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Research Article

MODIFIED HEAT AND TEMPERATURE CONCEPT EVALUATION OF BS ARCHITECTURE STUDENTS OF BULACAN STATE UNIVERSITY

Freya Gay A. Jingco[1]
[1]College of Science Bulacan State University City of Malolos, Bulacan, Philippines

Correspondence should be addressed to **Freya Gay A. Jingco**

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ABSTRACT

Alternative concepts must be expressed by the students for us; teachers would know then and look some ways to help address this problem.

The study aimed to explore students' conceptual understanding of heat and temperature. It attempts to answer the level of the common conception of the 2nd year BS Architecture students of Bulacan State University and their existing alternative conceptions on heat and temperature.

Descriptive survey method was used in this research to probe the common conceptual understanding of students. Data gathered were analyzed quantitatively and qualitatively based on students' answers derived from the 20-item modified HTCE, which is a free response and multiple choice exam. The researcher concentrated in investigating the common conceptions of the students' written responses to the test.

The respondents were purposively chosen by the researcher during the 1st semester of the school year 2016-2017 which utilized five integral sections of BS Architecture students of Bulacan State University and are currently taking their Mechanics and Heat (Physics 212) course.

Results revealed that students have their prevailing alternative conceptions and beliefs that are embedded in their minds as shown in their responses.

KEY WORDS: Alternative concepts, common conceptions, heat and temperature

INTRODUCTION

Students of physics have difficulties learning to deal with it because it is an intellectually demanding discipline. To add, the instruction given is less effective than they thought it was. Recent investigations (Reif, 1995) show that a lot of students come out from their basic physics courses with pre-scientific notations, observable scientific misconceptions, poor problem-solving skills, and unable to apply what they learned apparently even when they were given good grades. Thermodynamics is a key theory of chemistry, physics and all natural sciences but it presents students with many conceptual difficulties. Many science-oriented students have difficulty understanding these concepts at the qualitative level in addition to any difficulties that occur with the quantitative formulation. Difficulties at the qualitative level may go undetected. However, because a student's superficial knowledge of formulas and formula manipulation techniques can mask his or her misunderstanding of underlying qualitative concepts, he is likely to dress up his misconceptions in scientific jargon, giving the false impression that he has learned something about science.

Mathematical theory is not an assurance of good conceptual physics background because students with misconceptions may be proficient at the use of physics formulas and numerical manipulations (Clement, 1982, Halloun and Hestenes, 1985, Mc Dermott, Shaffer and Somers, 1994). Students see no distinction between Physics and Mathematics. Sometimes, they concentrate more on problem solving (purely in mathematics) and ignore conceptual ideas.

Physics is not only a collection of facts and formulas, although students view it that way. Hestenes (1985) goes on to say that "students are not easily weaned from a formula-centered problem-solving strategy that has been successful in the past."

To ascertain what students already know, teaching them accordingly is one of the teacher's roles. It is in their alternative conceptions that we gauge them for us, teachers to facilitate in their learning. It is also in the conceptions that research and hypotheses are done. Students must express alternative concepts in order for us; teachers would know them and look some ways to help address these problems.

An assessment tool designed for this purpose is a concept inventory. When these misconceptions are identified, they serve as a basis for developing an effective pedagogical plan in resolving the conflicts between students' beliefs and scientific theories. The first step in making teaching more effective is to diagnose students' conceptual problems. *Heat and Temperature Concept Evaluation* (HTCE) was used in exploring the conceptual understanding of heat and temperature of BS Architecture students of Bulacan State University (BSU).

