INFLUENCE OF INTELLECTUAL AND CULTURAL ENVIRONMENTS ON STUDENTS' CONCEPTIONS OF THE TOPIC HEAT IN SECONDARY SCHOOL AND UNIVERSITY PHYSICS EDUCATION

By

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APPROVAL

This thesis has been submitted for examination with our approval as University supervisors.

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DEDICATION

To my children Wangari and Njoki.

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Abstract

The topic of heat forms an important part of the science curriculum at all levels in the education system. However the poor performance on questions involving heat in examinations suggests that students have difficulties in conceptualizing heat and could have ideas that are incompatible with the accepted physical theories. This study investigated the kinds of ideas that students use to explain heat and its associated physical phenomena and sought to establish whether students' conceptions are influenced by their level of intellectual development, gender and cultural beliefs. Such information would be helpful to physics curriculum developers and teachers in planning and developing teaching strategies to present the concept of heat to students. The data was collected from 269 Form One and 225 Form Three students in 15 randomly selected schools from all mixed, district secondary schools in Nyandarua district and also from 68 Egerton University second year B.Ed - (science) and B.Sc - (physics) students. Hence a total of 562 students were involved. However to investigate influence of cultural beliefs on students conceptions only the secondary students of Kikuyu ethnic community were involved. A simultaneous cross-sectional survey research design was used. The research instruments comprised two questionnaires, one to solicit students' ideas on the physical phenomena associated with heat (QSPIH) and the other to assess influence of cultural beliefs on students conceptions of heat (QICBSCH). The questionnaires were pilot tested to determine their validity and reliability. Descriptive and inferential statistics were used for data analysis. Chi-square tests of analyses were used to determine whether the distribution of conceptions was dependent on students' level of intellectual development and gender. The hypotheses were tested at $\alpha = 0.05$. The findings obtained indicated that students in secondary schools and University have some misconceptions on the concept of heat. When students' conceptions were categorized in terms of the prevailing theories of heat namely caloric, pre-kinetic and kinetic, the results indicated that the distribution of conceptions was dependent upon the students' level of intellectual development but not gender. The findings further indicated that a particular metaphor concerning heat exists in the conceptions of the secondary students of Kikuyu ethnic community in Nyandarua District. Based on these findings, the study concludes that students' conceptions concerning heat are influenced by their level of intellectual development and to some extent by their cultural beliefs but not gender. The study recommends that the topic of kinetic theory of matter be taught to primary pupils before being introduced to the topic of heat. The study further recommends that misconceptions be emphasized in the science curricula of schools and teacher training institutions so that students' alternative conceptions on various concepts like heat can be addressed. Lastly the study proposes that aspects of indigenous culture that interact in a manner complementary to the accepted science be included in the curricula of schools. Further research should be conducted to investigate existence of cultural metaphors concerning heat in other ethnic communities living in Kenya.

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B.Ed	Bachelor of Education
B.Sc	Bachelor of Science
K.C.S.E	Kenya Certificate of Secondary Education
K.I.E	Kenya Institute of Education
K.N.E.C	Kenya National Examination Council
QICBSCH	Questionnaire to assess Influence of Cultural Beliefs on Students' Conceptions of Heat.
QSPIH	Questionnaire on Students' Physical Ideas about Heat

Hiũha:- Literally means 'get hot' but means 'hurry up'.

Ĩ na ũrugarĩ :- The literal meaning is that 'it has a heat' but it means 'it is very restless'.

Kũhiũhĩ te ta thathi wa mũnyuko:- Literally means 'the situation is as hot as the soup of a bony animal'. The intended meaning is that 'the situation is very bad'.

Moko mahiũ:- Literally means 'hot hands' but intended to mean 'quick hands'.

Nĩ kũhiu mũno:-Literally means 'it is very hot' but the intended meaning is 'the situation is very bad'.

Nĩ mũhiũ moko:- Literally means 'he has hot hands but the intended meaning is that 'he is quick with his hands'.

Nĩ mũhiũ mũtwe:- Literally means 'he has a hot head' but means 'he gets angry easily'.

Nĩ mũhiũ:- Literally means 'he is hot' but intended to mean 'he is quick'.

Ti mũhoro:- Literally means 'he is not cool' but intended to mean 'he is not okay'.

Werũ ũkwenda mbĩ a hiũ:-Literally means that 'the wilderness required a hot rat'. The intended meaning is that 'for survival one has to be very active'.

Wĩ mũhoro?:- Literally means 'are you cool'? The intended meaning is 'are you okay'?

CHAPTER ONE

INTRODUCTION

1.1 Background Information

During the past three decades there has been growing interest within the science education research into children's ideas about scientific concepts. Today there is widespread acceptance in the international physics education research communities that students at all levels of schooling over the world have a diversity of ideas prior to formal learning (Driver, 1989; Zietsman & Naidoo, 1997). According to Pfundt and Duit (1994) these conceptions about physical phenomena are formed early in life as children try to make sense of the physical world. The persistence of these preconceptions of the physical world is attested to by a great deal of research that shows that these conceptions continue even after the formal study of science (Champagne, Klopper & Anderson, 1980; Caramazza, McCloskey & Green, 1981; Clement, 1982; Osborne & Wittrock, 1983, 1985; Halloun & Hestenes, 1985). The highly robust nature of these preconceptions appears to indicate that they are deeply rooted in students' cognitive structures and makes plausible the idea that they are based upon 'alternative frameworks' (Lynch, 1995).

Then it can be asked that, "if children create alternative frameworks, when were they established and how?" In order to answer this question, it is necessary to trace and follow the development of children's views in a systematic way from childhood to adulthood. Relatively few such systematic studies have been undertaken in the field of misconceptions in physics education. For example Tiberghien (1984) carried out researches on students aged between 10 and 16 years aimed at elucidating their ideas on

the concept of light while Erickson (1980) investigated the development of students' ideas on the concept of heat and temperature. In both studies it was found that conceptualization increased with their level of cognitive development. Review of literature did not identify any study that traces the development of ideas about heat among students as they enter into secondary school up to the time they join University education in Kenya.

The topic of heat forms an important part of every science curriculum from primary school up to the University level. It is therefore important to understand the ideas about the concept of heat that students carry from one level to the next in the education system. For example as noted by Young (1992), a good understanding of the basic concepts of heat provides a necessary stage in comprehending 'thermodynamics'. The topic is also potentially interesting from the point of view of children's cognitive development probably stemming from the fact that children come into contact with 'hot' and 'cold' – an implicit sensation phenomenon at an early stage in life (Bar & Galili, 1994). This establishes contact between the child and its environment thereby providing greater individual experience.

Although the word 'heat' sounds familiar to everyone it is an apparently difficult concept in science education. This is demonstrated by the poor performance of students on questions involving heat in the Kenya Certificate of Secondary Education (KCSE) physics examinations. For example according to the Kenya National Examination Council (KNEC) (1999) the results of the KCSE Physics Paper 1A of the examination taken in 1998 showed that only 14% of the candidates who sat the paper were able to

explain 'expansion' of substances when heated in terms of the kinetic theory of matter. In the KCSE physics paper 1A examination of 1999, only 18% of the candidates were able to correctly distinguish between 'heat' and 'temperature' (KNEC,2000) while in Physics Paper 1B of the year 2000, results showed that many students could not explain the variation of the pressure of a fixed mass of a gas with temperature in terms of the kinetic energy of the molecules of the gas (KNEC, 2001).

Review of related literature revealed a considerable amount of work related to problems in teaching and learning about the concept of heat in secondary and tertiary physics. According to Harris (1981) and Se-Yuen Mak and Young (1987) the term 'heat' is frequently misused by laypersons and scientists alike. Erickson (1979,1980) claims that the subject of heat is one of the most misconceived in science education and that the source of this misconception centres on the semantic use of words like 'heat', 'heat flow', 'heat capacity' and so on. Bar and Travis (1991) found that while high school students know that the amount of heat a body has relates to how much its components move and that heat transfers from hot to cold substances, they are however not able to distinguish clearly between heat and temperature and do not have appropriate ideas about mechanisms of heat transfer. In their study Van, Sprang and Verdonk (1994) found that University students failed to relate 'heat' and 'work' to thermodynamic concepts. Hewson and Hamlyn (1984) observed a newspaper advertisement for an evaporative air conditioner in which it was claimed that as the water droplets evaporate they consume the 'heat molecules' in the atmosphere. The message of this advertisement is that heat is matter consisting of molecules. This view of heat is generally termed the 'caloric view' and is consistent with that prevalent in the seventeenth and eighteenth centuries. Erickson

(1979) found that in the Western countries, this view persist even though the current theory of heat as kinetic energy is formally taught in schools.

