International Journal of Science and Technology (STECH), Ethiopia
AFRREV Vol. 8 (2), Serial No 18, October, 2019: 45-63
ISSN 1994-9057 (Print) ISSN 2070-0083 (Online)
DOI: http://dx.doi.org/10.4314/stech.v8i2.4

GHANAIAN SENIOR HIGH SCHOOL SCIENCE STUDENTS' CONCEPTIONS ABOUT CHANGE OF STATE OF MATTER

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ABSTRACT

The article was based on the assertion that students' conceptions greatly influence the extent to which they grasp concepts. Based on this claim, this study sought to examine students' concepts and the reasons associated with learners' alternative conceptions relative to change of state of matter. This study employed the survey design hinged on retrospective and prospective paradigms. A sample of 240 final year (Form 3) science students were randomly selected from five senior high schools located within the Cape

Coast Metropolitan area, Ghana to participate in this research. The findings revealed that about three-quarters of the students held varied alternative conceptions on change of state of matter. Additionally, the results indicated that a number of reasons underpin why learners hold alternative conceptions of change of state of matter. For instance, students hold the alternative conception that temperature changes during phase transition and are also unable to interpret the numerical representation of the change of state of matter. It was, therefore, recommended that teachers should develop activities aimed at leading students to the development of scientifically correct conceptions thereby helping them correct their alternative conceptions.

Key Words: Alternative conceptions; change of state of matter; correct conception; latent heat; senior high school students

INTRODUCTION

Proficient concept development is one of the prime focus of education in the 21st century. Based on this premise, researchers in science education are exploiting ways of helping students come to terms with scientific concepts and exploring factors that hinder concept development. Change of state is a sub concept under heat energy and indicates the role heat plays when a substance changes its physical state from one form to another (Cutnell & Johnson, 2007; Walker, 2008). In this regard, at the boiling or melting points, a substance releases or absorbs heat energy without any change in temperature. It is only the physical state of the substance that changes as a result of the heat transferred or lost. For instance, heat energy taken in by ice cube at 0 ^{o}C changes the solid state of ice to water (the liquid state of ice) at the same 0 ^{o}C. In a similar vein, energy in the form of heat is absorbed by water in the liquid state at 100 ^{o}C to change its physical state (liquid) to steam (gas) at 100 ^{o}C. The heat energy described earlier at melting and boiling points was named *latent heat* by Joseph Black (West, 2014). In Ghana, one of the general objectives for Heat energy in the senior high school [SHS] teaching syllabus for elective physics, specified that ‘‘the student will be able to ‘‘understand the concept of heat, its relationship with temperature and its effect on substances’’ (Ministry of Education, 2010, p. 22). This means efforts must be made by teachers to help students understand the concepts by using effective teaching methods.

Several researchers, Alwan, (2010), Tanahoung, Chitaree & Swoankwan (2010), opined that learners struggle to comprehend concepts in the change of state of matter and also alluded to the fact that having an accurate conceptual knowledge of change of state requires that learners' understanding conform to current scientific explanations. Current scientific explanations in relation to change of state of matter indicates that there is no temperature change for a substance at melting and boiling points, even though heat energy is transferred or lost; there is a change of state of a substance at its boiling and melting points as a result of the heat energy transferred or lost; the average kinetic energy of the molecules within an entity remains constant at its boiling and melting points even though heat energy is transferred or lost; heat energy transferred or lost by a substance at boiling and melting points depend on mass; the heat energy transferred at melting point or released at freezing point is termed as the latent heat of fusion; and the heat energy transferred at boiling point or released at steam point is referred to as the latent heat of vaporisation (Walker, 2008).

Additionally, some researchers who have investigated students' conceptions of change of state of matter explored it among a range of concepts. Interestingly, most of these studies, with the exception of that conducted by Kamcharean and Wattanakasiwich (2016) focused on reporting and discussing findings without in-depth exploration into students' reasoning behind the conceptions. Some examples of these studies include: physics students' alternative conceptions of heat and temperature (Alwan, 2010); conceptions on the heat energy terms such as heat, heat capacity, latent heat, temperature and thermal equilibrium among students (Tanahoung et al., 2010); matter and its changes when represented on macroscopic and microscopic levels (Rahayu & Kita, 2010); concepts relative to particulate nature of matter among students (Ozmen, 2011); comprehension of thermal physics in everyday situation among learners (Georgiou & Sharma, 2012); comprehension of thermal concepts in relation to daily experiences among learners (Chu, Treagust, Yeo, & Zadnik, 2012); and the examination of research on particulate nature of matter and associated conceptions (Ozmen, 2013).

