



IDENTIFICATION AND SOURCES OF MISCONCEPTIONS HELD BY SECONDARY SCHOOL PHYSICS STUDENTS IN HEAT ENERGY IN RIVERS STATE, NIGERIA

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Abstract:

The study identified misconceptions held by secondary school students about the concepts of Heat energy and investigated the sources of the misconceptions in Rivers State, Nigeria. A mixed method research design, specifically the descriptive survey and the exploratory analysis, was adopted for the study. The study was guided by two research questions. Using the random sampling technique, a sample of 300 Secondary School 1 (SS 1) Physics students was selected for the study in Ikwerre Local Government Area, Rivers State. Data was collected using three research instruments titled "Heat Energy Performance Test" ($r = 0.80$), Sources of Misconceptions in Heat Energy Questionnaire" ($r = 0.74$) and "Misconception in Heat Energy Interview Template". This study revealed that secondary school students have misconceptions about Heat energy. This study further revealed that teachers' instructional presentation ranked 1st as the source of misconception in the concept of Heat energy, social interactions ranked 2nd, prior knowledge ranked 3rd while textbooks and reference materials ranked 4th. The study thus recommends that Physics teachers should always conduct a diagnostic test before instruction to correct any wrong preconceived notion held by the students about a particular concept before instruction. Also, well-designed and technology-assisted instruction should be adopted by Physics teachers to facilitate an accurate scientific understanding of heat energy.

Keywords: misconception, identification, sources, heat energy, physics

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1. Introduction

The modern world is a scientific world and science has become everyone's concern. Science is the most inexhaustible storehouse of knowledge. It provides an opening for new horizons of knowledge and continuously augments the ever-increasing new knowledge, new exploration, and new ideas. The continuously increasing pace of science has created a wide gap between the developed and the underdeveloped countries. This has, therefore, necessitated the underdeveloped countries to take more vigorous steps towards scientific and industrial development to bridge the gap. Developed nations adopted science education as the key instrument for the realization of the sustainable developments which they enjoy today because it assumes a crucial role in the building of human and infrastructural capacities and quickens the pursuit towards the realization of scientific and technological development through learning, skill acquisition and inventive qualities.

A student of science can study engineering and technology, medicine, agriculture or science-related/based courses. This can only be achieved when the teaching-learning process of science is positioned to prepare the learner for the future. There is widespread concern about the outcome of science teaching and learning in Nigeria. For Nigeria to compete successfully in a technology-intensive global community there is an urgent need to produce more high-grade scientists, technicians and engineers who possess the technical know-how. Issues of this nature had prompted the Federal Government of Nigeria to embark on sporadic reforms in the education sector. It is therefore stated explicitly in the National Policy of Education (FRN, 2014) that science shall cultivate inquiry, knowing and rational mind for the conduct of a good life and provision of knowledge and understanding of the complexity of the physical world. Science teaching-learning at the secondary school level in Nigeria is expected to be activity-oriented, creative and functional in the preparation of students in the area of science and technology. It also involves the development of learners' ability toward the application of scientific knowledge in everyday life. As more reliance is placed on scientific activities, the need to teach science concepts effectively becomes the task at hand for intellectual achievements in science.

Physics is one science subject that is associated with fields like engineering and technology, medicine, astronomy, geology, communication, and agriculture among others. It is increasingly becoming complex to cope with emerging areas of scientific knowledge without a background in Physics. The importance of teaching and learning Physics cannot be overemphasized as it contributes to technological development by nature of its concepts, principles and practice. Physics offers the students an opportunity to think critically, reason analytically and acquire the spirit of inquiry. The current Physics curriculum is structured on the thematic approach which emphasizes the understanding of basic concepts and principles.

In compliance with national and global issues that are dependent on the development of science-oriented students capable of solving practical problems inherent

in society, six themes were highlighted for the Physics curriculum to guide the programme. Heat Energy, one of the topics taught in the senior secondary school level 1 (SS 1), is embedded in the theme "Conservative Principle" which is one of the six themes under which concepts in the Nigerian secondary school Physics Curriculum are categorized. Heat is a form of energy which is also known as thermal energy that is transferred from a hot substance to a cold substance as a result of temperature difference. It is also referred to as energy on transit which occurs from a body of higher temperature to a body of lower temperature. Sub-concepts that permeate the understanding of Heat Energy are; the Concept of heat and temperature, thermal expansivity, anomalous expansion of water, change of state and Heat transfer. The underlying principles of Heat energy find a way into the understanding of several applications that are beneficial to man. For instance, the principle of operations of the refrigerator system, thermos flask, solar collectors, thermal insulators, halogen cooktop stove among others find its explanation using the concept of Heat energy.