Research in developing countries has identified cultural influences on students' conceptions in science. Lynch (1995) found that students' alternative frameworks are associated with cultural effects. Although many of these alternative conceptions are detrimental to learning there are others which are largely in agreement with the accepted physical theory (Zietsman & Clement, 1996). Researchers in the western countries have observed extensive caloric conceptions of heat in children, for example in England Shayer and Wylam, (1981) reported that about 80% of their subjects used a caloric model to explain heat. There is no current information regarding the presence of such extensive caloric conceptions in non-westerners known to the researcher. Hewson and Hamlyn (1984), reported very few such conceptions among the Sotho people of southern Africa. It is, however, well documented that there is a prevalent metaphor involving heat amongst many African peoples (Schapera, 1979; Hammond – Tooke, 1981; Verryn, 1981). This metaphor as pointed out by Lakoff and Johnson (1981) is grounded in experience and is a dominant aspect of the social and physical environment of the people. According to Hewson and Hamlyn this is interpreted as the instance during which the individual's conceptions may be influenced by both environmental factors and cultural beliefs.

Although gender bias against females has been observed in science learning, there could be areas in science education where girls stand at a relative advantage over boys to grasp better scientific concepts. One such area could be the concept of 'heat'. Massive studies

such as those conducted by the IPN (Institut fue die pedagogic der Naturwinsseenschaften) in Kiel (1995) on girls' naive conceptions of physics show that girls' interest and performance improve more than that of boys when the concepts are grounded in natural phenomena that reflect real life contexts. Traditional education among many African people, is based on the belief that social roles should be delineated by gender. For a long time women in African societies have performed such duties as washing, cooking, lighting fire and so on, all of which involve heat and heating. In a study to investigate the planning aspect of creativity among secondary school students, Okere (1996) found that girls performed better than boys in a problem that involved cooking to compare the performance of two charcoal 'jikos'. This study sought to explore students' conceptions concerning heat and to establish whether the conceptions are influenced by the students' level of intellectual development, gender and cultural beliefs.

1.2 Statement of the Problem

Heat is a very important concept in the curricula of primary, secondary and University science education. Understanding of the physical phenomena involving heat, for example expansion of matter when heated, transfer of heat through matter, change of state and others depend on conceptualization of heat as kinetic energy of molecules within a body. However students have difficulties in conceptualizing heat. This is demonstrated by their poor performance on questions involving heat and its associated physical phenomena in examinations.

It would, therefore, be important to investigate students' conceptions on the concept of heat to identify those that can be considered misconceptions and the factors upon which the conceptions depend. This study, therefore, explored secondary school and University Bachelor of Education (B.Ed)-science and Bachelor of Science (B.Sc)-physics undergraduate students' conceptions of heat and sought to establish whether the conceptions are influenced by the students' level of intellectual development, gender and/or cultural beliefs.

1.3 Purpose of the Study

The purpose of this study was to explore the kinds of conceptions that students use when explaining physical phenomena concerning heat and to establish whether the conceptions are influenced by the students' level of intellectual development, gender and/or cultural beliefs.

1.4 Objectives of the Study

Specifically the objectives of the study were to:

1. identify and describe secondary school and University B.Ed-science and B.Sc (physics) undergraduate students' conceptions of heat.
2. determine whether the level of intellectual development influences students' conceptions of heat .
3. determine whether there is any gender difference in students' conceptions of heat.
4. investigate whether cultural beliefs influence students' conceptions of heat.

1.5 Research Questions/Hypotheses

In order to achieve the above objectives the research addressed itself to the following questions/hypotheses:

Q1: What conceptions do secondary school and University B.Ed (science) and B.Sc (physics) students use to explain heat and its associated physical phenomena?

Ho1: Level of Intellectual development has no significant influence on students' conceptions of heat.

Ho2: Gender difference has no significant influence on students' conceptions of heat.

Q2: Do cultural beliefs influence students' conceptions of heat?

1.6 Significance of the Study

This study was conducted to investigate students' understanding of the concept of heat and the factors that may influence that understanding. This was meant to provide a basis for suggestions and recommendations necessary to improve learning of this concept in physics education. Firstly students' ideas about physical phenomena in general are widespread and appear in various domains (Bar & Galili, 1994). It is necessary that such ideas be investigated before formal learning of a concept so that alternative conceptions that may affect subsequent learning are identified and corrected. This study has attempted to provide useful insight into ways in which such students' ideas may be investigated.

Secondly, research findings have given the indication that there are misconceptions about physics concepts held by high school and University undergraduate students (Okere, 1996). This study has attempted to highlight some of the misconceptions that are held by

secondary and University B.Ed-science and B.Sc (physics) students on the concept of heat. As suggested by Okere one possible way of reducing misconceptions held by students would be to include the topic of misconceptions in the school physics syllabus. The results of this study would help in such an undertaking on the topic of heat. The results of the study are also likely to enhance the necessity of including concept learning of physical phenomena in the curricula of teacher training in our Universities.

Thirdly, the present study has attempted to highlight some of the factors upon which understanding of the concept of heat may (or may not) be dependent. These factors include students' level of intellectual development, gender and cultural beliefs. It is hoped that the results of this study will provide the curriculum planners at K.I.E and physics teachers with some insight into ways of dealing with some basic questions in the teaching of the concept of heat in schools, for example:-

(a) At what level should the concept be introduced to pupils in schools?

(b) What factors should be taken into account when developing teaching strategies to present the concept of heat to students?

Lastly, this study comes at a time when there is increased demand to make the curriculum more responsive to our societal needs. The UNESCO conference of ministers that took place in Lagos, Nigeria in 1976 made the recommendation that there is need to reform the educational content as a means of ensuring greater relevance to our natural and cultural environment (Okere, 1996). The results of this study demonstrate that it is possible to integrate indigenous thought with scientific theory. This would make science to be seen within the context of the students' cultural environment.

1.7 Scope of the Study

The physical concepts on the topic of heat that were covered in this study included the nature of heat, interaction of heat energy with matter, thermal expansion, heat transfer and change of state caused by heating. Only the aspect of cultural beliefs was used to investigate influence of cultural environment on students' conceptions of heat. The real life experiences used to investigate presence of metaphorical heat conceptions included anger, a cow on heat, initiation, childbirth, students under bees attack, menstruation, an active person and impatience.

1.8 Limitations of the Study

This study was limited to secondary schools in Nyandarua District and Egerton University – Njoro campus. Investigation of influence of cultural beliefs on students' conceptions of heat was limited to secondary students of Kikuyu ethnic group within Nyandarua District. As such the findings may be generalized to students of Kikuyu ethnic group within Nyandarua District and with caution to those outside the district.

1.9 Assumptions of the Study

In this study the following assumptions were made: -

1. The factors influencing change in heat conceptions and their effects remained constant across time during which the different levels of intellectual development were exposed to these factors.
2. All the students in each level of intellectual development were of the same chronological age.

3. All the Form One classes in the sample schools had covered the basic concepts of heat as outlined in the primary science syllabus.
4. All the Form Three classes in the sample schools had covered the concepts of heat as outlined in the Form One and Form Two secondary physics syllabuses.

1.10 Operational Definitions of Terms and Variables

The following terms and variables have been defined in the context in which they have been used in this study.

Alternative conceptual frameworks:- conceived understanding of concepts within contexts that are at variance with the accepted scientific theory.

Conceptualization:- process of forming an understanding of a concept.

District secondary schools:- secondary schools classified as 'district schools' in the Kenya's secondary school category system. These are at level three in the hierarchy of Kenyan schools.

Gender influence on students' conceptions of heat:- Dependency of the distribution of students conceptions on their gender when the conceptions are categorized as caloric, pre-kinetic and kinetic.

Influence of cultural beliefs on students' conceptions of heat:- Presence of metaphorical heat conceptions in students' explanations of various real life experiences. Such experiences include birth, pregnancy, menstruation, sickness and a variety of situations involving negative feelings, for example, anger, impatience and anxiety.

Influence of intellectual development on students' conceptions of heat:- Dependency of the distribution of students' conceptions of heat on their level of intellectual development when the conceptions are categorized as caloric, pre-kinetic and kinetic.

Misconceptions:- ideas which are incompatible with the currently accepted scientific knowledge.

Preconceptions:- conceived understanding of concepts before formal instruction.

Student's level of intellectual development:- the level to which a student has been exposed to formal learning. In this study secondary Form One and Form Three and University second year B.Ed-science and B.Sc (physics) students constituted three groups at different levels of intellectual development.

Student's gender:- Gender refers to the socially determined personal and psychological characteristics associated with being male and female namely 'masculinity' and 'feminity' (Garret, 1992). In this study gender was taken to mean the student's learned behaviors associated with one's sex.

Student's heat conceptions:- a set of categories of description representing student's understanding of heat.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

This study sought to investigate students' ideas on the concept of heat and the influence of the factors of the level of intellectual development, gender and cultural beliefs on students' conceptions. This chapter reviews the literature related to heat in science education, development of ideas about heat and students' ideas about heat. Literature related to the factors of the level of intellectual development, gender and cultural beliefs on students' conceptions of heat is also reviewed. A discussion of the theoretical framework on which this study was based concludes the chapter.