Tanahoung et al. (2010) and Rahayu and Kita (2010) on alternative conception research argued that some learners employed technical terms in an inappropriate context. For instance, according to Tanahoung et al. (2010), some students explained thermal equilibrium and specific heat capacity as the energy that causes a substance to change its physical state. Other researches have also shown that temperature is defined by many learners as a measure of the quantity of heat a body contains (Alwan, 2010; Tanahoung et al., 2010). According to Emeis (2004), early scientists believed that ''the measurement of temperature determines the quantitative measurement of heat flow requires'' (p. 1). However, the assertion by Emeis is inconsistent with current scientific explanations. To corroborate the latter, Georgiou and Sharma (2012) confirmed ''both heat and cold are substances and they can be transferred, the temperature can be determined by touch and temperature can be transferred" (p. 1133) as alternative conceptions held by some students. Furthermore, Alwan (2010) and Chu et al. (2012) found that learners thought that only one state exists during a phase transition of a substance.

Some specific examples are, *"liquid does not exist at boiling point . . ."* (Treagust, Chandrasegaran, Crowley, Yung, Cheong & Othman (2010)., 2010, p. 159), *"Ice is always at 0 °C . . . and . . . water cannot be at 0 °C"* (Chu, Treagust, Yeo & Zadnik, 2012, p. 1522). Other significant findings in the works of Alwan (2010) and Chu et al. (2012) indicated that temperature changes when a substance changes its physical state at melting or boiling points. For instance, Chu et al. (2012) reported that *''there is a direct variation between heating and temperature, which suggests that heating at all times causes an increase in temperature'' and ''temperature continually changes at boiling''* (p. 1521). It is against this backdrop that a study into learners' alternative conceptions in states of matter cannot be overemphasised.

PROBLEM OF RESEARCH

The West African Examination Council (WAEC) on responses students provided on examination questions related to states of matter are varied. For instance, while some comments made by the Chief Examiners of WAEC for the past decade suggest a weak performance in the change of state, other comments suggest a commendable performance. In relation to the former, two published reports by the Chief Examiners indicated that computational task on latent heat of vaporisation was poorly answered (WAEC, 2008) and students were unable to sketch the temperature-time graph to summarise the phase transition of a temperature of -10 ^{o}C for ice to a temperature of 100 ^{o}C for steam (WAEC, 2009). Similarly, it was reported that: ''. . . the heating curve diagram was poorly sketched by most candidates who answered this question. They also failed to state correctly what happens at each segment. Candidates were to indicate that the first and third segments involved sensible heat in which there is a change in temperature and the second and fourth segments involved latent heat in which there is a change in state'' (WAEC, 2009, p. 193).

On the other hand, about a period of five years after the earlier reports, the Chief Examiners indicated that candidates performed well on computational questions involving a change of state of matter (WAEC, 2013). For example, ''majority of candidates performed well on this sub-question as they correctly calculated problems related to the specific latent heat of fusion as well as the specific heat capacity of the liquid" (WAEC, 2013, p. 301). However, successful computations, according to Alwan (2010), do not imply accurate conceptions. To date, there appears to be limited research that explicitly and systematically examines these issues in most Sub-Saharan countries like Ghana. Hence, there is a need for a study that explores the reasons SHS science students in Ghana associate with their alternative conceptions of change of state. Consequently, the purpose of this study is in twofold. Firstly, this study sought to identify whether SHS 3 science students' hold 'correct' or 'alternative conceptions' on change of state. Secondly, the study explored the reasons that underscored SHS science students' alternative conceptions about the change of state of matter.

METHODOLOGY

The study employed the survey design hinged on retrospective and prospective paradigms. The retrospective and prospective paradigms in this study sought to provide data on the students' ideas held in the past and ideas that will be stated in the future respectively. It provided information on the kind of conceptions SHS 3 science students held when they were taught change of state of matter and the kind of explanations they will provide when examined. Quantitative and qualitative data gathering techniques were employed in this study. The quantitative technique used a Change of State Concept Achievement Test (CSCAT), whereas the qualitative data were obtained from the reasons given by students for their choice of an option.

A sample of 240 SHS 3 students in five schools was chosen randomly to take part in this research from a total of 650 students offering the General Science programme (i.e., they offer physics, chemistry, biology and mathematics as electives) in 10 senior high schools in Cape Coast Metropolis. These students were most appropriate for the study because they have been taught all aspects of thermal physics of which change of state of matter is a subtopic.

