immediately addressed by relating them to contexts that are understandable to the learners at their level.

Keywords: science education, misconceptions, heat and temperature, STEM students

Conceptual change is a gradual process that takes place as learners embed fresh data into their present constructs. Evaluating learning throughout this process needs action to diagnose misconceptions and fully grasp how information is changing. The conception of learners is grounded on their real-world experiences, which do not always align with scientific principles, however, these ideas may change as they mature. A student's embedded knowledge may be inaccurate or misunderstood. Misunderstandings of a concept are called misconceptions. Students' significant structural adjustment of concepts without the development of delusions depends on individual differences such as intellectual level, motivation difference, perception preference (Kuzgan & Deryakulu, 2004), and the teaching-learning environments (Sen & Yilmaz, 2012).

All teachers, not only as teacher-researchers, have the responsibility to determine the existing ideas of the students in order to structure in-depth lessons through the administration of diagnostic tests. This also serves as a reference for the teachers to ascertain the most appropriate, high-quality instructions that will elicit the best understanding of the students of the key science concepts that the students are expected to learn (Alwan, 2011).

On a personal note as a teacher, when trying to solve a complex problem in physics, it has been observed that students often over-generalize a particular principle in an attempt to solve the problem. Teachers of physics subjects share concepts with their students and those students who have previous knowledge of the topic can more easily relate to the subject.

Physics has intricate topics and students often digest it one step at a time, learning the basics then going to more complex topics, but if a single process is missed it can make the correct explanation ambiguous. It is surprising to teachers when students tend to have a narrow understanding of a physics lesson and frustrating when helping their students learn the basic concept of the lesson. Although students may be able to provide a correct response to physics-related queries, they implicitly show their understanding of the underlying physics theories based from deep-seated rote memory or worse, grasp onto a concept which they believe to be scientifically accurate but is not.

Concepts of Misconceptions

Misconceptions are ideas of individuals based on their comprehension and appreciation that are not scientifically accurate. Some people embrace a misconception because they do not fully understand the notion.

Misconceptions, misunderstandings, or incomplete ideas about a process or concept in a subject (Scheuermann & van Garderen, 2008), erroneous conception or a mistaken notion (Meyers, 2007), that differ from what is known to be scientifically correct, are common and can arise in any discipline. However, many researchers have emphasized that teachers should be focused on developing knowledge structures (Mesutoğlu & Birgili, 2017) instead of focusing on avoidable mistakes; equally important is correcting the misunderstanding and knowing what techniques can be used to work with them. Hence, students can have the opportunity to unlearn the misconception and learn the correct one.

Misconceptions should not be mistaken for preconceptions, alternate conceptions, naive ideas, and common sense conceptions for the reason that they do not specifically involve student understanding before instruction (Halim et al., 2019). These alternative concepts should be scrutinized and corrected after being exposed to formal instruction (Dolgos, 2006), with the discrepancy of students' ideas arising out of a confusion of informal thinking that is currently being welcomed by the scientific community. The risk in those misconceptions is when students have difficulty correcting their misconceptions because such preconceptions cannot be released or corrected as it is difficult for them to process new material properly.

Background of the Study

Early 21st century science teachers are facing multiple problems. Surprisingly, in science accomplishment, learners in the United States still fall behind learners in other nations, especially from many European and Asian countries (National Center for Education Statistics, 2007). Relatively, the results of the Programme for International Student Assessment (Pisa) by the Organization for Economic Cooperation and Development (OECD) in 2019 revealed that Filipinos fared worst among 79 countries in reading literacy and second lowest in both mathematical and scientific literacy (Reysio-Cruz, 2019).

Access to appropriate textbooks and classroom resources are just some of the complex problems in the field of science education (including pre-service and professional growth); other issues include political and religious objections to state-of-the-art science education, the need to satisfy norms and prepare learners for evaluation criteria, and the use of the Internet as a data source.

Anderman and Sinatra (2017) point out that science, engineering, and technology enable graduates to engage in open discussions on science-related topics, be responsible citizens of modern society and deal with a great deal of information in the scientific and technical areas, as they hold the key to meet current and future challenges. However, although for example, most U.S. employees have a certain degree of background on basic science concepts, not all do. This problem has led to a widespread call for a new approach to K-12 science education in the United States.