2.2 Heat in Science Education

2.2.1 Heat in Secondary School Science Courses

Ideas about heat are prevalent throughout science courses and will have been encountered by most if not all secondary school students. The present 8-4-4 primary school science curriculum indicates that the topic of 'heat' is taught to primary school pupils from standard five (K.I.E.,1999). In secondary schools, students are introduced to 'temperature' and 'expansion' in Form One and ideas about the 'modes of heat transfer' in Form Two. At these two levels ideas about heat in terms of its effects on solids, liquids and gases as well as experiments demonstrating various phenomena involving heat for example 'change of state', leading to introduction to particle theory of matter are covered. 'Quantity of heat' as evidence for interaction between particles (within the

context of a more vigorous treatment of particle theory) are covered in Form Three. At this level quantitative aspects of heat for example 'latent heat' and 'specific heat capacity' as well as qualitative aspects for example 'cooling by evaporation' are covered (K.I.E, 2000).

2.2.2 'Heat' and 'Thermodynamics' in University Physics

In Kenyan Universities, the Bachelor of Education (science) programmes draw their academic subjects from their respective faculties of science (Egerton University Calendar, 1999-2000). B.Ed (Physics) students are taught together with B.Sc students. On the topic of 'thermodynamics', the properties of a 'system' are described by observable characteristics like energy, pressure, temperature and volume (Bacon, 1983). To understand thermodynamic concepts, students need to have ideas of heat as energy of particles in a body (Young, 1992).

According to Linder and Erickson (1989), University physics evaluation system reflects a belief that passing problem-solving examinations is synonymous with acquiring conceptual understanding. As a result of their extra time and focused study in science, students are assumed to have acquired an understanding of scientific concepts that are congruent with contemporary scientific thinking. However it has been found that students with a rather tenuous understanding of physics concepts often manage to pass their examinations by memorizing sufficient material (Dahlgren & Marton, 1978; Dahlgren, 1979; Arons, 1981; Lin, 1982). While some may claim that being able to calculate right answers is probably the most important aspect of undergraduate physics, this cannot be

said to be true for graduates who will need to 'talk' and 'explain' physics such as secondary school physics teachers (Linder & Erickson, 1989).

2.3 Development of Ideas about Heat

2.3.1 History of the Scientific Perspective on Heat

The scientific perspective on heat has changed substantially during the last 300 years. The notion that 'heat' is a material substance is evident in the writings of the 17th century. for example Robert Boyles essays on 'effluvisms'. However the idea is much older possibly stemming from the early Greek civilization (Roller, 1950). The 'caloric theory' which is constructed around the material characteristics of heat came into general use in the 18th century. It proved more useful in explaining many phenomena involving heat. It included the postulates that caloric heat or 'matter of heat' is an elastic fluid, the particles of which are attracted by the particles of ordinary matter and which are indestructible as is all matter (Roller, 1950).

In the later part of 18th Century, attempts to discover the effect of heat on the mass of bodies were proving inconclusive. If heat had material characteristics then cooling would lead to loss of mass which was not the observed case. This brought about the idea that heat is a mode of motion of the particles in the substance. There were attempts to find the quantitative relations between phenomena, which later became recognized as representing conversions of energy from one form to another. For example Rumford compared the heat evolved by burning candles with that evolved by friction (Roller, 1950).

Later, Scientists like Mayer, Joule and others investigated the subject and established that heat is not a separate substance but is associated with the motions of particles of ordinary matter. By the second half of the 19th century heat was considered by most scientists to be the energy of particles in a substance which is transferred due to a temperature difference. This definition is in agreement with the more modern thermodynamic definitions except that in the later, the energy of particles is not heat but internal energy. In thermodynamic terms heat cannot 'exist' within a body. Heat is energy in the process of transfer between two bodies because of a temperature difference (Hamby, 1990). When transfer ceases, heat as a phenomenon has no further existence. When objects at different temperatures are brought into contact such that their temperatures equalize, the accepted scientific view would mean that energy has been transferred from the object at the higher initial temperature thus reducing its internal energy to the object at the lower initial temperature thus increasing its internal energy. As the energy is being transferred, it can be thought of as heat but when transfer is complete and the objects are separated, only internal energies of the objects exist (Summers, 1983).

It is worthwhile to note that internal energy cannot be equated to heat. It is an aggregate of kinetic and potential energies of the atoms in the object. It is possible to increase it without exposing the object to a higher temperature, for instance by doing work on the system. For example the internal energy and hence the temperature of a gas can be raised by compressing it. Therefore we can only talk of 'internal energy in a body'; not 'heat in a body'.

2.3.2 Modern Concept of Heat

Zemanksy (1970) described heat as a mysterious quantity which energy becomes during transfer from matter to matter but which cannot exist between matter; itself being subsumed into the energy of the constituent particles. The fact that energy is often transferred when matter is in direct contact with matter even at the molecular level adds to the confusion- can energy only exist as heat in a vacuum?. Warren (1972) and Zemansky both defined heat as "energy transmitted by means of a temperature difference only".

The usage of the word 'heat' in science classrooms is an incongruous mix of 'science' and 'everyday experience' (Zietsman & Naidoo,1997). This is also reflected in textbooks many of which treat heat and internal energy in a confused manner in an attempt to simplify scientific ideas. For example Duncan (1979) has used an analogy to describe the behavior of heat:-

> "Temperature decides the direction in which heat flows just as pressure does in liquid flow. Heat flows naturally from a body at a higher temperature to one at a lower temperature. A liquid flows of its own accord from a higher pressure to a lower one" (p. 123).

It is not difficult to imagine how 'heat flow' leads to a visualization of heat as having material characteristics in the minds of the students.

Summers (1983) suggested that the problem can be overcome by using the verb 'to heat' or 'heating' to mean the process by which internal energy transfers occur as a result of temperature differences. According to him 'heat' as a noun should be removed from

classroom use and that 'heat is transferred' has no meaning. Change in internal energy of an object is due to molecular interactions through which energy transfers occur.

Whether heat is energy flow brought about by temperature difference (Zemanksy, 1970), a process of energy change (Warren, 1972) or a process by which internal energy transfers occur due to temperature difference (Summers, 1983) the concept of heat depends intrinsically on the concept of energy. Warren in his article suggests that the problem of a 'materialist' view of energy has made the subject of thermodynamics almost unteachable. He concludes by making a plea that teachers of physics eliminate the word 'energy' entirely from elementary teaching. One of the greatest physists and teachers of physics, Richard Feynman describes the concept of energy as being very illusive; "It is important to realize that in physics today we have no knowledge of what energy is. We do not have a picture that energy comes in little blobs of a definite amount. It is not that way. However there are formulas for calculating some numerical quantity and when we add it all together it gives . . . always the same number. It is an abstract thing that it does not tell us the mechanism or the reasons for the various formulas" (Feynman, 1995; p.73). According to Zietsman and Naidoo, (1997), if physics cannot yet describe 'energy' and heat is closely tied to the concept of energy, one should expect a myriad of naive conceptions of heat that are not in accord with the physical theory.

2.4 Students' Ideas about Heat

Many different meanings of the word heat are in current usage. Students' ideas can be better understood against a background of the meanings that are likely to be encountered

in and out of classroom. The words 'hot' and 'cold' are related to everyday usage and experiences. The word 'heat' is commonly used as:-

(a) A metaphor, for example a 'heated argument' (Hewson & Hamlyn, 1984).

(b) An idiom, for example 'the heat is off' (Harris, 1981).

(c) A scientific term meaning 'a form of energy' (Warren, 1972).

In addition to these meanings of the word within 'everyday' and 'scientific context' there are the ideas that the students may have about heat which may not correspond exactly to either everyday or scientific meanings. Current research findings suggest that students have ideas about heat which not only differ from 'the scientist's view' but which also differ from the perspective sometimes presented in school science (Erickson, 1980). These ideas which are probably derived from students' experiences with common phenomena - for example cooking pots and pans changing temperature when on a hot place, often persist even after formal instruction.

A number of studies on students' ideas about heat have been undertaken in the western countries. These include, 'the learning aspect of the concept of heat' (Tiberghien, 1980); 'a critical review on the research aimed at elucidating the sense that notions of temperature and heat have for students aged 10 to 16 years' (Tiberghien, 1984); 'the teaching of the concept of heat' (Warren, 1972) and 'the use and misuse of the word heat in physics teaching' (Zemansky, 1970). All these studies have documented the kinds of ideas that students have about heat. The results of these studies show that the ideas can be classified into three view-points:-

(a) Caloric view-point:- thinking of heat as a fluid or as particles.

(b) Pre-kinetic view-point:- thinking of heat as a form of energy that can 'exist' on its own, within a body.

(c) Kinetic view-point:- thinking of heat as energy of particles in a body.

However these previous studies did not attempt to investigate a possible dependency of the distribution of heat ideas with the intellectual development of the students. Erickson (1980) suggested albeit tentatively that there may be a developmental sequence in students' conceptions of heat, that their ideas shift from caloric through pre-kinetic to kinetic conceptions. If learning is to be viewed in terms of conceptual change or development (Gilbert & Watts, 1983) then it is of value to understand more about the evolution of students' ideas with their intellectual development. The present study sought to establish whether the distribution of these conceptions depends on students' level of intellectual development.