One two-tier instrument called the CSCAT was used to collect data. Five multiple-choice items were developed to explore students' conceptions of change of state of matter. These questions were mostly related to the phase change of ice and water at melting and boiling points respectively. Each item was in two parts. The first part provided students with alternatives to choose from. But to gain insight into students' thought process and avoid guesses, the second part required explanations for their choice of options to each item. The instrument was validated by reviewing extensive literature and showing it to three physics experts in the Department of Science Education and two experienced SHS physics teachers who have taught physics for more than 15 years to check the content and construct validity. For reliability purposes, the test used for the main study was pre-tested to 35 students in the Komenda-Edina Eguafo Abirim district who have similar characteristics. The reliability coefficient calculated using Cronbach alpha method was .75.

The data obtained from the main study were collected by administering the test to the students and the data were analysed based on five conceptual areas. These conceptual areas include:

1. The phase change of an ice cube at its melting point when held in a palm of temperature 37 ^{o}C.
2. Representation of latent heat of fusion in terms of some proposed behaviours of molecules.
3. Representation of boiling in terms of some proposed behaviours of molecules.
4. Using diagrams to represent the latent heat of vaporisation.
5. Comparing the numerical values of latent heat of fusion and latent heat of vaporisation of a substance.

Frequencies and percentages were used to answer the research questions for each conceptual area. These descriptive statistics were used because for each conceptual area the number of students answering an item correct was determined and the reasons behind their alternative conceptions were explored.

RESULTS

1. Categories of Conception that describe Students' Understanding of Change of State

The objective of this research was to group students into those possessing *correct* and *alternative* conceptions. Table 1 displays the results on conceptions held by students on change of state of matter. As shown in Table 1, 32.9 % and 67.1 % of the students held the correct conception and different alternative conceptions respectively to the phase change of ice cube at melting point. Further, there were 1.7 % of the students who did not choose any of the alternatives. However, 19.2 % and 79.1 % of these students exhibited the correct conception and different alternative conceptions respectively to the latent heat of fusion. Additionally, 75.4 % chose diagrams that depicted different alternative conceptions of latent heat of vaporisation. However, only 22.7 % demonstrated the correct conception.

Table 1: Conceptions held by students on change of state of matter

Conceptual area	Students' responses /N (%)			
	Correct conception	Alternative conception	No answer	Total
1. Phase change of an ice cube at its melting point when held in a palm of temperature 37 ^oC.	79 (32.9 %)	161 (67.1 %)	0 (0.0 %)	240 (100 %)
2. Representation of latent heat of fusion in terms of some proposed behaviours of molecules.	46 (19.2 %)	190 (79.1 %)	4 (1.7 %)	240 (100 %)
3. Representation of boiling in terms of some proposed behaviours of molecules.	73 (30.4 %)	166 (69.2 %)	1 (0.4 %)	240 (100 %)
4. Representation of latent heat of vaporisation in diagrams.	59 (24.6 %)	181 (75.4 %)	0 (0.0 %)	240 (100 %)
5. Comparing the numerical values of specific latent heats	77 (32.1 %)	162 (67.5 %)	1 (0.4 %)	240 (100 %)

To end, a total of 32.1 % and 67.5 % of the students held the correct conception and different alternative conceptions respectively to specific latent heat. This implies that the conceptions held by most students with respect to change of state of matter are wrong or inappropriate.

2. **Reasons for Students' Alternative Conceptions relative to Change of State of Matter**

The second purpose of the study sought to explore the reasons students associate with the alternative conceptions they hold about the change of state. Hence, the reasons for alternative conceptions were reported in each conceptual area.

(i) The phase change of an ice cube at its melting point when held in the palm of temperature 37 *°C*

This conceptual area was meant to sensitise teachers on students' reasons for their alternative conceptions about the phase transition of an ice cube at its melting point. In fact, 161 respondents, according to Table 2, selected different alternative conceptions for this conceptual area.

Table 2: Statistics of Alternative Conception on phase change

Alternative Conception	N	%
1. Heat is absorbed by the melting ice cube and results in a change in its temperature.	123	76.4 %
2. Heat is lost by the melting ice cube and results in a change in its temperature.	24	14.9 %
3. Heat is lost by the melting ice cube without a change in its temperature.	14	8.7 %
Total	161	100.0 %

This study established that 76.4 % of the students believed that heat is absorbed by the melting ice cube and results in a change in its temperature. The students associated many reasons for the choices. For example, one of them reported that *"because the ice was 0 °C, it absorbed heat and in order for it to melt its temperature has to change from freezing point to a high temperature that can cause it to melt"*. Another student stated that:

- *this is because the temperature in the gentleman's palm is more than that of the melting point of the ice cube hence the palm transfers temperature to the ice cube. The ice cube melts and rises in temperature.*

Two other students said that:

- *the temperature of the palm is greater than that of the ice cube that heat from the palm is absorbed by the ice so as to melt and this melting brings about changes in temperature and*

- *the temperature of the palm is greater than that of the ice cube that heat from the palm is absorbed by the ice so as to melt and this melting brings about changes in temperature*, respectively.