REVIEW OF RELATED LITERATURE

A majority of students harbor serious misconceptions and misunderstandings of physical principles. They do not see how the information they are learning in physics class has any bearing on understanding the physical phenomena they see and experience around them every day. Without conceptual understanding, student cannot pass beyond the rote memorization stage and cannot proceed to develop the skill needed to solve open-ended, undetermined, real world problems. (Mazur, 1997)

Yeo and Zadnik (2001) developed the Thermal Concept Evaluation (TCE) to assess an extensive range of beliefs on thermodynamics concepts in 15 – 18 years old students in Western Australia. The TCE is composed of 26item, multiple choice type of questions that allow students to apply either "everyday" or "classroom physics." The following are some alternative conceptions the researchers reported: (1) Heat as a substance not energy; (2) Heat is same as temperature; (3) Cold bodies contains no heat; (4) Boiling point is maximum temperature; (5) Temperature can be transferred; (6) Thermal equilibrium is not a concept; (7) Materials like wool can warm things up: Metal can attract, hold, intensify heat/cold.

Luera (2004) used the TCE in her action research as pretest and posttest. The result of her study showed that students have trouble in applying content knowledge to similar situations. Students were unable to discern salient features in questions. Thermal conceptions are resilient to intervention.

Meltezer (2004) investigated learning difficulties in thermodynamics in both chemistry and physics courses in Iowa. The result of the study showed that majority of the students held incorrect or confused conceptions regarding fundamental thermodynamics principles following their introductory courses in physics and chemistry.

Chang (1999) administered an open-ended, written test to 364 students in Taiwan to assess students' conceptions about evaporation, condensation, and boiling. After evaluation, some students were interviewed in a semi-structured manner to obtain their conceptions. The test result showed that their understanding of the condensation and boiling concepts still needed to be enhanced. The research found out that learning difficulties regarding the concepts mentioned above could be a result of poor understanding of water vapor.

Kesidou and Duit (1993) have discussed the common student confusion between the terms "heat and temperature." Heat is frequently viewed as an intensive quantity and temperature interpreted as the degree of heat, i.e. as a measure of its intensity. However, heat is a process dependent variable and represents a transfer of a certain amount of energy between objects or systems due to their temperature difference. Temperature, by contrast, is a measure of the average kinetic energy of molecules in a particular system.

In a study carried out in Germany by Duit and Kesidou (1988), 14 students were interviewed in order to discover 10th grade (about 16 year old) students' understanding of the Second Law and irreversibility. Results show that most of the students had the correct idea that heat flows from a hot body to a cold body and that temperature differences tend to equalize. Contrary to this result, there was a considerable number of students who thought that a certain temperature difference might arise after the temperature equalization. Their concluding remark was that students' ideas about the natural processes were mainly based on everyday experiences rather than scientific ones taught in school. In a subsequent study, Kesidou and Duit (1993) suggested two procedures to overcome this misunderstanding. Firstly, the experiments should be carried out by the students and secondly a framework should be provided that conceptualizes the thermal interaction as an exchange of heat that flows spontaneously as long as there is a temperature difference.

Obrero (1999) found out from his study that college students also hold several alternative conceptions in topics of heat, temperature, and thermal expansion, first and second laws of thermodynamics, heat transfer, and change of state. Some of the respondents attempted to define thermodynamic concepts or explain thermodynamic phenomena using their informal prior knowledge from everyday experiences. Other misconceptions expressed the students' confusion of various thermodynamics concepts and the tendency to generalize thermodynamics principles beyond the given particular condition. Other alternative conceptions held by students show their lack of knowledge or failure to apply fundamental thermodynamics concepts.

The studies reviewed above revealed that alternative conceptions on heat and temperature are prevalent among students in all levels disregarding their races. These studies also suggested that there is really a need to address the conflict between students' belief and scientific theories. The misconceptions of students were explored and identified using assessment tools like conceptual inventories, and observation of students' activities.