Based on a survey, the number of Overseas Filipino Workers (OFWs) who worked abroad at any time during the period April to September 2019 was estimated at 2.2 million (Philippine Statistics Authority | Republic of the Philippines, 2020), economically contributing to both GNP of the Philippines and GDP of the countries where they are situated. However, some of the Filipino professionals who have worked overseas have found it difficult to get a good opportunity based on the degree they have finished because the educational institution in the Philippines is different from abroad (Ednave et al., 2018). Since the implementation of the K-12 curriculum in 2013, the educational system of the Philippines is still in the process of renewing in order to correct some factors that have been identified. People in the education sector are making every effort to address the needs of the people and to provide the Philippines with a quality education program that offers an adequate time frame for mastering concepts and skills, cultivating lifelong learners and training graduates for tertiary education, middle-level skills development, jobs, and entrepreneurship. Though the goal is not to send Filipinos abroad, it is a reality that there are greater job opportunities for them in many foreign countries where they can improve their standard of living.

The curriculum is an essential aspect of the academe and Filipino learners are adjusting to the academic arena to suit the K-12 curriculum's current layout since its conception in 2013. The K-12 curriculum is the consequence of the education sector's three-year mediation by

Philippine policy implementers and was subjected to tedious and complex processes before it was implemented (Cabili & Capilitan, 2015). However, the transition from the Basic Education Curriculum (BEC) to K-12 Curriculum in the education system in the Philippines drew negative reactions from different groups of society. Grageda (2016) stated that the Philippines is not yet ready with this significant shift in the whole education system. Despite the calls to suspend this, the government remains firm on this new transition, believing that the additional years in education will enable the nation, especially the learners, to meet the standards of the global market. Meanwhile, the Science framework for Philippine Basic Education contains three curriculum components: (1) inquiry skills, which explain and discover physical phenomena; (2) scientific attitudes, which refers to the values and habits of mind; and (3) content and connections, which give meaning to the context of the subject matter that is under exploration (Gonzales, 2019).

Under the K-12 curriculum of the Department of Education, senior high school students have to select a track as they enter grade 11. They can choose among three tracks: Academic; Technical-Vocational-Livelihood; and Sports and Arts. The Academic track includes three strands: Accountancy, Business, and Management (ABM); Humanities and Social Sciences (HUMSS); and Science, Technology, Engineering, Mathematics (STEM). Each strand is unique as they offer subjects relevant to each strand as they move up to the tertiary level.

Luis Palad Integrated High School (LPIHS) is one of the five high schools in the Division of Tayabas located at Brgy. Ipilan, Tayabas Quezon. It has recently become the first ISO 9001:2015 certified public high school in Quezon Province, and the third in Calabarzon. For the school year 2019-2020, it had nine hundred sixty-two (962) senior high school enrollees. The school offers academic tracks that include STEM, HUMSS, ABM, and GAS. Currently, the Senior High School Department of LPIHS is in its second year of offering STEM. With this, the students and the faculty are still refining their understanding and navigating the course offerings, particularly in the sciences.

As a central focus of the study, students enrolled in the STEM strand are required to take additional science and math subjects, which include pre-calculus, basic calculus, general chemistry 1 and 2, general biology 1 and 2, and general physics 1 and 2. Looking at the performance of STEM students in these subjects, it is evident that learning gaps are present based on their mean percentage score (MPS) for the past two years. In particular, the MPS for general physics 2 is lowest in 2018 (64.18) and in 2019 (58.15). This value is far below the passing rate of 75 set forth by the education department.

Being considered by many as the most essential and over-arching with other sciences, physics has had a significant effect on all other scientific advancements. In addition, students in many fields try to learn physics because it plays a basic role in all other phenomena. True enough, it corresponds to what used to be called natural philosophy, from which most modern sciences emerged (Gottlieb & Pfeiffer, 2013). With this in mind, there is a need to look at how well students in the Philippines have really understood concepts in physics, as they have low test performance in the subject, in the hope of identifying misconceptions they may still possess despite being grade 12 students in the STEM strand.

Student misunderstandings are omnipresent across the fields of science, technology, engineering, and math (STEM). Introductory core subjects such as physics is a good venue to determine and remediate students' misconceptions since it is a prerequisite to various STEM-related courses such as engineering and technology, however it is confirmed that there are several identified misconceptions, particularly in the introductory level (Neidorf et al., 2020). Because STEM classes tend to build on each other, it can be particularly detrimental to student learning to transfer misconceptions. These misunderstandings are often recognized through interviews, inventories of concepts, or analysis of a text. However, misconceptions of learners become particularly apparent in student-generated writing (Halim et al., 2019) because it offers more data about knowledge of learners than multiple-choice issues or other forced-response evaluations.