Table 2 also shows that 14.9 % of the students agreed that heat is lost by the melting ice cube and results in a change in its temperature. Examples of reasons to this alternative conception are *"heat escapes from the surface of the ice cube in the form of vapour and changes the state of the ice cube to water which causes a temperature change" and "heat which is a form of steam moves away from the ice cube to increase its temperature in order to change to water".*

The less popular alternative conception by 8.7 % of the students was that heat is lost by the melting ice cube without a change in temperature. Some students justified this alternative conception by reporting that *"latent heat of fusion comes from the ice cube like steam and changes ice at melting point to water at a constant temperature" and "a steam like substance in the form of heat escapes from the surface of the ice cube to change it to water at its melting point".*

(ii) Representation of latent heat of fusion in terms of some proposed behaviours of molecules

This conceptual area was intended to reveal students' reasons to the alternative conceptions they have about latent heat of fusion. As such, this conceptual area focused on molecular behaviour during a phase transition at the melting point. Significantly, 190 students exhibited different alternative conceptions to this conceptual area. Table 3 displays the data to the students' alternative conceptions.

Table 3 indicates that 45.3 % of the students believed that latent heat of fusion is the energy used in replacing molecules of an ice cube with molecules of water during the melting process. The students assigned reasons to their alternative conceptions as *"latent heat of fusion is the energy required to change a liquid into a solid"; "energy required to change ice to water"; "latent heat of fusion refers to the energy required to change a solid at melting point into a liquid or liquid at freezing point into a solid without a temperature change"; and "latent heat of fusion aid in the melting of the ice therefore as the ice melts, its molecules are continuously changed into water molecules".*

Furthermore, 34.7 % of the students held the alternative conception that latent heat of fusion is the energy that causes an increase in the average kinetic energy of ice cube molecules during the melting process and presented in Table 3. The reasons to this alternative conception were that "m*olecules of ice cubes are tightly packed so the molecules don't move (i. e., zero kinetic energy) so there is the need for some amount of energy to make the ice melt which shows that molecules were increasing in kinetic energy" and "by increasing their kinetic energy the molecules turn to vibrate and move faster thereby causing the intermolecular forces of the solid to be overcome".*

Table 3: Statistics of Alternative Conception on the representation of latent heat of fusion

Alternative Conception	N	%
1. Energy used to replace molecules of an ice cube with molecules of water during the melting process.	86	45.3 %
2. Energy used in increasing the average kinetic energy of ice cube molecules during the melting process.	66	34.7%
3. Energy used to change the size of ice cube molecules during the melting process.	38	20.0 %
Total	190	100.0 %

The least represented alternative conception, by 20.0 % of the students was that energy is used to change the size of ice cube molecules during the melting process. Most of the students claimed that their reasons for their choice were "t*his is because latent heat of fusion is the amount of energy needed to change the state of a solid to liquid"; "latent heat of fusion is the quantity of heat required to change the state of solid at its melting point into a liquid without a change in temperature"; and "since the latent heat of fusion deal with mass (size), the size of ice cube molecule reduces and melts".*

(iii) Representation of boiling in terms of some proposed behaviours of molecules

This conceptual area was meant to reveal the students' reasons for the alternative conception they have about molecular behaviour during boiling. This study established that 166 students selected different alternative conceptions to this conceptual area. The statistics to these alternative conceptions are shown in Table 4. In this study as shown in Table 4, 75.3 % of the students believed that during boiling average kinetic energy of water molecules increases. They defended this alternative conception by stating that:

- "d*uring boiling, when the water is heated the molecules of the water move with an increasing velocity and hence the average kinetic energy increases";*
- *"this is because the higher the temperature of a substance, the higher the kinetic energy of its molecules";*
- *"when water is being heated, the molecules of the water absorbs energy as heat energy and is transferred to kinetic energy which makes lighter molecules move up"; and*

- *"at the boiling point average kinetic energy of molecules increase because of the dissociation of hydrogen bond holding the water molecules together, therefore, kinetic energy increases as a result of molecules gaining energy and breaking the bonds between molecules".*