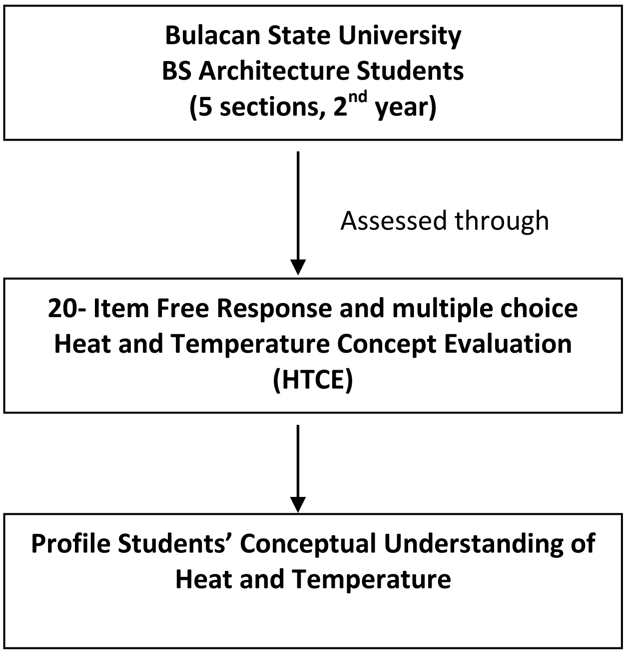
In this research, the Heat and Temperature Concept Evaluation (HTCE) developed by Ron Thornton and David Sokoloff was modified into 20-item free response and multiple choices HTCE to draw out students' understanding to the concepts of heat and temperature. The test was administered by the researcher in August 2016 of 1st semester SY 20016-20017 to Filipino BS Architecture students of Bulacan State University, City of Malolos, Bulacan. It is a pre test- post test instruction.

CONCEPTUAL FRAMEWORK

Students go wrong in physics for various reasons. In dealing with physics, they could go wrong in its mathematical treatment. They could also commit random errors. But often, students commit mistakes because of the difficulty in dealing with certain concepts. To address this problem in learning, teachers need to identify and evaluate student's pre-conceptions.

The figure below presents the research paradigm of the study.

Figure 1: Research Paradigm



In figure 1, the common conceptions of heat and temperature of the BS Architecture students of Bulacan State University (BSU) were explored using the 20-item Heat and Temperature Concept Evaluation (HTCE) test. The researcher concentrated in investigating the common alternative conceptions of the students by identifying, categorizing and tallying students' written responses to the test.

STATEMENT OF THE PROBLEM

The study aimed to explore student's conceptual understanding of heat and temperature. Specifically, it attempted to answer the following question:

1. What is the level of the common conception of BS Architecture students of Bulacan State University (BSU) on heat and temperature?
2. What are the existing alternative conceptions of BS Architecture students of Bulacan State University (BSU) regarding heat and temperature?

SIGNIFICANCE OF THE STUDY

The result of the study provided a profile of Bulacan State University, BS Architecture student's competence across the domains of heat and temperature. The result of this study would help teachers to raise their awareness of misconceptions of heat and temperature strongly held by their students. This will provide opportunities for teachers to engage in research for the improvement of their teaching methods that would effectively address student's naпve ideas of heat and temperature. More training, short term courses or scholarships may be offered to cater the needs of teachers to deepen their physics concepts, most especially those who are not physics majors teaching, and to upgrade their methods of teaching. It would also help students to be enlightened on the misconceptions that they unconsciously adhere as correct conceptions, thus improving their learning.

SCOPE AND DELIMITATION

This study attempt to investigate student's conceptual understanding of heat and temperature using the 20-item Heat and Temperature Concept Evaluation (HTCE). The investigation was done through identifying, categorizing and tallying the responses done in the modified HTCE test. Instead of looking only for correct answers, the researcher concentrated in looking into the pattern of frequently mentioned responses that were considered alternative concepts of the students.

The study was conducted to five integral sections BS Architecture Students of Bulacan State University (BSU) during the 1st Semester of the school year 20016-20017. BSU is a State University in Region 3.