2.5 Influence of Intellectual Development on Students' Conceptions of Heat

Three major systems influence stability and change in human cognitive development (Baltes & Nesselroade, 1979). These influences have their origins in:-

(a) Biological factors:- these refer to those determinants that show a strong correlation with chronological age across history and a range of individuals.

(b) Environmental factors:- these have a pervading effect on individuals experiencing a particular environment. They include physical, social and intellectual factors.

(c) Intervention:- these include planned learning experiences provided by a wide range of educational institutions that are deliberately designed and form the educative process.

The interaction of these influences form the basis for cognitive development of students in schools. Intervention influences are usually planned for a particular stage of development and are directed towards highly specific outcomes. Lack of change or constancy in characteristics involves lack of success in the administration of the intervention.

Time has a significant influence to cause change in cognitive development. Increasingly there is recognition that the effects of environmental and intervention influences are time related in so far as exposure to the environment or to the intervention has significant consequences for the magnitudes of measurable outcomes. Erickson (1980) suggested tentatively that development of students' conceptions of heat may be time related, that their ideas evolve with their intellectual development and intervention. This study looked at students' conceptions of heat at three levels of education namely Form One, Form Three and University.

2.6 Gender Influence on Students' Conceptions of Heat

Biologically whether a person is considered to be a male or female depends on the pattern of the individual's inherited chromosomes (Doherty & Bielby, 1985). Gender refers to the socially determined personal and psychological characteristics associated with being male and female namely masculinity and feminity (Garret, 1992). The phenomenon of

gender has been found to be enhanced by among other factors gender roles and gender identity. As children become inclined to behave like one sex or another through interacting with others and tend to display strong gender identity (that is to think themselves as either a boy or a girl), then more and more of their behavior will elicit appropriate reciprocal behavior from others boosting their gender identity further. Rubin and McNeil (1985) have noted that people not only identify themselves in terms of their gender but this identification serves to influence many of their choices and behaviors. In addition, Kohlberg in Maccoby (1966) has argued that the process of forming a gender identity is a part of the process of conceptual development and a product of the child's active structuring of his or her experiences.

Traditional education among many African people is based on the belief that social roles should be delineated by gender (Shumba, 1995). It has been found that boys perform better than girls in physical sciences in Kenyan schools (Twoli, 1986). However there could be instances where the girl child may stand at a relative advantage over the boy child to conceptualize better scientific concepts. Okere (1996) found that girls performed better than boys in a problem that involved cooking to compare the performance of two charcoal jikos. He attributed this to gender roles where girls are expected to perform such duties as cooking, washing, lighting fires and others that involve heat and heating. This study sought to establish whether students' conceptions of heat when categorized as caloric, pre-kinetic and kinetic are influenced by gender.

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2.7 Influence of Cultural Environment on Students' Conceptions of Heat

In non-western societies, it is increasingly becoming clear that understanding the contribution of traditional culture's world view to science learning is significant to the adoption of science, its methods and values (Ogawa, 1986; Ogunniyi, 1986, 1988; Cobern,1993). As Cobern notes, in developing countries there is need to ask questions about world-view and the compatibility of various non- western world-views with modern science. This issue of cultural context with reference to African countries is also articulated by Morris (1983) who notes that education does not take place in a cultural vacuum, it occurs against the background of a view of the world and humanity's society.

Science then must be studied in relation to socio-cultural variables and traditional world-views if effective integration of the traditional world-view and the scientific world-view is to take place (Solomon,1997). Before such integration takes place, it is worthwhile to ask how specific aspects of indigenous culture interact with science, in other words are there areas within the African cultural context that interact in a manner complimentary to the accepted scientific world-view?

It is well documented that there are prevalent metaphors involving heat amongst many African peoples. Schapera (1979), Hammond- Tooke (1981) and Verryn (1981) found such metaphors among the Sotho people of Southern Africa. The metaphors are well grounded in the cultural and physical environments of the people. Among the kikuyu, there is a belief that 'Coolness is good' (implying health and social harmony) while the converse 'hot is bad' (implying sickness and social disharmony). This is even reflected in the popular Kikuyu greeting "*Wĩ Mũhoro*?" which directly translates as "are you cool?"

or the metaphor to describe a very bad situation, "*nĩ kũhiũ mũno*" which directly translates as "it is very hot". This is probably as a result of their basic concern for the climate. The Kikuyu are predominantly farmers and a cool wet climate to them means a bamper harvest, while on the other hand a hot dry climate means harsh conditions leading to poor harvest drought and famine.

Lynch (1995) observed that in a society which is much closer to subsistence demands, it is not surprising that the notion of world-view will incorporate the cultural values revolving around the social and physical environment of the society. Hewson and Hamlyn (1984) observed metaphorical heat conceptions among the Sotho people of Southern Africa which they attributed to the harsh environmental conditions surrounding them. As Lakoff and Johnson (1981) pointed out all metaphors are grounded in experience. This study sought to find out whether such metaphors concerning heat exist in students' explanations of real life experiences among the Kikuyu people living in Nyandarua District. Such experiences include birth, pregnancy, menstruation, sickness and a variety of situations involving negative feelings, for example, anger, impatience and anxiety.

2.8 Theoretical Framework

Petrie in Hewson and Hamlyn (1984) provides a model (figure 1) which forms the theoretical basis of this study.

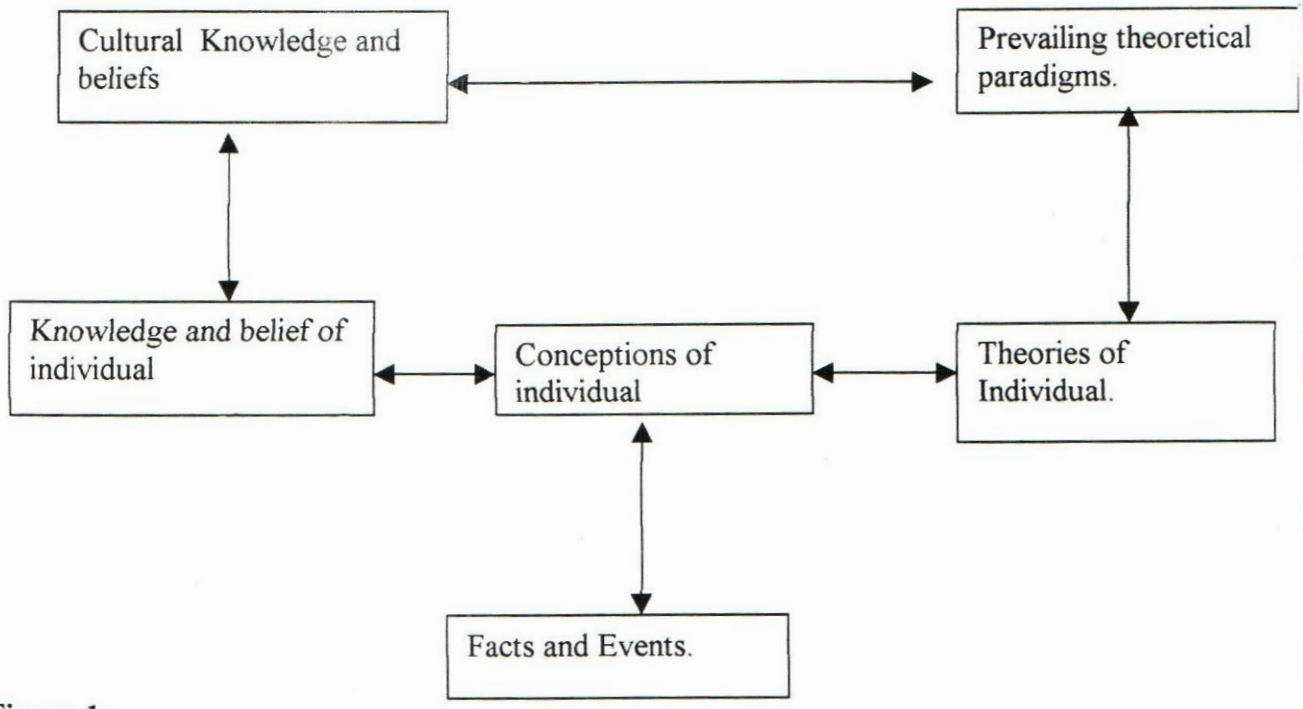


Figure 1:

Diagram showing the dynamic interaction between conceptions and the cultural knowledge, prevailing paradigms and physical facts and events.