Table 4: Statistics of Alternative Conception on the representation of boiling behaviour of molecules

Alternative Conception	N	%
1. The average kinetic energy of water molecules increases during boiling.	125	75.3 %
2. Molecules of water are replaced with molecules of water vapour.	22	13.3 %
3. Molecules of water increase in size during boiling.	19	11.4 %
Total	166	100.0 %

The results in Table 4 show that 13.3 % of the students thought that molecules of water are replaced with molecules of water vapour during boiling. Some reasons for this alternative conception are:

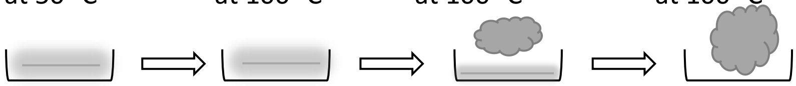
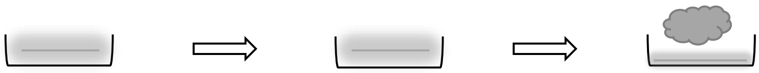
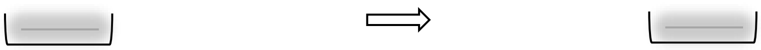
- *because it is changing into vapour, hence the molecules of water will also have to change to vapour molecule;*
- *during boiling water changes from liquid state to water vapour; and*
- *this is because during boiling the molecules of water move out and that of water vapour enters.*

The findings from Table 4 indicate that 11.4 % of the students selected the alternative conception which states that molecules of water increase in size during boiling. A reason for this alternative conception is that *"the molecules of water increases in size during boiling because water expands on heating and also water is able to expand due to the expansion in the molecules".*

(iv) Representation of latent heat of vaporisation in diagrams

This conceptual area was influenced by the different representational formats that are employed when teaching change of state of matter. According to Kohl and Finkelstein (2005), "representational formats refer to the . . . many ways in which a particular concept or problem can be expressed'' (p. 1). Some examples of representational formats are: mathematical equations, numerical, graphical and pictures (Meltzer, 2005). The results of this study on this conceptual area indicate that 181 students selected different alternative conceptions to the representation of latent heat of vaporisation in terms of a set of diagrams. The statistics to the alternative conceptions are stated in Table 5.

Table 5: Statistics of Alternative Conception on latent heat of vaporisation in diagrams

Alternative Conception	N	%
1. 3 kg water at 50 °C → 3 kg water at 100 °C → 3 kg water-steam at 100 °C → 3 kg steam at 100 °C 	72	39.8 %
2. 3 kg water at 50 °C → 3 kg water at 100 °C → 3 kg water-steam at 100 °C 	61	33.7 %
3. 3 kg water at 0 °C → 3 kg water at 100 °C 	48	26.5 %
Total	181	100.0 %

From Table 5, 39.8 % of the students opted for a set of diagrams which suggests that latent heat of vaporisation is the energy transferred to water at 50 °C in order to increase its temperature and change its state to steam at 100 °C. The reasons of the students to this alternative conception are:

- *this is because the amount of heat supplied will increase water from 50 °C to its boiling point and begin to change into steam before completely changing into steam;*
- *"latent heat of vaporisation* is the quantity of heat absorbed when liquid change *its physical state to vapour;*
- *water starts to boil at 100 °C and at this temperature steam will evolve out but the water will continue to be 100 °C until the water molecules will be converted to steam molecules; and*
- *it only follows the principle of anomalous expansion of water where water does not change state from 50 °C to 99 °C till it gets to 100 °C and starts to change to steam.*

Table 5 indicates that 33.7 % of the students chose a set of diagrams which suggests that latent heat of vaporisation changes temperature and that the state of water at 50 ^{o}C, when mixed with water at 100 ^{O}C, remains a mixture of water and steam at 100 ^{o}C. This suggests that these students think that latent heat of vaporisation takes into account temperatures below boiling point. The reasons stated by the students are:

- *when water is heated from 50 ^{o}C to 100 ^{o}C it reaches its steam point at the point vapour does not come out but when the heat is continually applied the temperature does not change and steam or vapour begins to come out;*
- *latent heat of vaporisation is the heat needed to change the state of a substance say liquid to vapour without a change in temperature; and*
- *when the constant amount of heat is applied to water at 50 ^{o}C it does not completely break the bond in the water thus the presence of steam.*