DEFINITION OF TERMS

i. **Misconceptions:** Ideas conceived by the students that are erroneous, produce wrong understanding, and are detrimental to their scientific literary (GonzalesEspada, 2003)

ii. **Conceptions:** Refers to an individual's interpretation of things or events.

iii. **Alternative Conception:** They include common sense beliefs that are incompatible with established scientific theory. These are also known as misconceptions. (Clement, 1993)

iv. **Caloric Theory of Heat:** Heat is a fluid called caloric which could be transferred from one body to another. (Garmon, 1998)

v. **Kinetic Theory of heat:** A theory explaining physical properties regarding the motion of particles. The molecules of atoms of a gas are in continuous random motion, and the pressure exerted on the walls of a containing vessel arises from the bombardment by these fast moving particles. These have average speeds, at normal pressures and temperatures, of around one kilometer per second. When the temperature is raised these speeds increase, so consequently does the pressure. If more particles are introduced or the volume is reduced, there are more particles to bombard unit area of the walls and the pressure also increases. When a particle collides with the wall, it experiences a rate of change of momentum, which is equal to the force exerted. (Academic Dictionary of Physics).

METHODOLOGY

Research Design

The descriptive survey method was used in this research to probe the common conceptual understanding of students on heat and temperature. Pre test and post test were administered. Data gathered were analyzed quantitatively and qualitatively based on student's answers derived from the 20-item modified HTCE.

Research Sample / Selection of Samples

The respondents of the study were purposively chosen by the researcher. It utilized five integral section, a total of 203 BS architecture second year students of Bulacan State University (BSU). These were heterogeneous classes because students were admitted on a first-come-first served basis. This means that students were randomly assigned to their class. The study was conducted during 1st semester of school year 20016- 2017. The two hundred students of BS Architecture had taken up their heat and temperature lesson after their pre test within the 1st semester of school year 2016-2017. The pre-test was administered by the researcher on August of 1st semester of the SY 20016-20017 to Filipino BS Architecture students of Bulacan State University, City of Malolos, Bulacan and on September of 1st semester of the SY 20016-2017.

BSU is located at the town proper of City of Malolos, Bulacan. Students undergo an entrance/qualifying examination during their 4th year high school. The said city is basically commercial.

Instrumentation

The instrument used in this study was adopted from the 25-item version of the survey on heat, temperature and heat flow called Heat and Temperature Concept Evaluation (HTCE) developed by Ron Thornton and David Sokoloff from Oregon University, Oregon, USA. The HTCE was designed to assess an extensive range of beliefs or understandings about thermodynamics concepts of 15 to 18 years old students. The situation in each item were in common context that allow students to apply either "every day" or "classroom" physics.

The HTCE was modified into 20-item free response and multiple choices HTCE to draw out the conceptual understanding of Filipino students in general. The researcher modified the original HTCE version into a free response multiple choice type questions to be able to determine the consistency of the students' answer and identify the basis of their choice. It is believed that the "guessing" factor can be avoided and would give a better inventory of what is on the mind of the students. Five items were also eliminated from the original HTCE because they are items under thermodynamics which are not in the syllabus. It was also believed that reducing the number of items would give the respondents ample time to think of their answers and to draw as many conceptions as possible.

Table 1

Label	Topic	Question numbers
A	Heat transfer	1,2,3,4,5,6,7,8,13,14,15,16,18,19,20
B	Thermal properties	9,10,11,12
C	temperature	17

Table 1 presents the table of specifications used in the instrument. It is adopted from the study of Hestenes, et al. (1992). The test items were 14 categorized according to topic in Thermodynamics along with the corresponding item number in which they appear. When the researchers grouped the selected 20 items, only item # 17 was under the category of temperature.

Data Gathering Procedure

The respondents took the pre test for 1 hour, before discussing the topic about heat and temperature and post test 1 week after discussing the topic about heat and temperature. The test was administered by the researcher in August 2016 and September 2016 of the 1st semester of the SY 2016-2017 at Bulacan State University main campus. It is a pre test –post test instruction. There were no experiments conducted from the topics that the instruments have covered. The answers of the students were tallied to obtain the frequency of the common responses in the HTCE. There was no interview conducted in this research.