Misconceptions have long-term consequences but practicing science in the classroom helps to correct misunderstandings and fosters enthusiasm for the scientific sector (Meyers, 2007). Student misconceptions are a hindrance to science, technology, engineering, and math courses and unless the students do well, the misconceptions will continue to cause learning difficulties as the students make progress in their studies (Halim et al., 2019).

To further provide quality education to the youth, it is of utmost importance that student learning should be based on how well they can apply concepts learned in the classroom to real-life situations. This would be possible if they would be free from misconceptions as they finish their senior year. Thus, appraising how well STEM students understood scientific concepts from grades 7 to 12 would aid in determining possible misconceptions they may have formed to help them and the school realize ways to address this issue.

Statement of the Problem

STEM students have been performing poorly in their physics classes, particularly on the concept of heat and temperature, for the past two years. In order to determine the learning gap of the students, this study is concerned with the appraisal of their misconceptions on heat and temperature.

Specifically, it sought to answer the following questions:

1. What are the misconceptions of STEM students regarding heat and temperature based on the Heat and Temperature Concepts Questionnaire (HTCQ)?
2. How did STEM students come up with their answer for each test item?
3. What are the possible factors that affected the conceptions of the STEM students towards heat and temperature concepts?

Significance of the Study

The findings of this study are deemed significant for various stakeholders such as students, science educators, teachers, administrators, educational researchers, and the researchers themselves.

Students. This study will help learners to correct their heat and temperature misconceptions. A previous understanding of the student can be used as a construction block to acquire fresh understanding. They are now free to ask about those thoughts with this understanding that provide incorrect views. This makes the learners more engaged in the process of teaching-learning where they can participate actively. Students have previous misunderstandings about content that make it even more difficult to understand the larger image, hence a scheme needs to be developed to make use of the preconceptions for a better understanding of the material.

Science educators. The results will provide links between the previous understanding of the student and the introduction of fresh science ideas. Essentially, when both students and teachers have a chance to actively participate in learning science, students recognize the fallacy of their misunderstandings, and conceptually clarify the freshly obtained data. The significance and persistence of these obstacles to real comprehension should not be underestimated by a science teacher.

Teachers. The teacher becomes a co-learner and facilitator. The results of this study may provide some direction for teachers on how to prepare their lesson plans and generate new teaching techniques to understand learners for a more efficient teaching-learning process. Identified misconceptions will be the springboard of the educators on which tactic will be the best means to correct the confusion among their future scientists, which has a great potential to cause confusion with new learning. Also, it can be a guide in helping the students to construct or reconstruct a correct framework for their new knowledge.

Administrators. This research study will give an idea to the university administrators to initiate a seminar related to the new strategies that will present materials that can aid in correcting students' misconceptions. It would be greatly beneficial to support the teachers to develop their pretest misconception material for their course, such as instructor's manuals, textbook material, and their knowledge of the field. It also benefits school administrators who are involved in educational system reforms in the country thru the continuous improvement of the K-12 curriculum.

Educational researchers. Researchers can use the data of this study to conduct more extensive research that may lead to the development of new materials or processes that may enhance the facilitation of learning.

Limitations of the Study

The investigation was limited to Grade 12 students taking the Science, Technology, Engineering, and Mathematics (STEM) Strand at Luis Palad Integrated High School. The program consisted of 151 students during the first semester of the school year 2019-2020.

The questionnaire was simultaneously administered among the student-participants during the first quarter wherein the topics were not yet discussed in their General Physics subject, consequently, the conceptions that students may currently have had are solely based on their schema acquired during their grade 11 and junior high school years.

The focused subject matter in this study are topics that were included in the Department of Education Science Curriculum under the K to 12 Program. The instrument deals only with limited topics on heat and temperature. The questionnaire encompassed the subtopics, namely concepts of heat and temperature, heat transfer and temperature change, and thermal properties of materials.

The results of the study were used to determine the alternative concepts of the students about heat and temperature where the teachers utilized the results to correct the misconceptions through the course of the lesson by applying the various conceptual change models suitable for the factors causing the alternate concepts of the students.

Methodology

Research Design

This research study involved a methodology for conducting an investigation that encompassed collecting and analyzing information and integrating mixed methods of quantitative and qualitative research.

The objective for the researchers was to understand the identified misconceptions about heat and temperature of the senior high school STEM students, which were obtained through the quantitative analysis of their responses through the Heat and Temperature Concepts Questionnaire (HTCQ).

Furthermore, qualitative research was utilized to corroborate their responses to better understand and explain the causal processes involved, hence, an interview was conducted. It was for the students to express how they come up with their answers for each item.