Lastly, Table 5 indicates that 26.5 % of the students chose a set of diagrams that suggests that latent heat of vaporisation is the energy that converts water at 0 ^{o}C to water at 100 ^{o}C. The reasons for these students are *"latent heat of vaporisation is the heat energy required to change water at 0 ^{o}C to water at 100 ^{o}C"; "because latent heat of vaporisation is the energy that changes state from liquid to vapour"; and "latent heat of vaporisation occurs between substances of the same temperature".*

(v) Comparing the numerical values of specific latent heats

This conceptual area was aimed at exploring respondents' alternative conceptions about specific latent heat of fusion and specific latent heat of vaporisation. Conceptually, specific latent heat of fusion of a substance is less than its specific latent heat of vaporisation. For instance, water has a specific latent heat of vaporisation of 2260000 J/kg whereas specific latent heat of fusion of water 336000 J/kg. According to Table 6, there were 162 students who held different alternative conceptions to this conceptual area.

Table 6 indicates that 55.6 % of the students believed that that latent heat of fusion of a substance is greater than the latent heat of vaporisation for the same mass of a substance. The reasons to this alternative conception are that *"the energy required to break the bonds of a solid is greater than that required for a liquid due to the stronger intermolecular forces of attraction in solids than liquids"; "this is because more heat is needed to change the state of a solid to liquid than that to change from liquid to gas"; and "this is because specific latent heat of fusion is greater than specific latent heat of vaporisation".*

Table 6: Statistics of Alternative Conception on comparing numerical values of specific latent heats

Alternative Conception	N	%

1.	For the same mass of a substance, latent heat of fusion of a substance is greater than the latent heat of vaporization	90	55.6 %
2.	For the same mass of a substance, any of the two terms (either latent heat of fusion or latent heat of vaporisation) may be greater at a point in time.	72	44.4 %
Total		162	100.0 %

Table 6 also shows that 44.4 % of the students believed that any of the two terms (either latent heat of fusion or latent heat of vaporisation) may be greater at a point in time. The reasons associated with this alternative conception are that:

- *latent heat of fusion and vaporisation differ from every substance. Sometimes latent heat of fusion can be greater than vaporisation or vice versa;*
- *substance in the solid state will have a greater latent heat of fusion than latent heat of vaporisation whereas a substance in the gaseous state will have a greater value of latent heat of vaporisation than latent heat of fusion;*
- *latent heat depends directly on the mass; and*
- *the boiling point of one substance might be the freezing point of another.*

DISCUSSION

The first purpose revealed that close to three-fourth of the students holds alternative conceptions about the change of state of matter. For instance, less than half of the students disagreed that the transfer of heat from the palm to the ice cube changes the state of the ice cube to water without a change in temperature. Hence, this finding is an example of Rahayu and Kita's (2010) assertion that many learners do not accurately understand phase transition from solid to liquid. Additionally, more than three-fourth of the students do not believe that work is done in separating the molecules of an ice cube during melting. The latter implies that these students hold alternative conceptions about the behaviour of molecules when examined in the context of latent heat of fusion. Hence, corroborates the findings of Ozmen (2011) that many learners do not understand how molecules behave when a substance freezes or melts. Further, about a quarter of the students believed that forces of attraction between molecules of water become weak when water is boiling at normal atmospheric pressure. The latter suggests that the majority of the students hold alternative conceptions about the behaviour of molecules when water is boiling at normal atmospheric pressure. Another proof indicates that three-fourth of the sample disagree with the set of diagrams that shows the phase change of water at 100 ^{o}C to steam at 100 ^{o}C. Hence, many students hold alternative conceptions about the representation of the latent heat of vaporisation in terms of diagrams. This strengthens Chu et al. (2012) finding that many learners think temperature does not remain constant during boiling. Further, the data suggest that far more than half of the sample do not believe that latent heat of vaporisation is greater than the latent heat of fusion for the same mass of a substance. Hence, these students hold alternative conceptions about specific latent heat. Thus, there is a good reason to conclude that many learners are unable to interpret the numerical representations of change of state. Therefore, this finding supports Alwan's (2010) assertion that a successful computation does not imply understanding.

The second results of this study found that the majority of learners who held alternative conceptions to melting ice cube thought that an increase in temperature of an ice cube causes melting. Other reasons revealed that temperature increase was described as a causative agent of melting. In contrast to the latter, some learners considered a change in temperature as a by-product of melting. Interestingly, some students believed that the temperature of the palm reduces as that of the melting ice cube increases until they arrive at a common temperature. This comment confirms the assertion of Tanahoung et al. (2010) that students misapply thermal equilibrium when discussing change of state. The misapplication of thermal equilibrium by these students might be due to the absence of this topic in the 2010 elective physics syllabus. Possibly, due to this absence, teachers are not aware of the specific objectives, content, teaching and learning activities required for better delivery.