Misconceptions are personal notions that are created to establish the meaning of an individual understanding of the physical world (Gooding & Metz, 2011). Misconceptions refer to knowledge gained by individuals from experiences and events which are educational or informal and do not have the acceptable scientific meaning of a concept (Allen, 2014). Soeharto, et al. (2019) views misconceptions as ideas about a scientific concept, which are not well structured, possessed by students from life experience or informal education. They are incorrect preconceived notions about a Physics concept based on their observations of physical phenomena or experiences in daily life (Neidorf, et al., 2020). Misconception could then be seen as an individuals' preconceived view, thought or knowledge about nature that could have been constructed or obtained from a formal or informal setting but are not consistent with the scientific definition of a concept. Misconceptions cannot be repaired unless they are recognized, thus the need for identification. Thus, misconceptions can only be detected through the students' responses to questions on the concept.

Students' misconceptions about Physics have received considerable attention in the past years. Alamina (2018) noted that two sources of misconceptions can be categorized as the "*deficiency factor*" and "*misrepresentation factor*". The deficiency factor describes learners' lack of baseline knowledge or cognitive structures relevant for the construction of new knowledge related to problem-solving capabilities while the misrepresentation factor deals with the inappropriate presentation of instructional materials leading to a lack of understanding of the content. Halim, et al. (2019) found that textbooks, teaching methods and knowledge content, students' factors such as preconceptions and wrong intuition, and teacher factors such as lack of content knowledge are part of the causes of misconceptions. In the same vein, Patil, et al. (2019) from a review of studies, collated sources of misconceptions such as textbooks and reference materials, teachers, students' personal experiences, students' peer groups, family members/parents, cultural beliefs and media. Similarly, Khalid and Embong (2020) found that superficial understanding of concepts by students and teaching

methods that lack creativity are sources of misconceptions. An account of the source of misconceptions in physics is given below:

a. Textbooks and reading materials

A science textbook is an important instructional tool needed for the process of teaching and learning as it shows the scope and content limitations of the curriculum. It is also a tool that guides the teacher during content development for teaching. Zajkov, Gegovska-Zajkova and Mitrevski (2016) noted that, for the teachers, the textbook acts as the instructional material guide for the selection of topics and ways to go about teaching while for students, the textbook provides the opportunity to consolidate his/her understanding independent of the teacher. The significance of the textbook is quite overwhelming as it is a treasure of knowledge that provides learners with interest in the subject. Development of textbooks and science in Nigeria is done by curriculum bodies, professional organizations and private academic experts under the auspices of a recognized publishing house. Slisko & Hadzibegovic (2011) however lamented that there are textbooks in which, often under the guise of simplification, there is a lack of adequate care in defining terms thus bringing in major inconsistencies. Deshmukh and Deshmukh (2017) similarly noted that though some textbooks were written by experts, they are embedded with errors that may be due to improper choice of words or misprint leading to misconceptions.

b. Prior knowledge/Cognitive features

Prior knowledge is that portion of learners' baseline knowledge existing in the learners' cognitive structure that is needed to anchor new information for effective understanding. Svinicki (2017) reiterated that when there is an absence of these existing portions of knowledge in the learners' cognitive structure, he or she is thrown back to fundamental characteristics of knowledge such as symbols, language, sound or even rote memorization. Little wonder science education theorists have advocated strongly the importance of prior knowledge for effective learning of science. Lee (2012) informed that it is important that teachers probe students' prior knowledge before the commencement of the new lesson in order to predict how learners will react during science lessons.

c. Teachers' instructional presentation

Teaching is an attempt to help learners acquire sound knowledge, skills and attitude. It involves a system of action designed to achieve meaningful learning. The actual process of teaching is the act of informing or instructing, providing guidance, suggesting activities and supplying materials to stimulate learning. However, it is appalling to state that some teachers use terms and concepts which make it complex for learners to link their prior knowledge in providing adequate conceptual interpretations, which ends up in the development of misconceptions (Adolphus and Aderonmu, 2008).

d. Social interactions

In this age of collaborative knowledge acquisition and sharing, social interactions which might be the face-to-face (off-line) means or by the use of online social media platforms is a fundamental avenue of knowledge dissemination. The 21st-century learners who are referred to as digital natives are learners who are born and bred in this age of emerging technologies. This set of learners is vast with the application of technological devices in search of knowledge through individual and collaborative means. They view blogs, scientific sites, and online video clips, and interact through social media platforms like Facebook, Instagram, Badoo, WhatsApp, Quora.com, etc, just to access and share knowledge. Most of the time, they depend on the knowledge shared during peer group interactions. However, some of these platforms convey incorrect scientific information which may lead to the development of misconceptions about scientific ideas, as noted by Bekalu, et al. (2019) that social media has more adverse effects than positive ones on students, especially in the aspect of misconception, and as reported by Yalçinkaya, et al. (2018) who found that majority of the students expressed distrust at the information provided on social media.