Respondents

A total of 151 Grade 12 students, who are enrolled in the Science, Technology, Engineering, and Mathematics (STEM) Strand in Luis Palad Integrated High School (LPIHS), Division of Tayabas City, Quezon, were given consent by their parents to participate in this study. The participants were purposely chosen for the reason that these students had finished Grades 7-11 at LPIHS and were anticipated to have a strengthened and profound knowledge about the topic. Furthermore, they were expected to pursue science and engineering-related courses upon entering the tertiary level. In addition to this, twenty (20) students who got the lowest scores in the HTCQ were identified and subjected for an oral interview. This number of interviewees was selected so that saturation of interview responses may be minimized (Saunders, et.al., 2018).

Research Instrument

Heat and Temperature Concepts Questionnaire (HTCQ)

To determine the alternative concepts of the STEM student, the Heat and Temperature Concepts Questionnaire (HTCQ) was adapted (Alwan, 2011). Originally, it was constructed through the suggested steps by Robbins (1998) on the constructional course of the multiple-choice questionnaires. The adapted HTCQ consisted of thirty multiple-choice questions, which are situated in everyday circumstances. Questions 1 to 26, 28 and 29, 27, and 30 were originally from Yeo and Zadnik (2001), Driver (1989), and Elwan and Almahdi (2007), respectively.

The test items were adapted from the HTCQ and grouped into four sub-topics that they fall into, namely; (1) heat, (2) temperature, (3) heat transfer and temperature change, and (4) thermal properties of materials.

Heat and Temperature Alternative Concepts Interview

Twenty students from the 151 members of the study group with the lowest scores based on the HTCQ were interviewed to determine their alternative concepts about heat and temperature. They were asked to explain how they arrived with an answer to each question. They were also interviewed to gather a more complete and comprehensive understanding of the factors that might have affected their responses.

Data Gathering Procedure

The researchers directed a letter requesting permission to administer the HTCQ and conduct an interview with the intended student participants, to the schools' division superintendent of the Division of Tayabas City. The approved letter was forwarded to Luis Palad Integrated High School to formally endorse the conduct of the study.

Each student was asked to accomplish and submit a duly signed consent form by their parents, thus, allowing them to become student-participants in the study. An orientation was held where the purpose of the research study was explained to the student respondents, before the administration of the test.

Upon evaluation of the answered instruments, twenty students who got the lowest scores in the HTCQ were interviewed to attempt to unravel the factors that might have affected their alternative understanding of the concepts. At the start of the interview, the student respondents were reminded that the questions during the interview aimed to measure their reasoning ability, not their correct response to any specific item.

Data Analysis

The students' responses in the HTCQ were scrutinized through item analysis using the ZipGrade® app. The percentage of incorrect answers were considered and analyzed to determine the students' alternative concept in each item.

The twenty students who got the lowest scores were interviewed and their responses were transcribed and analyzed to determine the possible factors that affected the conceptions of the STEM students towards heat and temperature concepts. To determine how the alternative conceptions (Table 1) of students formed, their explanations for the provided response in each item were analyzed.

Results

All of the student-respondents answered the HTCQ simultaneously; their knowledge about the topics were based on their learning from their previous grade level from the spiral progression of lessons in science, hence students received formal learning before the study was conducted. Item analysis showed the percentage of incorrect responses in each item opposite their alternative conceptions.

The results show that only about 36% of the students had the correct concept of heat especially in the relationship between "cold" and "heat" with the highest percentage of alternative response *(Students' Conceptions of Heat)*. Correspondingly, data in Students' *Conceptions of Temperature* presents that only an average of 39% of the students had accurate ideas of temperature, specifically item no. 21 shows only 10% of students having correct concepts. In terms of *Students' Conceptions about Heat Transfer and Temperature Change*, only 35% of the students comprehended it correctly. Lastly, the results of *Students' Conceptions on the Thermal Properties of Substances* show that there were only 37% of students who had correct ideas about the topic.

After the evaluation of the students' conceptions about heat and temperature, the students who scored as the lowest twenty (20) were interviewed, thus the percentage shown in Table 2 represents the interviewed students per se. The students were asked to explain how they came up with an answer in each item (see Table 2). Commonly, some students simply guessed from the provided selection of possible answers, in addition to those who expressed that they knew little about the topic: either they forgot that it was taught or they did not fully understood the essence of the concepts in real-life application. A majority of the students also explained that their responses were based on their personal experiences and that is how they comprehended the ideas as applied and observed in their daily encounters, but were not correctly aligned to the scientific principles behind the experiences.