Data Analysis

Comparing the students' answer with the answer key scored each item. The total correct answers of each student were determined. A frequency chart of scores was plotted to analyze the respondents' distribution scores. A chart for correct response was also plotted to know the percentage of correct responses. The mean, standard deviation and skewness of the scores were also computed.

Since there was a need for an entry threshold scores in this research, The State Universities, and State follow the minimum requirement to pass an exam/subject prescribed by the Commission on Higher Education (CHED) which is 50%, was used. Fifty percent is quite fair because all items in the modified HTCE require Kinetic view point to answer them correctly.

Table 2: Level of Students' Understanding of Heat and Temperature

TCE Scores Percentage (%)	Level of students' Understanding	Category
75 and above	high	Kinetic viewpoint
50-74	average	Kinetic viewpoint
Less than 50	low	Caloric viewpoint

Table 2 shows the level of students' understanding of the tally with modified HTCE scores percentage and category used in this study. The category used in this study was adopted from the work of Erickson (1980).

The explanation below was the basis for using the categories in this study. Kinetic and caloric theories of heat are the two different theories explaining phenomena involving heat and temperature. The Caloric theory is the obsolete theory which explains that heat is a substance (caloric) that can be transferred from one body to another while kinetic theory is the accepted theory of heat in modern times. Kinetic theory of heat is a theory explaining physical properties regarding the motion of particles. The molecules of atoms of a gas are in continuous random motion and the pressure exerted on the walls of a containing vessel arises from the bombardment by these fast moving particles. These have average speeds, at normal pressures and temperatures, of around one kilometer per second. When the temperature is raised these speeds increase, so consequently does the pressure. If more particles are introduced, or the volume is reduced, there are more particles to bombard unit area of the walls and the pressure also increases. When a particle collides with the wall it experiences a rate of change of momentum, which is equal to the force exerted. (Academic Dictionary of Physics).

The alternative conceptions of students were identified by comparing their respective responses to the table of alternative conceptions collated by Yeo and Zadnick (2001) in their study as shown in Table 3. These alternative conceptions were tallied and the frequency of each was computed. The result was plotted in a histogram, and the most common four misconceptions of the students were determined.

Table 3: Yeo and Zadnik present the following Alternative Conceptions in their study.

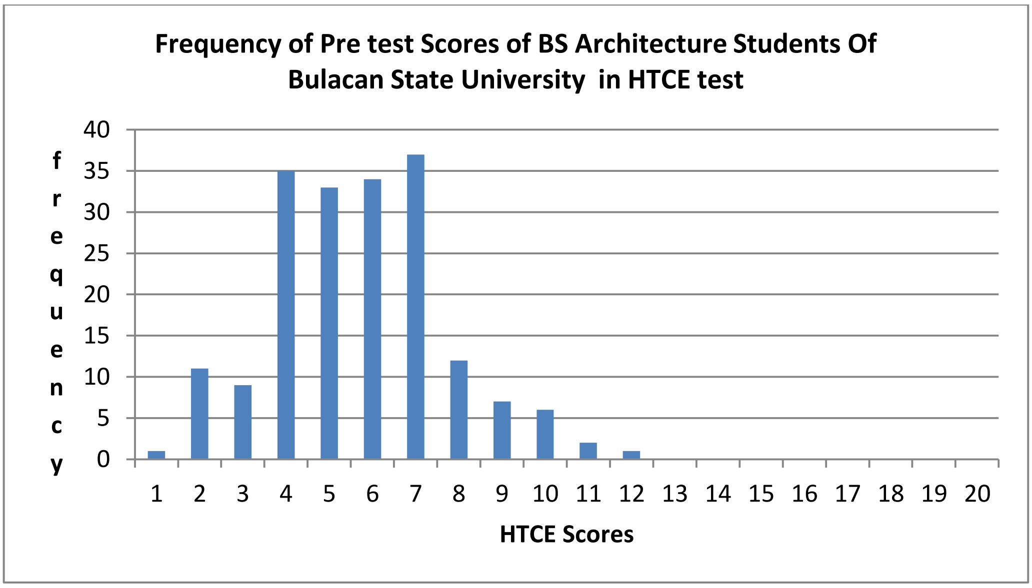
Alternative Conceptions	
Students' conceptions of heat	i. Heat is a substance. ii. Heat is not energy. iii. Heat and cold are different, rather than opposite ends of a continuum iv. Heat and temperature are the same thing. v. Heat is proportional to temperature. vi. Heat is not a measurable, quantifiable concept.
Students' conceptions of temperature	i. Temperature is the intensity of heat. ii. Skin or touch can determine temperature. iii. Perceptions of cold and hot are unrelated to energy transfer. iv. When temperature at boiling remains constant, something is "wrong." v. Boiling point is the maximum temperature a substance can reach. vi. A cold body contains no heat. vii. The temperature of an object depends on its size. viii. There is no limit on the lowest temperature