In this model conceptions are seen as existing in a dynamic interaction between the cultural and social beliefs of the society; the prevailing paradigms or theories; and the input from the facts and events of the physical world. Concept formation is interpreted according to the varied mental sets of individuals which are a function of their intellectual and physical environments (Hewson & Hamlyn, 1984). From the perspective of this study, learning is viewed as a process in which learners are continually constructing and

adapting their knowledge of the world (Driver & Bell, 1986). Their knowledge is viable to them and although often not in accord with the accepted scientific theory, they use this knowledge to make sense of the world. In this sense making process which takes place within a context of social interaction and agreement, learners construct knowledge in ways that are coherent and useful to them. Since learning (knowledge construction processes) is influenced by social experiences, the knowledge constructed by each individual is not normally completely personal and idiosyncratic. Existing knowledge and social agreements about meaning not only limit how new experiences are interpreted but also influences what is perceived in each new situation. Thus two individuals exposed to the same events will perceive and interpret them in ways that may or may not be very different depending on their underlying knowledge and beliefs and the ways in which these beliefs are influenced by the social interactions out of which they are formed (Zietsman & Naidoo, 1997). The variables in this study are inter-related as illustrated in figure 2 below.

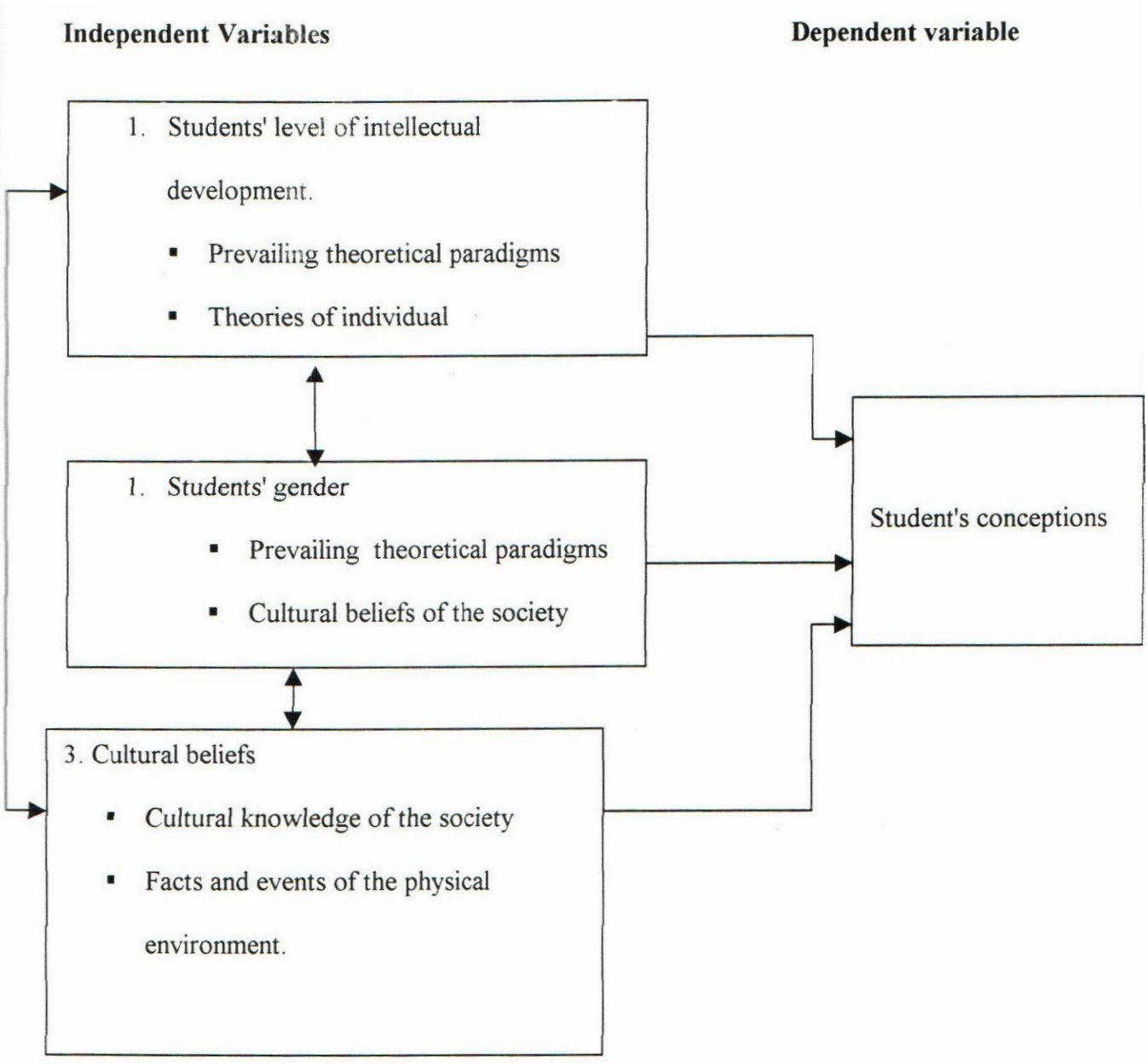


Figure 2:

Diagram showing inter-relationships between the variables of the study.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The purpose of this study was to explore the kinds of conceptions that students use when explaining heat and its associated physical phenomena and to establish whether these conceptions are dependent upon the students' level of intellectual development and/or gender. The study also sought to investigate whether cultural beliefs influence students' conceptions of heat. This chapter describes and justifies the research methodology used. It therefore describes the research design used, population, sampling techniques, instrumentation as well as data collection and analysis procedures.

3.2 Research Design

This was generally an exploratory survey. Surveys are an efficient way of obtaining information needed to describe people's thoughts, opinions and feelings (Zechmeister & Schaughnessy, 1992). Survey research is described as normative (Kathuri & Pals, 1993; Leedy, 1993). This is because its primary role is to explore the present status of a phenomenon in order to guide practice in the immediate future (Turney & Robb, 1971; Mouly, 1978). To enable comparison of the conceptions held by the different levels of intellectual development, the study adopted simultaneous cross-sectional survey design. According to this design two or more cross-sectional surveys are conducted at the same point in time with groups possessing an attribute at different levels for purposes of comparison (Von, 1985). Each group is sampled out by each cross-sectional study. The

same variables are observed for each sample. The data matrix for this design is illustrated in figure 3 below.

Group	Sample	Time Point	Observed variables
A_1	S_1	T_1	$V_1, V_2, \ldots \ldots \ldots V_e$
A_2	S_2	T_1	$V_1, V_2, \ldots \ldots \ldots V_e$
.	.	.	.....
.	.	.	.....
.	.	.	.....
A_m	S_m	T_1	$V_1, V_2, \ldots \ldots \ldots V_e$

Figure 3:

Data matrix for simultaneous cross-sectional design.

According to the data matrix (figure 3) there are *m* groups of subjects which are observed with respect to *e* variables. This design was chosen because it allows for groups at different levels of an attribute to be studied at the same point in time with the assumption that the factors influencing change and their effects have remained constant across time during which the different groups have been exposed to these factors (Borg & Gall, 1989).

3.3 Target area and population

3.3.1 Target area

The study confined itself to secondary schools in Nyandarua District and Egerton University-Njoro campus. These areas were purposely selected because of their convenience of accessibility by the researcher as well as their possession of the specified characteristics amenable to this study. To guard against gender bias and to reduce chances of selecting students hailing from outside Nyandarua District, only mixed day schools of the district category were considered.

Nyandarua is one of the seven districts in central province. It is well known for its agricultural productivity. It is predominantly occupied by the Kikuyu ethnic group who are mainly small-scale subsistence farmers. For this reason, climatical conditions are of special concern to them and as such 'heat' pervades many aspects of their lives. Egerton University-Njoro campus is one of the six public Universities in Kenya. It trains among others graduate science teachers drawn from all over the country to teach in Kenyan secondary schools.

3.3.2 Target Population

The universe population of the study was all the secondary students within Nyandarua District and Egerton University B.Ed (science) and B.Sc (physics) students. The target population of the study was made up of three groups. The first group consisted of all Form One students in district schools in Nyandarua District. This group was purposely chosen as it represented the kind of conceptions that primary school pupils graduate with at the end of their primary education. There were a total of 3947 enrolled Form One

students in 79 district schools in the district (District Education Office, Nyandarua District).

The second group comprised all Form Three students in district schools in Nyandarua District. This group was purposely selected because they had covered the basic concepts of heat taught in secondary science. There were a total of 1191 enrolled Form Three physics students in 51 district schools in the district (District Education Office, Nyandarua District).

The third group consisted of all second year B.Ed-science and B.Sc (physics) students of Egerton University. This group was purposely selected because they had covered 'heat and thermodynamics' as outlined in the University physics syllabus. There were a total of 68 enrolled second year B.Ed-science and B.Sc (physics) students at Egerton University (Office of Assistant Registrar, Faculty of Science, Egerton University).

3.4 Sampling Techniques

Two lists, one comprising all mixed, district, day secondary schools with their Form One physics enrollments and the other comprising the same kind of schools with their Form Three physics enrollments in Nyandarua District were made. These formed the sampling frames. Simple random sampling technique was used to draw the sample schools. This technique was considered appropriate because it ensured that all the schools had an equal chance of being included in the study sample. Besides, simple random sampling gives random samples which yield data that can be generalized within margins of error that can

be determined statistically (Borg & Gall 1989; Mugenda & Mugenda, 1999). Due to the small number of schools to sample from, this study employed balloting method. This involved assigned a numeral to each of the 79 schools for Form One and 51 schools for Form Three groups respectively, placing the numbers in a container and then picking a number at random. Schools corresponding to the numbers picked were included in the study sample. The sample schools for each group were drawn independently. Each time a school was drawn, its physics enrolment for the respective group was noted. This continued until the desired sample size for that group was reached. In the end 7 and 10 schools were selected for Form One and Form Three groups respectively (Appendix A).