Based on the responses of the STEM students regarding the factors that have affected their conceptions about heat and temperature, they find the topic difficult to understand mainly because they have forgotten what their teachers taught them from the previous grade levels. The respondents also claimed they had not yet encountered some of the topics asked from the questionnaire, which confused them as they answered it. These instances are, one way or another, factual especially since there are several reasons for classes to possibly be interrupted, e.g., natural catastrophes and non-academic activities, yet the curriculum is ideally designed to consume the prescribed number of school days without interruption. Furthermore, they added that they did not analyze each item thoroughly, thus resulting in misinterpretation of questions. Some also recalled that they disliked the way the topic was taught back then, which led them to become bored and uninterested. Finally, many lacked the confidence and self-esteem to explain the heat and temperature concept because they relied mostly on their stock knowledge.

Table 1

Students' Conceptions of Heat, Temperature, and Thermal Properties

Students' Conceptions of Heat

Alternative Concept	*Item Numbers*	*Incorrect Response, %*
Heat is a substance and not a form of energy.	10, 22	70, 47
Heat and cold are different, rather than opposite ends of a continuum.	10, 13, 18, 23, 24	70, 73, 49, 90, 91
Heat and temperature are similar.	15, 18, 27, 30	66, 49, 79, 51
Heat is proportional to temperature and cannot be quantified.	7, 11, 15	51, 45, 66
Average		*64.07%*

Students' Conceptions of Temperature

Alternative Concept	*Item Numbers*	*Incorrect Response, %*
Temperature is not an interval data·	15	66
Sense of touch can determine the temperature of an object.	16	50
Cold is a quantity that can be held by an object	10, 18, 21, 22	70, 49, 90, 47
Continues heating of boiling water gives rise to its temperature	5	59
Boiling point is the highest temperature a material can reach.	19	84
Cold bodies do not contain heat.	7,10, 11, 22, 26	51, 70, 45, 47, 60
Size of an object affects its temperature, hence it is an extrinsic property	1, 9, 14	61, 67, 49
The lowest temperature has no limit.	25	72
Average		*61.00%*

Students' Conceptions about Heat Transfer and Temperature Change

Alternative Concept	*Item Numbers*	*Incorrect Response, %*
An increase in temperature is always due to heating	3, 4, 5	79, 67, 59
Heat only travels upward making it rise	20	59
Heat and cold flow from one material to another	10, 13	70, 73
Temperature adds up if two objects were combined together	7, 13	51, 73
When objects of different temperature became in contact, will cause warm temperature to become cold and vice versa, but they do not possess similar temperature. The students are unfamiliar with the thermal equilibrium concept.	1, 2, 3, 6, 9, 10	61, 73, 79, 69, 67, 70
A hot object readily cools down and a cold object readily warms up.	17, 24	43, 91
Temperature can be transferred through materials	3, 13	79, 73
Heat transfer is not explained through the kinetic theory	25	72
Energy transfer has nothing to do with hotness or coldness of an object	18, 20, 21	49, 59, 90
Average		*65.27%*

Students' Conceptions about Thermal Properties of Materials

Alternative Concept	*Item Numbers*	*Incorrect Response, %*
Temperature is a particular property of an object	9, 14, 16, 24	67, 49, 50, 91
Alternative Concept	*Item Numbers*	*Incorrect Response, %*
Heat and cold can be absorbed and held by metals for a longer period of time, hence the metal feels cold.	9, 14, 16, 20	67, 49, 50, 59
When an object can instantly become warm, it doesn't instantly become cold.	25	72
Colder objects has more heat to lose	11	45
The water will only boil at 100°C	4, 8, 12,19,28	67, 82, 45, 84, 60
Ice is always at 0°C and its temperature depends on its size	1	61
Water melts the ice which makes the ice warmer, thus it cannot be at 0°C.	2, 11	73, 45
Steam is colder than the boiling water.	6, 19	69, 84
Materials like wool have the ability to generate heat on its own.	17, 23	50, 90
There are materials that are resistant to heating, some are easily heated some are not	26	60
Heating separates the hydrogen and oxygen atoms of water	12	45
When heated object has constant temperature, heat is added.	29	61
Average		*63.00%*

Table 2

Explanations of Student Responses for Each Item

Item Number	Respondents' Conceptions
1	When asked about the temperature of ice cubes in a refrigerator, 40% of the interviewed students thought that the size of the ice cubes will affect their temperature. As they had already perceived, the freezing point of water is 0°C, thus the ice cubes maintained that temperature.