Students' conceptions about heat transfer and temperature change	i. Heating always results in an increase in temperature. ii. Heat only travels upward. iii. Heat rises. iv. Heat and cold flow like liquids v. Temperature can be transferred. vi. Objects of different temperatures that are in contact with each other or in contact with air at different temperature do not necessarily move toward the same temperature. (Thermal Equilibrium is not a concept) vii. Hot objects naturally cool down; cold objects naturally warm up. viii. Heat flows more slowly through conductors making them feel hot. ix. The kinetic theory does not really explain heat transfer. (Explanations are cited but not believed.)
Students' conceptions about "Thermal Properties" of materials	i. Temperature is a property of a particular material object. ii. Metal has the ability to attract, hold, intensify or absorb heat and cold. iii. Objects that readily become warm do not readily become cold. iv. Different materials hold the same amount of heat. v. The boiling point of water is 100℃ only. vi. Ice is at 0℃ and/or cannot change temperature. vii. Water cannot be at 0℃. viii. Steam is more than 100℃. ix. Materials like wool have the ability to warm things up. x. Some materials are difficult to heat: They are more resistant to heating. xi. Bubbles mean boiling. xii. The bubbles in boiling water contain air, oxygen or nothing.

RESULTS AND DISCUSSION

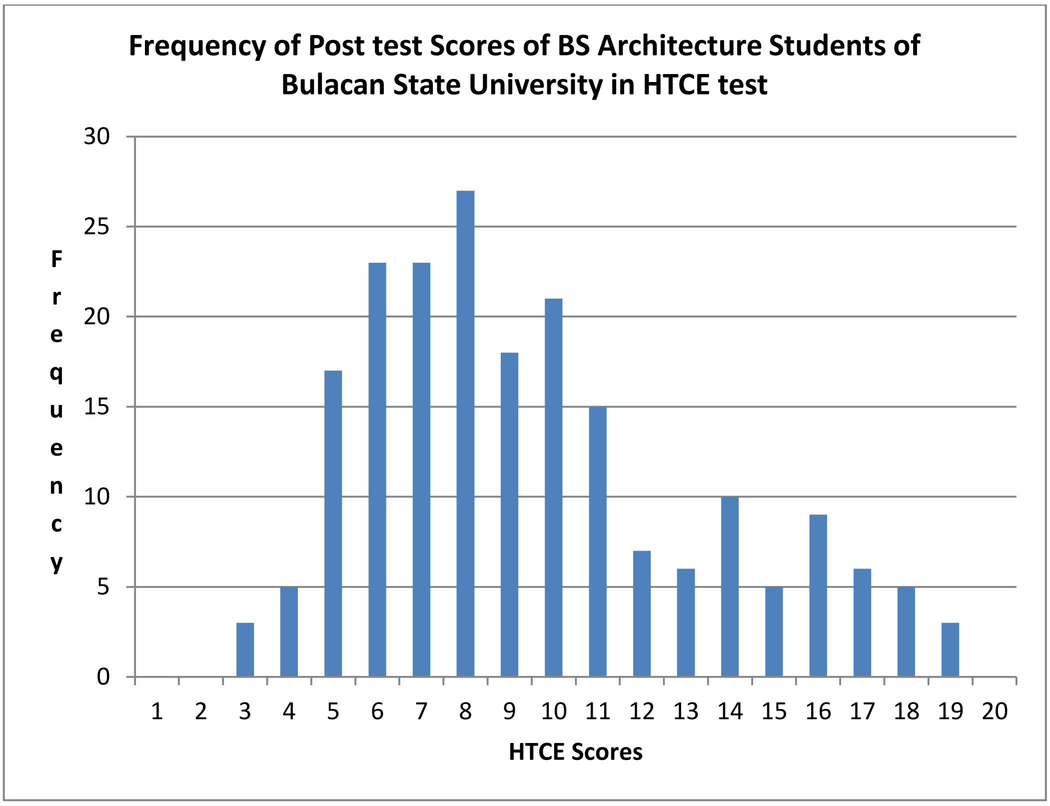
A. Students' Understanding of Heat and Temperature