Alters and Alters (2001) in Madu and Udoh (2016) opined that misconception held by learners ranges from a mere misunderstanding of concepts to complete rejection of the concept. In the learning of physics, incomplete or inaccurate ideas or misconception about a concept is very common. Misconceptions can also be created and as well reinforced when learners' explanations, resolution of problems, and decoding of information are built on faulty reasoning. Aderonmu and Arokoyu (2021) explained that difficulties encountered by students in constructing coherent mental representations of physical phenomena and deficiencies in linking prior knowledge or experiences between different physics concepts are causes of students' misunderstanding and poor academic performance in physics. Worthy of note is that the longer the formation of misconception in the learners' cognitive schema, the higher the possibility of providing disjunctive scientific explanations. Antwi and Aryeetey (2015) had expressed that misconceptions have been found to have a significant effect on students' learning of science concepts. This can justify why the alarming rate of students' misconception about physics concepts is quite responsible for the consistent abysmal performance in external examinations.

Despite the importance of the Heat energy concept, Physics students have continued to demonstrate weak performance regarding their content knowledge of Heat energy as reported in the West African Examination Council Chief Examiner's report (2014, 2015 & 2018). Students find the concept of Heat energy difficult to answer which arises as a result of misconceptions held concerning the concept. In cases where few students attempted it, their scores were very low. Almahdi (2011) found that most Physics students were not sure of the differences between temperature and heat. In the same vein, Gonen and Kocakaca (2010) in Eric, et al. (2021) found that 41% of the sampled students hold misconceptions about the concept of heat and energy and a general misunderstanding of ideas related to thermal equilibrium, heat transfer and temperature concept. Eric, et al. (2021) similarly found that Physics students show a very high level of

misconceptions about heat and temperature. Arguably, this scenario may have been contributing significantly to their generally poor performance in external physics examinations. These observations are supported by Saglam and Millar (2016) who asserted that students' misunderstanding and contradiction suggest that they possess deviant ideas about the concept of heat energy. This implies that misconception poses a significant threat to learning as it hinders students from learning "correct physics". In which concepts of Heat energy do students have misconceptions? What are the sources of the misconceptions? This study, therefore, sought to identify the misconceptions held by secondary school students about the concepts of Heat energy and investigate the sources of the misconceptions.

2. Aim and objectives of the study

The aim of the study was to identify the misconceptions held by secondary school students about the concepts of Heat energy and ascertain the sources of the misconceptions. Specifically, the objectives of the study were to

- 1) identify the misconceptions held by secondary school students about the concepts of Heat energy.
- 2) investigate the sources of misconceptions held by secondary school Physics students about the concept of Heat energy.

2.1 Research questions

- 1) In which concepts of Heat energy do students have misconceptions?
- 2) What are the sources of misconceptions held by students about the concepts of Heat Energy?

3. Materials and Methods

The study adopted the mixed-method research design, specifically descriptive survey and exploratory analysis which provided both qualitative and quantitative data. Using a population of 2221 Senior Secondary One (SS1) Physics students in Ikwerre Local Government Area of Rivers State. A sample size of 300 students was selected for the study which consisted of 150 males and 150 females using the random sampling technique in all the 13 Government secondary schools in Ikwerre Local Government Area of Rivers State. Three research instruments were used for the study titled "Heat Energy Performance Test" (HEPT), Sources of Misconceptions in Heat Energy Questionnaire" (SMHEQ) and "Misconception in Heat Energy Interview Template" (MHEIT). HEPT contained 17 open-ended questions with diagrams and illustrations intended to obtain students' responses using acceptable scientific explanation(s) in order to identify students' misconceptions about the concept of Heat Energy. The constructed test items were drawn from the template of the secondary school Physics curriculum based on the performance objectives and the sub-concepts that permeate the content of Heat Energy.

SMHEQ contained 20 items structured on contents covering sources of misconception as perceived by secondary school students. Accordingly, items 1-5 were raised to determine if social interaction (online and offline) is a source of misconception, 6-10 considered teachers' instructional presentation as a source of misconception. Items 11-15 were posited to determine if textbook/reference material is a source of misconception, while items 16-20 were raised to ascertain if prior knowledge is a possible source of misconception.