Item Number	Respondents' Conceptions
2	Seventy percent of the interviewed respondents only guessed their answer when asked about the most likely temperature of water when the ice cubes added to it stopped melting. They believe that adding water to the glass will result in a higher temperature. They further believed that when ice cubes are put in water, their temperature is transferred to the water.
3	Ice cubes which have nearly melted totally and are resting in a pool of water on the counter most probably have a temperature of 5^{o}C, according to the students. Sixty-five percent also answered that if ice melts, the temperature will be higher. These answers were just assumed by the respondents and they find it hard to explain their responses with confidence.
4	When asked about the most likely temperature of water as it started to rapidly boil, 40% responded that the initial temperature is 100^{o}C. The same percentage of respondents also believed that the highest boiling point of water is 110^{o}C.
5	In answering this question, 55% of the respondents said they only guessed their answer on the temperature of water, which is continuously boiling. They hold the conception that the highest boiling point of water is 110^{o}C and that the temperature of water rises because it has been left in a hot temperature.
6	When asked about the temperature of steam above boiling water, 40% reasoned that steam has a lower temperature than boiling water. They also added that their response to the question was simply a guess.
7	45% of the students only assumed their response to the temperature of a mixture of two cups of water wherein the first is at 40^{o}C and the second cup of water is at 10^{o}C. To determine their answer, 20% of them added the two values of temperature, which resulted in a higher temperature value. They said honestly that they did not fully analyze the question.
8	In answering the effect of high altitude on the boiling point of water, 60% said that they only guessed their responses. They thought that the boiling point of water is inversely proportional to the altitude where it is being boiled.
9	In comparing the temperatures of the plastic bottle and the cola inside, 40% of the students thought that it relies on the volume of cola and size of the bottle. They also believed that when placed in the refrigerator, the cola in the can would cool faster compared to the cola in the plastic bottle.
10	When asked why the countertop in the given situation feels colder than other areas of the counter when a cola can was placed on it, 35% of them thought that the temperature of the cola can is transferred to the countertop.
11	Thirty-five percent of the interviewed students thought that ice will lose more heat than water because it is colder than the latter. In addition, they also believed that the lower temperature of ice caused it to lose more heat.

Item Number	Respondents' Conceptions
12	In explaining what is inside the bubbles that form in boiling water, 25% of the respondents believed that it is simply air. In addition, they also believed that it is the heat rising up. This question also raised confusion among the students.
13	When asked to explain the cooling process of a hot egg placed in cold water, the respondents were able to describe what happens to the egg and the water. But on a deeper note, 75% were not able to reason out how this process happened.
14	The students were confused when asked why metal chairs are colder than the plastic ones. 45% of them explained that it is simply because metals are conductors and have higher heat capacity, which is why they are colder than plastic materials.
15	When asked which statement is correct when a radio announcer said that "tonight it will be a chilly 5°C colder than the 10°C it was last night," 55% answered that it will be twice as cold tonight as it was last night. They believed that the numerical difference in temperature will result in a doubling of effect in the temperature scale.
16	In explaining why the metal ruler felt colder than the wooden one, 45% of the students said that metal is a great conductor; that's why it absorbed more coldness than wood. They also pointed out that wood is naturally warmer than metal and it does not conduct much heat or cold.
17	In determining the most likely room temperature in the given situation, 45% of the interviewed students found it hard to analyze the question and said that they did not actually know this concept. They tried answering that the dry cloth has absorbed heat but were not able to solve for the actual room temperature.
18	When asked to compare the warm carton with the cold carton, 40% reasoned out that the refrigerator uses more cold, thus, making the carton cold as well unlike in the countertop which is hot.
19	When asked to explain how food is cooked faster in a pressure cooker than a typical saucepan, 65% of the interviewed students answered that it is due to the sealed lid which distributes heat evenly. They added that the high pressure cooks the food faster since the higher the pressure, the higher temperature.
20	In explaining why cakes are cooked at the top shelf inside the electric oven, 55% the students answered that the temperature of an electric oven at the top and at the bottom are the same. They added that metal trays are conductors of heat.
21	When asked to explain how sweating cools down the body, 70% of the students only guessed their answer. They answered that it is due to the temperature change and that the body releases heat through the sweat to cope with the temperature of the environment. They added that because sweat is cold, the skin becomes cold as well.