Figure 2: Frequency histogram of the pre-test free response multiple choice modified HTCE scores of BS Architecture students of BSU, N=203, and the perfect score is 20.



The figure above shows the frequency histogram of the pre-test based on the free response multiple choice modified HTCE raw scores of BS Architecture students of BSU. The score distribution has a standard deviation of 13.58. This can be seen from the range of their score which is 1 to 12 with a skewness of 1.34. The mean of 9.4 implies that the students' scores are below the threshold to kinetic viewpoint. As shown in the figure, the highest score is 12 or 60 %, and the lowest score is 1 or 5%. Nobody got at least 15 or 75% of the answer correctly. Nine students or 4.44% of the respondents are under the average level of caloric viewpoint and 194 students or 95.56% are under the low level of caloric viewpoint. This means that the students are in the caloric category of understanding of heat and temperature before discussing the heat and temperature lesson.

Figure 3: Frequency histogram of the post-test free response multiple choice modified HTCE scores of BS Architecture students of BSU, N=203 and the perfect score is 20.



The figure above shows the frequency histogram of the post test based on the free response multiple choice modified HTCE raw scores of BS Architecture students of BSU.

The score distribution has a standard deviation of 8.59 and a skewness of 0.626 which is positive skew, as can be gleaned from the graph, less students got a score from 15 to 20. As shown in the figure, the highest score is 19 or 95 % and the lowest score is 3 or 1.5%. Twenty eight or 13.8 % got a score of 15 above or 75% of the answer correctly. Fifty nine students or 29% of the respondents are under the level of kinetic viewpoint and one hundred sixteen or 57 % of the respondents are under the low level of caloric viewpoint. The mean of 10.15 implies that the students' scores are within the threshold to kinetic viewpoint. This means that majority of the students are promoted to kinetic category of understanding of heat and temperature after discussing the topic heat and temperature. It can be inferred from the modified HTCE scores that majority of the students understand the concepts of the topics Heat and Temperature but they also possessed existing beliefs that are incompatible with the established scientific theory.

B. Alternative Conceptions

The top four misconceptions of the students were: (1) *water having lower temperature cools faster,(2) the transfer of heat is affected by the object's mass only,* (3) *temperature is a property of a particular material/object, (4) object of different temperature that are in contact with each other at different temperature do not necessarily move towards the same temperature (thermal equilibrium is not a concept).* Twenty-seven (27) students or 13 % expressed their explanation in Filipino language while one hundred seventy six (176) students or 87% expressed their explanations in the English language.

The first misconception is **water having lower temperature cools faster.**

Student # 8 wrote in item # 3 of the test question: "Mas madami yung heat na inapply sa cup A" (more heat was applied to cup A).