HEPT and SMHEQ were validated by two experts in Science education and two other experienced secondary school Physics teachers. HEPT and SMHEQ were trial-tested with 30 Senior Secondary one (SS1) Physics students similar in characteristics to the sample but not part of the sample. The responses to HEPT were subjected to Kuder-Richardson's formula 21 (K-21) to obtain a reliability coefficient of 0.80. The reliability of SMHEQ was obtained using the test-retest method and thereafter, the Person Product Moment Correlation was used to obtain a reliability coefficient of 0.74 for it.

Misconception on Heat Energy Interview Template (MHEIT) was designed and employed for the interview session that provided the qualitative data for the study. MHEIT consisted of 12 questions that were asked by the researcher which required free oral expressions of the participants and are required to complement their initial response on HEPT and SMHEQ. The interview session for the participants engaged lasted for 40 minutes. The recorder was used for this session as permission was obtained from the participants. The recorded responses were further transcribed for coding as well as the thematic content analysis was employed to ascertain existing similar patterns across the data set. MHEIT was validated for both face and content validity by two experts in Communication Studies and two in Science Education. The data collected were analysed using frequency count, mean and percentage.

3. Results and Discussions

Research question 1: In which concepts of Heat energy do students have misconceptions?

Table 1: Percentages of misconceptions held by secondary school students about Heat Energy concepts

S/N	Heat Energy Probe Test items	SCC	MIC	Remarks
1.	Knowledge of definition of heat (direction of heat flow).	38.0%	62.0%	MISC
2.	Knowledge of kinetic theory explanation of temperature.	27.0%	73.0%	MISC
3.	Knowledge of increase in molecular vibration as a function of heat flow.	19.0%	81.0%	MISC
4.	Identification of thermionic emission as an effect of heat.	31.0%	69.0%	MISC
5.	Understanding of the differences between heat and temperature.	42.0%	58.0%	MISC
6.	Knowledge of expansion and contraction of a metallic substance based on the application and removal of heat.	25.0%	75.0%	MISC
7.	Identification of temperature range required for anomalous expansion of water.	40.0%	60.0%	MISC

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8.	Knowledge of graphical deductions during anomalous expansion of water.	31.0%	69.0%	MISC
9.	Knowledge of the natural application of anomalous expansion of water.	39.0%	61.0%	MISC
10.	Knowledge of thermal conductivity of water.	36.0%	64.0%	MISC
11.	Knowledge of the differences between conductor and insulator.	41.0%	59.0%	MISC
12.	Knowledge of the difference between the modes of heat transfer.	52.0%	48.0%	SCC
13.	Knowledge of absorption of radiation by different surfaces.	26.0%	74.0%	MISC
14.	Knowledge of current flow in land and sea breeze (convection current in nature).	18.0%	82.0%	MISC
15.	Knowledge and explanation of thermal conductivity of different metals	19.0%	81.0%	MISC
16.	Knowledge of radiation as a mode of heat transfer from the sun to earth.	24.0%	76.0%	MISC
17.	Knowledge of the thermos flask and the modes of heat transfer.	27.0%	73.0%	MISC
Aggregate mean percentage		31.0%	69.0%	MISC

Note: (SCC - Scientific Conception), (MIC - Misconception)

Table 1 shows that more than 50% of the students have misconceptions in 16 out of the 17 items listed under Heat energy. This is confirmed by the result that the aggregate mean percentage of 69.0% of the students have misconceptions about Heat energy. This result indicates that secondary school students have misconceptions about Heat energy.

The finding of this study that students have misconceptions in Heat energy is confirmed by one of the participants interviewed commented that:

"I don't know that there is a difference between heat and temperature, I thought that both words are the same."

Some other participants commented that:

"I am aware that when two objects are in contact, there will be a flow of heat, but I usually think that it only occurs when the two objects have the same temperature."

"Heat flows, but mostly from a body that has lower temperature to one with higher temperature."

Many of the students in the study could not specify the right direction of heat flow based on the definition of heat. Worst still is the fact that some students thought that heat is a substance and not a form of energy. The study also showed that students hold misconceptions concerning the idea of expansion and contraction of objects as a result of the increase and decrease in heat energy of the object.

The finding agrees with the finding of Almahdi (2011) that most Physics students were confused about the differences between heat and temperature. The study similarly agrees with that of Gonen and Kocakaca (2010) in Eric, et al. (2021) that 41% of the sampled students hold misconceptions about the concept of heat and energy and a

general misunderstanding of ideas related to thermal equilibrium, heat transfer and temperature concept. The finding also agrees with the finding of Eric, et al. (2021) that Physics students show a very high level of misconceptions about heat and temperature.