Item Number	Respondents' Conceptions
22	In explaining why the metal pump becomes hot when pumping up bike tires, 70% of the students responded that metals are conductors of heat and the pumping generates friction which in turn generates heat.
23	In explaining why we wear sweaters in cold weather, 70% of the interviewed students explained that it keeps the cold out and it generates heat so heat loss can be reduced. They added that without a sweater, heat will be removed from the body.
24	When asked to explain why the wooden sticks of a popsicle from the freezer have a higher temperature than the ice part, the students answered that wooden sticks contain more heat compared to the icy part. Accordingly, they said that wood attracts more heat. Seventy percent of them also added that they only guessed their answer.
25	When asked about making super-conductor magnets at -260^{o}C, 30% answered that super conductors cannot be cooled at this temperature and that it's colder than the average freezing point.
26	Based on the response of the students, 45% were confused by the question. They added that the blanket used was a poor insulator and did not carry heat energy.
27	When asked to define what temperature is, the students answered that it is the scale value of heat. 35% of them also point out that temperature depends on heat.
28	In reading the temperature between two cans with varying amounts of boiling water, 50% responded that the can with the lesser amount of water will have higher temperature than the other can as both come to a boil.
29	When asked why the temperature readings have several 420^{o}C, the 70% answered that the records were added to get that value. They also added that they find it hard to analyze the question.
30	When asked what heat is, 40% of the interviewed students stated that it comes from the body or transferred from one to another. Their answer to this question is simply based on their experience.

Discussion

As we construed from the findings, the results show that the students' misconceptions can be categorized into various conceptual change models. It is evident that the learners possess alternative concepts of heat and temperature, which may partly be because of how the terms "heat" and "temperature" are used in daily semantics (Limon, 2001). Since heat and temperature concepts are quite complicated to understand, students find it difficult to understand how they are applied in actuality making it hard for them to explain the occurrence of related phenomena. Hence, more than half of the student respondents could not distinguish heat from temperature and thought they can be used interchangeably, which is consistent with findings in other similar studies (Ericson & Tiberghien, 1985; McDermott, 2003). Additionally, several students thought that cold is another quantity independent of heat instead of thinking that the transfer of heat goes from the hot object to the cold object. Likewise, students thought of temperature as an extrinsic property of an object that it is a function of the amount of matter, where they erroneously assume that a bigger object is hotter than a small one. These results coincide with Vosniadou and Skopeliti's (2013) claim that students construct a naive understanding of physics as a product of their daily encounters in the context of lay culture to form a coherent conceptual system, which they use as a basis for the explanation of their experience, however, a misconception occurs in the combination of learned scientific facts with the prevailing—however, mismatched naive--physics frameworks.

One of the rudimentary topics under heat and temperature that students have difficulty telling apart is the concept of specific heat and heat capacity, specifically in item 7, in which the students had difficulty analyzing due to the mathematical nature of the question, thus grounding their answers by performing basic arithmetic instead of using the formula $Q=mc\Delta t$, wherein the amount of heat energy lost or gained (Q) is equal to the mass of the substance (m) multiplied by its specific heat (c), and the change in its temperature (Δt). Though half of them got it correct, the interview group cannot explain how they came up with the correct answer other than by intuition. It also shows that even if the question was a common daily encounter such as mixing tap water to boiling water in preparing warm enough chocolate drinks, still they cannot relate the physics concepts to experience. Additionally, the phase change is one of the processes that is incorporated in heat and temperature and students commonly thought that an increase in temperature is always due to heating; also, their misconceptions can be due to the integrity of their basic knowledge in evaporation and condensation, which were taught in the previous science subjects in junior high and elementary school, which is conclusive of either their weak foundation or poor retention, similar to the study conducted on the first-year high school students (Ayas & Costu, 2001) that temperature increases when a material continues to get heat from an external source, thus the concept of thermal equilibrium is not acknowledged. The students can confront these conceptual challenges in thermodynamics through the use of self-generated analogies (Haglund & Jeppsson, 2013) reinforced by the laboratory model of conceptual change (Ohlsson & Cosejo, 2013). Through these models, the students will be able to become familiar with the new topic through recategorization experimentation, which has the potential to give thorough information of the sequential dynamics of learning, revealing how initial conceptions are eventually transformed.

In terms of heat transfer, students have the notion that heat and cold are particular properties of materials, thus objects are normally warm and cold. They also hold onto the idea that cold moves from one material to another rather than heat moves from warmer to a cooler object, which only a little less than 30% of the students knew. Students also perceived that using the sense of touch one can quantify both heat and temperature mainly because we have this common practice of measuring someone's body temperature by feeling their forehead.