3.5 Sample Size

There does not seem to be a clear-cut guide to the selection of an optimum sample size. Nevertheless Mugenda and Mugenda (1999) have provided a formula that can be used to estimate the sample size required in social science research ;

$$n = \frac{z^2 p q}{d^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where ;

n = the desired sample size

z = the standard normal deviate at the required confidence level

p = proportion in the target population estimated to have characteristics being measured

q = 1- p

d = the level of statistical significance

Since in this study there was no available estimate of the proportion in the target population assumed to have the characteristics being measured, then as recommended by Fisher et al. in Mugenda and Mugenda (1999) 50% was used. The z-statistic used was 1.65 and the level of the desired accuracy was set at 0.05. Mugenda and Mugenda (1999) further suggest that where the target population is less than 10,000 a final sample estimate (n_f) is smaller than the desired sample size and is determined using the formula;

$$n_f = \frac{n}{1+{}^{n}/_{N}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

where n = desired sample size

N = estimate of population size (< 10,000)

According to the design of this study, the final sample sizes of Form One and Form Three groups were determined independently using the formulas 1 and 2 described above and are shown in table 1 below. However for the University group, since there were only 68 students, all participated in the study.

Table 1: Sample Size of the Study Groups.

Group	**Population (N)**	**Final sample size (n_f)**
Form One	3947	269
Form Three	1191	225
University	68	68
Total	5206	562

3.6 Instrumentation

Two questionnaires were used to collect the data sought in this study. The first part of each of the questionnaires explained the purpose of the study to the respondents and requested their assistance in not only answering the questions but forthrightly as well. Details of each of the research instruments is briefly outlined in the subsections 3.6.1 and 3.6.2 below.

3.6.1 Questionnaire on Students' Physical Ideas about Heat (QSPIH)

The purpose of this questionnaire (Appendix B) was to elucidate students' ideas on the concept of heat and its associated physical phenomena. The questionnaire contained 7 items which investigated students' ideas on the concepts of the nature of heat, interaction of heat energy with matter, thermal expansion, heat transfer and change of state. The items were open-ended questions which gave the respondents an opportunity to provide their own ideas on the concepts. The general trend was to ask the respondents to explain their views about a given phenomenon. The instrument was administered to students in all the levels of intellectual development.

3.6.2 Questionnaire to Assess Influence of Cultural Beliefs on Students' Conceptions of Heat (QICBSCH)

This questionnaire (Appendix C) consisted of 8 items whose aim was to establish whether students use metaphorical heat conceptions to explain various life experiences. A

real life situation involving people and/or animals was described to the students and were asked whether those people and/or animals could be described as 'hot'. They were then asked to explain why they said so. The items closely resembled those used by Hewson and Hamlyn (1984) but the selected life situations were those that have some cultural significance among the Kikuyu people. These include circumcision, birth, pregnancy, sickness and others. The questionnaire was only administered to the secondary Form One and Form Three students. Oral interviews to further probe students' reponses in the QICBSCH were conducted on 24 students. These included 14 students randomly selected from those classified as subscribing to the category described as 'behavioural changes' and 10 from the category described as 'biological changes' (see section 3.6.3). A student was classified as belonging to any of these categories if in 6 or more out of the 8 items in the questionnaire, the student used ideas in that category to explain the responses to the items. The interviewed students comprised 5% of all the students in each category. The interview was not structured by a strict schedule but the interviewer (researcher himself) had an agenda in mind. The aim was to establish whether students' explanations could be related to their cultural beliefs. The interview used formal conversational format.

3.6.3 Validity and Reliability of the Research Instruments.

In order to eliminate bias in the results, the research instruments were systematically evaluated to ensure their validity and reliability. Validity refers to how well an instrument measures what it is intended to measure (Abouserie, 1992). On the other hand reliability refers to how consistent an instrument will produce similar results if used with the same or similar respondents on different occasions (Abouserie, 1992; Peil, 1995; Babbie,

1998). The first step was to consult research references on ways in which questionnaires are constructed. The draft instruments were then discussed with the research supervisors and other experts in the Faculty of Education and Human Resources – Egerton University. Revisions were made based on their comments and recommendations.

Borg and Gall (1989) recommend a thorough pre-testing of research instruments before they are used in research. However, research literature does not appear to provide a universally accepted method of determining the number of respondents to participate in a pilot survey. Greenan et al. (1998) used 10 subjects in piloting instruments for their study that had a universe population of more than 2000 subjects. For this study 68 subjects in two mixed, district, day secondary schools in Nyandarua District that were not part of the main study sample were used for each of the questionnaires.

To establish the reliability of the QSPIH, the students' responses were scored according to the scoring scheme described in Appendix D. Students' scores obtained in each item were correlated with the scores across the whole questionnaire. The items Pearson's product-moment correlation coefficients obtained are shown in table 2.

Table 2: Items Pearson's Correlation Coefficients

Item Number	1	2	3	4	5	6	7
Pearson's Correlation Coefficient	0.71	0.73	0.71	0.79	0.82	0.79	0.74

The results show that all items had a correlation coefficient greater than the 0.7 recommended for consistency in social science research (Borg & Gall, 1989). All the items were therefore used for data collection. To further estimate the reliability of the whole questionnaire Cronbach's coefficient alpha was computed using the formula:-

$$\text{Alpha} = \frac{m}{m-1}\left(\frac{1-\Sigma V_i}{V_{total}}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where m = the number of items

ΣV_i = sum of the variances of scores on the individual items

V_{total} = Variance of the total scores

The value of alpha obtained was 0.74 which is above the level of 0.7 recommended by Wallen and Fraenkel (1991). The data from the pilot study was used to ascertain the suitability of the QICBSCH. The items in the questionnaire were reviewed for clarity and systematically refined before being used for the main data collection.

Apart from pre-testing the research instruments, the pilot study was also used to ascertain the range of possible responses from the main study. The results of the pilot study indicated that students' responses in the QISPH could be grouped into three categories in the context of the prevailing paradigms as found in the early and contemporary scientific theories of heat. These categories include caloric, pre-kinetic and kinetic conceptions as described in section 2.4.

Analysis of explanations given by the students who responded in the affirmative that the term 'hot' could be used to describe the people or animals in the given situations in the

QICBCSH showed that the students could be grouped into two categories:- those subscribing to behavioural and biological changes. These categories are described below:-

- Behavioural changes:- included those who used the concept 'hot' to describe a change in behaviour of the people or animals in the described situations.
- Biological changes:- included those who used the concept 'hot' to describe a state of increased body activity of the people or animals in the described situations.

These categories were used in data analysis as described in section 3.8 and chapter four.

3.7 Administration of Research Instruments

The researcher first obtained preliminary information on schools from the Nyandarua District Education Office. This information assisted in the sampling process. Letters to inform the sample schools of the intended study were sent to the headteachers of the schools well in advance of the visits. The QSPIH and QICBSCH were administered to the students by the researcher with the assistance of physics teachers in the respective schools. The students were allowed sufficient time to respond and to give their independent views. A 30-minutes break was allowed between the two questionnaires.

The respondents to participate in the interview were informed of the interview on the researcher's second visit to the schools. In all the cases the interviewer first introduced himself to the respondents and the University from which he comes. The respondents were reassured that the information sought was not for any other reason apart from achieving the objectives of this study. All interviews were recorded on tape and

subsequently transcribed for analysis. The QSPIH was administered to the Egerton University B.Ed-science and B.Sc (physics) students during the last hour of their 3-hour practical session. The researcher was assisted by the personnel in the department of physics, Faculty of Science of Egerton University.

3.8 Data Analysis

Analysis of data on students' physical conceptions of heat involved identifying the conceptions that students used to explain heat and categorizing the conceptions as either caloric, pre-kinetic or kinetic as described in sections 2.4 and 3.6.3. The data was analysed for each of the concepts involving heat described in section 3.6.1. Frequencies of the categories were derived for each level and the distribution of the conceptions analysed using chi-square tests to establish whether they were dependent upon the students' level of intellectual development and gender. The analysis was done using the Statistical Package for Social Sciences (SPSS). The tests of statistical significance were computed at $\alpha = 0.05$.

Analysis of data obtained using the QICBSCH and the interview involved identifying those students who responded in the affirmative that the term 'hot' could be used to describe the people or animals in the described situations in the items. Their explanations were categorized as behavioural or biological changes as described in section 3.6.3. Tables of descriptive statistics – frequencies and percentages were generated.