Another student (student #101) wrote: "It will take a longer time to cool the water in cup A, since the initial temperature is higher".

Student #32 wrote in item #7: "Dahil mas mataas ang temperature ng A sa B"

Student #168 wrote: "Because cup A contains 100g has higher temperature than cup B which has more water but lower temperature."

Student# 133 wrote: "It is because water has its own element that affects the temperature."

Student #2 wrote: "because its temperature is closer to that of the room. That's why it will cool down faster, until it reaches equilibrium with the external temperature."

The responses made by the students exhibited their beliefs that if the temperature of the water is low, it will cool faster. The students failed in considering mass and temperature difference as a factor affecting heat transfer.

The second misconception **is the transfer of heat is affected by the object's mass only.** The student wrote in test question #7 that: "*they may fight for each other. Cup A will increase temperature while cup B decreases. "*

While student #67, 31 and 9 wrote: "The temperature outside is not the same as inside".

The students hold a Kinetic Point of view about heat transfer but still they possessed misconceptions. It was very evident in their responses that the students are not familiar with the concept of heat transfer.

The third misconception is **temperature is a property of a particular material/object.**

The students were asked in item # 10, which is about thermal properties

"Which of the object above would have the lowest temperature?" and question # 12 which would have the highest temperature?

Students fall under the misconception; temperature depends on the composition of the material. Student # 23 wrote: "*In heating, "(metal), it absorbs and still maintain its physical looking, the other two object may burn."*

Eighteen students wrote: "It has more compact molecules to transfer the heat/temperature."

One student wrote: "The cotton is a light material"

Student #1 wrote: "because it absorbs temperature easily'"

Student #120 and 172 wrote: "metal, it has a strong conducting property due to its compact molecules, heat will be transferred faster."

Student #8 wrote: "the cotton has loosed property, which makes a slow heat movement trough the object."

The students' answers were consistent to their conception that temperature depends on the composition of the material. They also believed that the object that becomes cold first will have the lowest temperature. This can be attributed to their sense of touch. It can be inferred from the responses that the respondents do not have a clear understanding about temperature.

The fourth misconception is, **object of different temperature that are in contact with each other at different temperature do not necessarily move towards the same temperature (thermal equilibrium is not a concept).**

Student #103 wrote in question #7:"because when you add these 2 cups, maybe the temperature will decrease."

Student # 96 wrote in question# 6 "Student #19 wrote" because temperature is directly proportional to time. And difference in rate means difference in time. Since it is said that temperature=time, more time means more heat. If it does happen, the temperature will not be maintained."

The responses presented above show that the students still hold different alternative conceptions even if they have a kinetic viewpoint.

CONCLUSION

The researcher explored the conceptual understanding of senior students on heat and temperature using 20free response multiple choice modified HTCE test results and written responses.

Based on the data gathered, the researcher concluded that:

The level of understanding of heat transfer and temperature categories of BS Architecture students of Bulacan State University was categorized as **Kinetic Viewpoint.**

The respondents of BS Architecture students of Bulacan State University possesses these common alternative conceptions: (1) *water having lower temperature cools faster,(2) the transfer of heat is affected by the object's mass only,* (3) *temperature is a property of a particular material/object (4) object of different temperature that are in contact with each other at different temperature do not necessarily move towards the same temperature (thermal equilibrium is not a concept).*

RECOMMENDATION

The researcher recommends the following:

i. The 20-item HTCE test be translated to students' vernacular when used in a similar study for the students to answer each item easily, and to draw conceptions of students.
ii. An interview should be conducted to verify and provide in-depth analysis on the consistency of responses.
iii. A parallel study may be given to other senior students from other schools since the researcher conducted the study only to a sample of senior students of BSU and PAC.
iv. Parallel studies must be done in other regions all over the Philippines to produce a taxonomy of alternative conceptions based on the accumulated responses on the open-ended HTCE test and eventually come up with a Filipino version of the HTCE multiple-choice options.

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