Similar misconceptions are also found in several studies when performed in classes of preservice teachers (Gönen & Akgün, 2005) and K to 12 teachers (Quan et al., 2011). Nonetheless, several students had a correct understanding of conductors and insulators, however, they could not point out the mechanism of heat transfer in these objects. They also misused the term heat capacity indicating it as the heat carried by an object. This result models Thagard's (2014) study on explanatory identities of ordinary things with scientific ones, since the students barely define the meaning of heat capacity, they are not able to explain its concept in heat transfer hence, that to gain conceptual change students need to examine and experience it to gain insights and justification about the scientific concept.

Looking at the statements about the factors that have affected the students' conceptions about heat and temperature, they can be attributed to the teacher, the topic, and the learner (Potvin, 2013). The way their teacher taught the topic during their junior and senior high school years has an impact on how well the students have understood these concepts. It should not be disregarded that one factor to such a misunderstanding by students is the failure of the teacher (Kartal et al., 2011) that can lead to various kinds of students' misconceptions.

Thus, even adults, including teachers, can occasionally have misconceptions (Burgoon et al., 2010). Several pieces of research (Wandersee et al., 1994; Astolfi et al., 2006) indicate that misconceptions still exist despite the formal instruction the students received, for the reason that there was no check and balance between the taught concept of the teachers and how the students grasp the context. However, this alternative conception can be improved if the teachers have properly described the information processing task and the cognitive mechanisms responsible for those activities that will correct misconceptions through Rusanen's (2013) mechanistic alternative model.

Finally, the students themselves contributed to their conception of heat and temperature because their behavior towards the topic and their study habits as well were not constructive based on their responses to the interview questions. They neglected to deeply process given information and simply aimed to finish the task at hand without realizing and reflecting about whether their responses we correct or not. Thus, as Erman (2016) recommended, the teacher should identify misconceptions about prior knowledge or concepts prior to teaching the basics, identify reference book learning, and facilitate effective communication so that information received by the students is complete and correct.

Conclusion and Its Implication to Teaching and Learning

From the outcomes of the study, the researchers have determined and classified three propositions that could address issues that arose from the findings. These implications are anchored on the students' misconceptions about heat and temperature, the underlying reasons for their alternative conceptions, and the factors which could have affected them.

Revealing the misconceptions of STEM students in heat and temperature gave a different perspective on the depth and breadth of their conceptual understanding of the topic when compared to the currently mandated spiral progression curriculum. This study has further shown gaps in the curriculum which may be solved at earlier stages before they become detrimental to student learning as they progress educationally, such as lack of vertical interconnectedness in a certain discipline and horizontally with other fields.

Additionally, it is recommended that educators should demonstrate heat and temperature concepts by using the prior experiences of students to be able to provide correct settings and effective strategies as well. Since the learners already possess ideas regarding heat and temperature before entering the classroom, the teacher must provide pedagogical approaches that place more focus on assisting learners to construct scientific knowledge and analysis. This idea is similar to the work by Ali Alwan (2011) that shows providing appropriate situations and effective pedagogies such as multi-contexts should be used to introduce and explain heat and temperature concepts, so students can better understand the concept and see how the concepts are transferred and applied. Also, constructivism can be used to take students' misconceptions into account when designing instruction. The method of dealing with misconceptions was to use strategies of conceptual change designed to promote the acquisition of new concepts as a consequence of the exchange and differentiation of the existing concepts and the integration of new concepts with existing ones (Baser, 2006). Incorporating inquiry-based activities can also significantly improve students' conceptual understanding of heat transfer as measured by questions closely related to the instructional activities (Nottis et al., 2018).

Even though the STEM students were able to provide some theoretical knowledge and explanations regarding heat and temperature, some of them do not fully comprehend the underlying concepts about the subject, which is critical when they pursue science-related courses in the future. Hence, teaching must focus on:

1) Conceptual understanding of physics or theoretical and mathematical problems that challenge students' initial common sense framework.
2) Guiding students in the construction of new systems of concepts for understanding these concepts. Teachers must know what techniques, representational tools, and conceptual resources to draw upon to make new concepts intelligible to students, and also how to build these constructions in a sequenced manner.
3) Classroom discourse that encourages students to identify, represent, contrast, and debate the adequacy of competing explanatory conceptual-change processes including making students aware of their initial conceptions, helping students construct an understanding of alternative frameworks, motivating students to examine their conceptions more critically, and promoting their ability to evaluate, and at times integrate.
4) Providing students with extended opportunities for applying new systems of concepts to a wide variety of problems. Repeated applications develop students' skill at applying new concepts, refine their understanding and help them appreciate its greater power and scope.

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