Table 3: Summary of Data Analysis

Hypothesis	Independent Variable	Dependent variable	Method of data analysis
H_01: Level of Intellectual development has no significant influence on students' conceptions of heat.	Student's level of intellectual development	Student's conceptions of heat	Chi - square test.
H_02: Gender difference has no significant influence on students' conceptions of heat.	Student's Gender	Student's conceptions of heat	Chi - square test

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This study sought to explore the kinds of conceptions that students use to explain heat and its associated physical phenomena and to establish whether the conceptions are dependent upon the students' level of intellectual development and gender. The study also sought to establish whether students use cultural metaphors concerning heat to explain various real life experiences. In this chapter the results obtained are analysed both descriptively and inferentially. The contents of the results are presented in form of tables, bar charts and excerpts and their interpretations follow. Finally a discussion of the results is given.

4.2 Students' Physical Heat Conceptions

A major aim of the study was to use the QSPIH to not only explore the kinds of conceptions that students use to explain phenomena associated with heat but to also identify their alternative conceptions. The study also aimed at establishing whether the distribution of students' conceptions, when categorized as caloric, pre-kinetic or kinetic is dependent upon the students' level of intellectual development and/or gender. The questionnaire solicited students' ideas on their understanding of:-

a. the term heat and the nature of heat (items 1 and 2)

b. interaction of heat energy with matter (items 3 and 4)

c. thermal expansion (item 5)

d. heat transfer (item 6)

e. change of state (item 7)

The data was analysed for each of the above concepts and is presented as follows:-

1. Distribution of conceptions among the levels of intellectual development and between gender (for Form One and Form Three levels). A bar chart is also used to illustrate the distribution of the conceptions. It should be noted that in cases where the total number of categorized conceptions in a concept does not tally with the sample size of each level, it means there were non-respondents. These included cases where either the student did not respond to the item or where the response could not be categorized due to illegibility and any other reason.
2. Chi-square tests of statistical significance to determine whether the distribution of the conceptions is independent of the students' level of intellectual development and gender. It should be noted that because of the small number of female students (12) compared to their male counterparts (56) at the University level and because there was no sampling, gender comparisons at this level were not done.
3. Examples of students' responses subscribing to each category are given. In the excerpts only the code name of the student is given using the following pattern; Level/Gender/Student number. The responses are quoted directly with only minor modifications where necessary to make reading possible. The symbol # is used to stand for the serial number of students and excerpts.

4.2.1 Students' Understanding of the Term 'Heat' and the Nature of Heat

In item number one the students were asked to explain what they understood by the term heat. Item number two required the students to either agree or refute a statement that "the

molecules of heat are very small" and to give their own understanding of the nature of heat. The conceptions held by students are presented in table 4.

Table 4: Distribution of Students' conceptions of Heat and the Nature of Heat Among Three Levels of Intellectual Development in Numbers and Percentages of the Totals of the Three Levels.

Level	N_i	Conceptions		
		Caloric	Pre-kinetic	Kinetic
		Number %		
Form One	259	61	126	72
		23.5	***48.6***	***27.8***
Form Three	222	28	115	79
		12.6	***51.8***	***35.6***
University	67	6	16	45
		9.0	***23.9***	***67.1***

Note: Percentage values of N_i are in bold italics.

The results were further represented in the bar chart (figure 4).

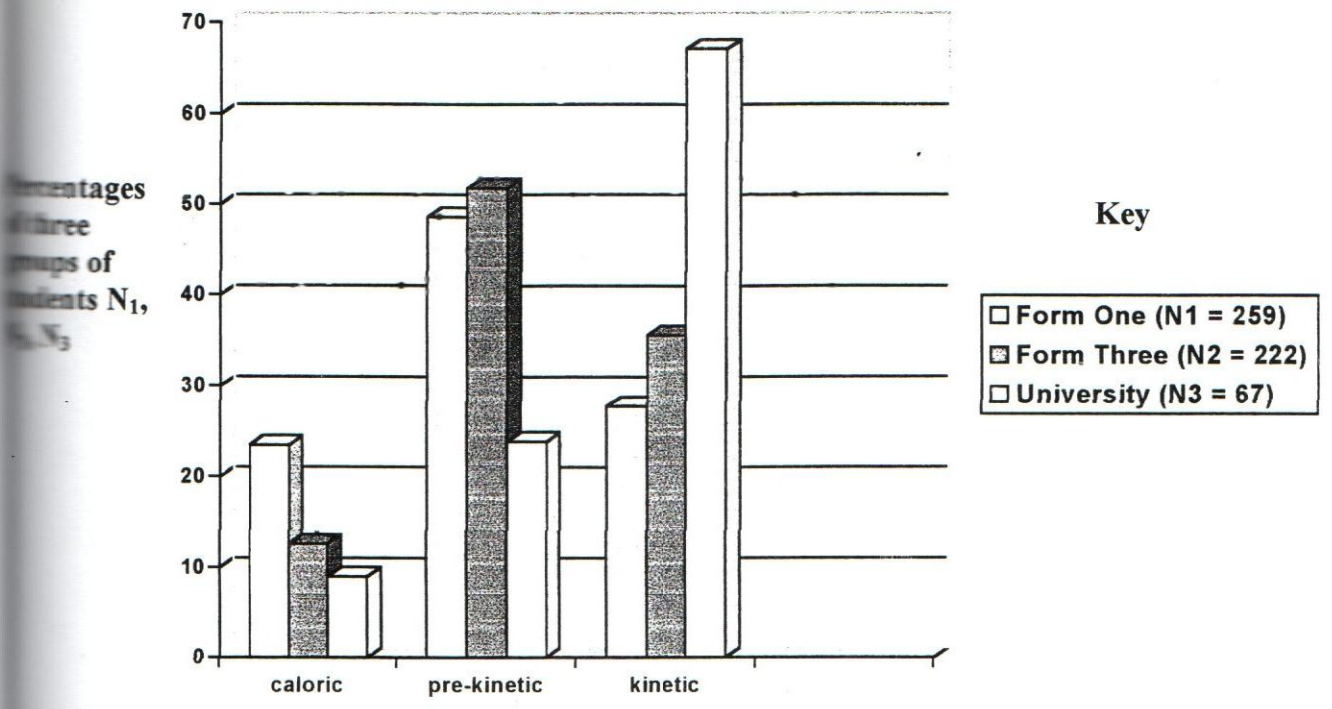


Figure 4.

Distribution of students' conceptions of heat and the nature of heat among the three levels of intellectual development.

The bar chart (figure 4) shows that the percentage of students for Form One and Form Three peak at the pre-kinetic conceptions while that of University students peaks at the kinetic conceptions. In all the three levels, the percentage of caloric conceptions is the lowest. However they appeared more among Form One students (23.5%) followed by Form Three (12.6%) and least among the University students (9.0%). The reverse is true for kinetic conceptions (University – 67.1%; Form Three – 35.6%; Form One- 27.8 %). Pre-kinetic conceptions were most common among Form Three students (51.8%) followed by Form One students (48.6%) and then University students (23.9%). Further analysis was done using chi-square test in order to establish whether the distribution of

the conceptions was independent of the students' level of intellectual development. The results are shown in tables 5 below.

Table 5: χ^2-Test Analysis of the Distribution of Students' Conceptions of Heat and the Nature of Heat Among the Levels of Intellectual Development.

	Conceptions				
Level	Caloric	Pre-kinetic	Kinetic	χ^2-value	P-value
Form One	61	126	72	48.2	0.00
Form Three	28	115	79		
University	6	16	45		

($\chi^2_{Tab} = 9.49$, df = 4, $\alpha = 0.05$)

The results (table 5) show that at $\alpha = 0.05$ and 4 degrees of freedom the critical value of chi-square (χ^2_{Tab}) is 9.49. Since the calculated value of chi-square ($\chi^2_{Cal} = 48.2$) is bigger than the table value, it was concluded that the distribution of the conceptions was not independent of the students' level of intellectual development. The distribution of conceptions in terms of gender for Form One and Form Three levels is presented in table 6 below.

Table 6: Distribution of Students' Conceptions of Heat and the Nature of Heat Between Gender for Form One and Form Three Levels.

		Conceptions		
Level	Gender	Caloric	Pre-kinetic	Kinetic
Form One	Male	33	69	40
	Female	28	57	32
Form Three	Male	19	65	51
	Female	9	50	28

In order to establish whether the distribution of the conceptions was independent of the students' gender at each level, chi-square tests of analyses were done. The results are shown in table 7 below.

Table 7: χ^2-Test Analyses of the Distribution of Students' Conceptions of Heat and the Nature of Heat Between Gender for Form One and Form Three Levels.

		Conceptions				
Level	Gender	Caloric	Pre-kinetic	Kinetic	χ^2-value	P-value
Form One	Male	33	69	40	0.03	0.99
	Female	28	57	32		
Form Three	Male	19	65	51	1.95	0.38
	Female	9	50	28		

($\chi^2_{Tab} = 5.99$, $df = 2$, $\alpha = 0.05$)

The chi-square values obtained ($\chi^2_{Cal} = 0.03$ for Form One and $\chi^2_{Cal} = 1.95$ for Form Three level) were both less than the critical value of chi-square ($\chi^2_{Tab} = 5.99$) for 2 degrees of freedom at the 0.05 level of significance. This means that the distributions of conceptions was independent of gender for these levels.