Further, these learners conceived the water vapour that escapes from the surface of the ice as changing the temperature and state of the ice cube to water independently. However, others thought that as heat is leaving the surface of the ice cube in the form of steam, it increases the ice cube's temperature in order to change its state. The latter contradicts Alwan's (2010) assertion that some students conceive heat as a liquid and temperature as a measure of the magnitude of heat. Thus, Alwan's assertion is limited to some aspects of heat. This is because it is logical to say that if heat rises from a substance the amount of heat left reduces thus temperature reduces.

Recall that the unpopular alternative conception to the phase change of melting ice was 'heat is lost by the melting ice cube without a change in temperature'. The reasons suggest that the students are aware of the role heat plays during melting but differ when it comes to the direction of heat transfer. These students confused sublimation with heat.

As mentioned earlier, many students believed that latent heat of fusion is the energy used in replacing molecules of an ice cube with molecules of water during the melting process. Some reasons for this alternative conception suggest that learners acknowledge liquid as a particular state of matter and solid as a different state of matter. Interestingly, some reasons revealed words like solid molecules and liquid molecules. Therefore, students might have thought that molecules of an ice cube are entirely different from molecules of water. Additionally, one of the reasons, which was scientifically accurate, suggests that some learners hold independent views about the macroscopic explanation and microscopic explanation of latent heat of fusion. The latter indicates that when learners provide a good macroscopic definition of latent heat of fusion, it does not guarantee that they have a better understanding of how molecules behave during a phase change of an ice cube. Hence, *''. . . practical rules of thumb can be effectively employed even in the face of total ignorance of the theoretical principles that lie behind them''* (Linderberg, 2007, p. 4). In conclusion, a reason which consistently appeared indicates that molecules of ice cube melt to form water molecules. Possibly, students of this category might have thought that since physically ice cube changes to water then microscopically molecules of ice cube change into molecules of water. These points confirm the assertion of Ozmen (2011) that learners describe molecular behaviour of substances using physical changes. Additionally, the comments by the students confirm the assertion by Rahayu and Kita (2010) that some students use technical words inappropriately. Note that melt was used inappropriately.

As stated previously, few students held the alternative conception that latent heat of fusion is the energy used in increasing the average kinetic energy of ice cube molecules during the melting process. Examination of reasons, to this alternative conception, suggests that as some students think that the molecules of a solid do not move, others think the molecules have a lower rate of vibration. Scientific explanations to change of state agree with the fact that comparably the molecules of a solid have lower kinetic energy but not zero kinetic energy (at 0 ^{o}C) (Pople, 1989). In relation to the latter, these students might have thought that during a phase change molecule increase their rate of vibration. Excerpts of students' responses confirm that some learners believe that molecules move very fast to cause a phase change from ice to water. Two examples which did not appear as reasons are:

- *As the ice melts its temperature increases thus the molecules vibrate faster so there is an increase in kinetic energy which makes the water coming from the ice covers extra distance* and
- *Kinetic energy allows particles to move therefore the ice molecules gain K.E and begin to move, flow (melt). Latent heat of fusion changes the state of a substance in this case ice to water*.

Note that these comments contradict theory since there is no increase in temperature and average molecular movement when an ice cube is melting.

As stated earlier, the least popular alternative conception to the latent heat of fusion was that energy is used to change the size of ice cube molecules during the melting process. Most reasons were grounded in the fact that latent heat of fusion is the product of mass and specific latent heat of fusion ($Q = mL_f$). Possibly, these students were trying to apply this formula. Thus, the students might have thought that mass represents an individual atom or molecule. Hence, a reduction in the atom's mass results in melting. This is also similar to an alternative conception about naphthalene reported by Rahayu and Kita (2010).

Recollect that more than three-fourth of the students who held alternative conceptions to boiling believed that the average kinetic energy of water molecules increases. To justify this alternative conception, some students argued that there is a linear relationship between kinetic energy and velocity. In relation to the latter, these students thought that the average velocity of molecules increases during boiling. On the other hand, other learners related average kinetic energy to temperature. These students believed that temperature increases during boiling thus accounting for an increase in the average kinetic energy of molecules. The latter supports the finding of Chu et al. (2012), who opined that some students believe that the temperature of a liquid changes during boiling. Significantly, a reason linked average kinetic energy to weakening bonds. That is an increase in molecular vibration causes molecular bonds to break apart.