Research question 2: What are the sources of misconceptions held by students in the concepts of Heat Energy?

Table 2: Frequency and percentages of responses on the sources of misconceptions held by secondary school students in Heat Energy classified by gender

Source	Male			Female			Total		
	Freq	%	Rank	Freq	%	Rank	Freq	%	Rank
Teachers' instructional presentation	78	52.0	1st	64	42.7	1st	142	47.3	1st
Textbooks and reference materials	37	24.7	3rd	41	27.3	3rd	78	26.0	4th
Prior knowledge	33	22.0	4th	47	31.3	2nd	80	26.7	3rd
Social interactions	49	32.7	2nd	38	25.3	4th	87	29.0	2nd

Table 2 shows that from the views of the 150 male students, Teachers' Instructional Presentation ranked 1st as the source of misconception in the concept of Heat Energy, Social Interactions ranked 2nd, Textbooks and Reference materials ranked 3rd while Prior Knowledge ranked 4th.

From the views of the 150 female students, Teachers' Instructional Presentation ranked 1st as the source of misconception in the concept of Heat Energy, Prior Knowledge ranked 2nd, Textbooks and Reference materials ranked 3rd while Social Interactions ranked 4th.

Across the 300 students sampled, Teachers' Instructional Presentation ranked 1st as the source of misconception in the concept of Heat Energy, Social Interactions ranked 2nd, Prior Knowledge ranked 3rd while Textbooks and Reference materials ranked 4th.

These findings agree with the findings of Halim, et al. (2019) who found students' preconceptions, textbooks and teaching methods to be part of the causes of misconceptions. These findings also agree with the finding of Khalid and Embong (2020) that the teaching method is a source of misconceptions. These findings similarly agree with Patil, et al. (2019) who from a review of studies, collated textbooks and reference materials, teachers, students' personal experiences, and students' peer groups as some sources of misconceptions.

The finding of this study that Teachers' Instructional Presentation is a source of misconception is confirmed by a Physics student who participated in the study who commented that:

"Most times, our Physics teacher read from the textbook to us during his lesson. He does not offer adequate explanation rather we are meant to copy our notes."

Another participant commented that:

"I have never noticed my Physics teacher using any technological device to teach us. We still use only the chalkboard."

Another student yet lamented that:

"My Physics teacher is very good while teaching especially when solving physics problems, but he is very fast and this makes me not understand a reasonable part of the lesson."

The finding of this study that textbook/reference material is a source of misconception is confirmed by an interviewed participant who noted that:

"I find it difficult to study heat energy using two different Physics textbooks. This is because both textbooks have different definitions for one concept."

This finding is supported by Deshmukh and Deshmukh (2017) who noted that though some textbooks were written by experts, they are embedded with errors which may be due to improper choice of words or misprint which may lead to misconceptions.

The finding of this study that prior knowledge is a source of misconception is supported by another participant who lamented that:

"At 0°C, ice is supposed to be converted totally into water. But when taught anomalous expansion of water, we were informed that at that temperature value, there is a mixture of water and ice...I am quite confused."

The finding of this study that social interaction is a source of misconception agrees with the submission of Bekalu, et al. (2019) that social media has more adverse effects than positive ones on students, especially in the aspect of misconception. It also agrees with the finding of Yalçinkaya, et al. (2018) in which the majority of the students expressed distrust of the information provided on social media. However, an interviewed participant in this study noted that:

"I prefer using google search whenever I am doing my studies...using quora.com enable me to ask questions and share problems."

"I am very sure that I receive from social media platforms are correct."

4. Recommendations

1. Physics teachers should always conduct a diagnostic test before instruction to correct any wrong preconceived notion held by the students about a particular concept before instruction.
2. Well-designed and technology-assisted instruction should be adopted by Physics teachers to facilitate an accurate scientific understanding of heat energy.
3. Physics teachers should be mindful of the fact that students may come into the class with misconceptions and as such endeavour to encourage students to ask questions where they lack understanding of Physics concepts.
4. Writers of textbooks and reference materials should endeavour to ensure the correctness and clarification of definitions, meanings and illustration of scientific concepts in textbooks and reference materials.

5. Conclusion

It is evident that students have misconceptions about Heat energy. This has been traced to sources such as teachers' instructional presentations, textbooks and reference materials, prior knowledge as well as social Interactions. Efforts have to be made to correct these misconceptions and address their sources. This will foster a better understanding of Heat energy leading to a better performance of students in internal and external examinations. It will as well translate to the application of the concept for the technological advancement of the nation.

Conflict of Interest Statement

The authors declare that there is no conflict of interest.

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