The findings reveal that less than a quarter of students who held alternative conceptions to boiling thought that molecules of water are replaced with molecules of water vapour. In relation to this alternative conception, the learners thought that molecules of water are different from molecules of water vapour. Thus, some learners thinking might have evolved from steam escaping from bubbles. The latter was evident in some students thus adds to the assertion of Ozmen (2011) that some students use daily experiences with the environment to elucidate the behaviour of the molecules of matter.

The data show that far less than a quarter of students who held alternative conceptions to boiling mentioned that molecules of water increase in size. The reasons from the test suggest that an increase in the volume of water during boiling is an indication that molecules expand during boiling. This supports Ozmen's (2011) finding that some learners believe that particles of a substance get larger when they are heated.

The outcomes of the research also demonstrate that majority of learners agreed to a set of diagrams which suggests that latent heat of vaporisation is the energy transferred to water at 50 ^{o}C in order to increase its temperature and change its state to steam at 100 ^{o}C. The reasons revealed that learners applied their daily experiences of raising the temperature of water to its boiling point to prepare food. This supports the assertion of Georgiou and Sharma (2012) that students' conceptions are influenced by their daily experience. On the contrary, some students chose a set of diagrams which suggests that latent heat of vaporisation changes temperature and the state of water at 50 ^{o}C, when mixed with water at 100 ^{O}C, remains a mixture of water and steam at 100 ^{o}C. An examination of the reasons to the latter also suggests a transfer of knowledge from the regular experience of heating water to its boiling point. It is also likely that these students confused evaporation at any temperature with boiling at normal atmospheric pressure.

Further findings indicate that few students chose a set of diagrams that suggests that latent heat of vaporisation is the energy that converts water at 0 °C to water at 100 °C. The reasons, by the students, reveal an explanation based on evaporation and a wrong application of thermal equilibrium. Previous data indicate that about half of the students who held alternative conceptions to specific latent heat believed that latent heat of fusion of a substance is greater than the latent heat of vaporisation for the same mass of a substance. The results revealed that students' reasons were mostly hinged on the greater force of attraction that exists between the molecules of a solid relative to liquid and gas. Additional follow-ups also suggest that learners' choice of this alternative conception was based on the energy involved in fusion in the context of nuclear physics. The latter could possibly influence learners' decision on the magnitude of energy involved in fusion in the context of a change of state of matter. To conclude, the likelihood that students depended on the numerical values of specific latent heat cannot be underestimated. Numerically, the specific latent heat of fusion of water is 336000 J/kg whereas that of specific latent heat of vaporisation is 2260000 J/kg (Pople, 1989). Hence, it is possible that these students think 3.36 is greater than 2.26 when specific latent heats are expressed in standard form as 3.36×10^5 J/kg and 2.26×10^6 J/kg. Since these figures were not found in the students' explanations and semi-structured interview, further studies which take these numerical values into account will need to be undertaken.

To conclude, the rest of the students who chose alternative conceptions to specific latent heat thought that any of the two terms (either latent heat of fusion or latent heat of vaporisation) may be greater at a point in time. A reason for this alternative conception reveals that some students think that latent heat of fusion is greater for one substance but smaller for another substance. The same explanation applies to the latent heat of vaporisation. A possible remedy to this confusion is that tutors should assist learners to compare the values of the specific latent heat of fusion and specific latent heat of vaporisation for different substances. In relation to the latter, this will enable learners to identify trends for their understanding. On the contrary, a reason suggests that some students think the state and mass of a substance determine the magnitudes of specific latent heat of fusion and specific latent heat of vaporisation. The latter seems to be consistent with current scientific explanation, however, a possible difficulty is the students' inability to relate latent heat of fusion to a phase change from solid at its melting point to liquid and latent heat of vaporisation to a phase change from the liquid at its boiling point to gas. Lastly, other reasons suggest a comparison of melting and boiling points for different substances.

CONCLUSIONS AND RECOMMENDATIONS

It can be concluded from the findings of this research, that many students hold alternative conceptions about the change of state of matter. They lack a clear understanding of the behaviour of molecules of substances during phase transition. The students hold the alternative conception that temperature changes during phase transition and are also unable to interpret the numerical representation of the change of state of matter. Several reasons underscore why students hold alternative conceptions of change of state of matter, which are clear manifestations of why students have difficulty in understanding that conception. Since these students' alternative conceptions are grounded and lead to difficulties in learning the change of state of matter, teachers must cite examples of inaccurate conceptions when teaching, in order to guide students. Additionally, teachers must develop activities aimed at leading students to the development of scientifically correct conceptions thereby helping students debunk their alternative conceptions.

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