The following excerpts illustrate some of the caloric conceptions that were expressed by students on this concept:-

Excerpt #1: I understand heat to be some kind of molecules which provide some hotness in an object and also in a human body (Form 1/Male/Student # 112).

Excerpt #2: The term heat refers to hot particles from a source for example sun. Yes, the molecules of heat are very small because they penetrate most substances (Form 3/Male/Student # 8).

Pre-kinetic conceptions can be illustrated by the following excerpts:-

Excerpt #3: Heat is a form of energy which comes out after burning. No, she is not right because heat has no molecules, it's energy. I understand the nature of heat to be wave-like (Form 3/Female/Student # 29).

Excerpt #4: Heat is the energy inside bodies that makes them hot. No, she is not right because heat is not molecular, but is only energy. Heat is a form of energy (Form 1/Male/Student # 33).

The excerpts below illustrate some of the expressed kinetic conceptions :-

Excerpt #5: Heat is the transfer of energy from a high temperature to a lower temperature body. The student is wrong because heat is energy and energy does not involve molecules. The nature of heat is that it is energy which is characterized by its ability to do work (University/Male/Student # 21).

Excerpt #6: Heat is the change in temperature of a body. Heat has no molecules, so she's wrong. I understand the nature of heat to be energy of particles of a body (Form 3/Male/Student # 43).

Analysis of alternative frameworks in this area showed that students are confusing the terms heat and temperature. Many students take the two terms to mean the same. An example of a typical response from which this confusion is inferred is presented below:-

Excerpt #7: I understand heat to be the hotness of a body

(Form 3/Female/Student # 2).

In some cases it was not clear whether the students' meaning of the term heat refers to a process or an absolute end state, for example:-

Excerpt #8: I understand the term heat to refer to the state an object becomes when its temperature rises (Form 3/Male/Student # 211).

A number of students expressed conceptions based on everyday experiences involving heat. For example:-

Excerpt #9: Heat is something that comes out of a fire after burning

(Form 1/Female/Student # 113).

Some students used the 'cause and effects' concept to explain the term heat:-

Excerpt #10: Heat is the effect which causes substances to change their state from one to another (Form 3/Female/Student # 28)

A number of students mostly in Form Three and University levels defined heat as infra-red radiations from the sun:-

Excerpt #11: Heat is the infra-red radiations that come from the sun

(University/Male/Student # 14).

4.2.2 Students' Understanding of Interaction of Heat Energy with Matter

In item number three the students were required to either agree or refute a suggestion that heating a substance would increase its weight as the substance now *'contains heat'*. To further probe students' understanding on this concept, item number four asked the students to explain how *'heat exists'* in a heated body. The italicized phrases were

pseudo-scientific expressions deliberately used to find out whether students would be distracted to think calorically. Students' responses were analysed and their conceptions categorized. The results are presented in table 8 below.

Table 8: Distribution of Students' Conceptions of Interaction of Heat Energy with Matter Among Three Levels of Intellectual Development in Numbers and Percentages of the Totals of each Level.

		Conceptions		
Level	N_i	Caloric	Pre-kinetic	Kinetic
Form One	262	53	131	78
		20.2	***50.0***	***29.8***
Form Three	221	19	120	82
		8.6	***54.3***	***37.1***
University	68	5	10	53
		7.4	***14.79***	***77.9***

Note: Percentage values of N_i are in bold italics

Figure 5 represents a bar chart that illustrates the distribution of the conceptions in percentages of totals for each group.

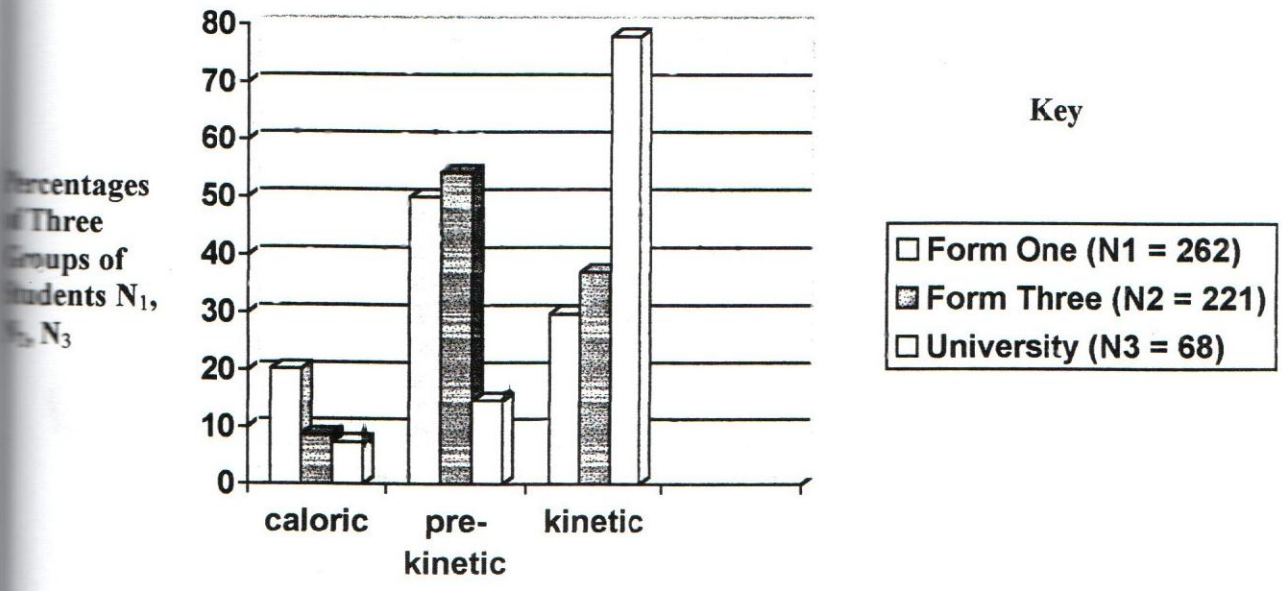


Figure 5:

Distribution of students' conceptions of interaction of heat energy with matter among the three levels of intellectual development.

The bar chart (figure 5) shows that majority of Form One and Form Three students expressed pre-kinetic conceptions (50.0% and 54.3% respectively). Form One level had the highest percentage of caloric conceptions (20.2%) followed by From Three (8.6%) and least at the University level (7.4%). The reverse is true for kinetic conceptions (University –77.9 %; Form Three – 37.1%; Form One – 29.8%). Further analysis was done to establish whether the distribution of the conceptions was a function of the students' level of intellectual development. The results are presented in table 9 below.

Table 9: χ^2 – Test Analysis of the Distribution of Students' Conceptions of Interaction of Heat Energy with Matter Among the Levels of Intellectual Development.

	Conceptions				
Level	Caloric	Pre-kinetic	Kinetic	χ^2-value	P-value
Form One	53	131	78	64.5	0.00
Form Three	19	120	82		
University	5	10	53		

($\chi^2_{Tab} = 9.49$, df = 4, $\alpha = 0.05$)

Results in table 9 show that the chi-square value obtained ($\chi^2_{Cal} = 64.5$) is higher than the tabulated value ($\chi^2_{Tab} = 9.49$) for 4 df at the 0.05 level of significance. This means that the distribution of students' conceptions of interaction of heat energy with matter was not independent of the students' level of intellectual development. The distribution of the conceptions in terms of gender for Form One and Form Three levels is presented in table 10.

Table 10: Distribution of Students' Conceptions of Interaction of Heat Energy with Matter Between Gender for Form One and Form Three Levels.

		Conceptions		
Level	Gender	Caloric	Pre-kinetic	Kinetic
Form One	Male	29	74	46
	Female	24	57	32
Form Three	Male	10	77	48
	Female	9	43	34

Chi-square tests of analyses were done to establish whether the distribution of the conceptions was independent of the students' gender. The results are presented in table 11.

Table 11: χ^2 – Test Analyses of the Distribution of Students' Conceptions of Interaction of Heat Energy with Matter Between Gender for Form One and Form Three Levels.

		Conceptions				
Level	Gender	Caloric	Pre-kinetic	Kinetic	X^2-value	P-value
Form One	Male	29	74	46	2.96	0.24
	Female	24	57	32		
Form Three	Male	10	77	48	1.28	0.52
	Female	9	43	34		

($\chi^2_{Tab} = 5.99$, df = 2, $\alpha = 0.05$)

Results in table 11 show that the chi-square values obtained for both the levels (χ^2_{Cal} =2.96 for Form One level and χ^2_{Cal} = 1.28 for Form Three level) were both less than the critical value (χ^2_{Tab} =5.99) for 2 df at the 0.05 level of significance. Thus the distribution of students' conceptions of interaction of heat energy with matter were independent of gender for both Form One and Form Three levels.

The following examples of students' responses illustrate some of the caloric conceptions held by students on this concept:-

Excerpt #12: The heated water weighs more because heat molecules increase the molecules in water. When an object is heated, heat attaches itself to the molecules of the object (Form 1/Male/Student # 42).

Excerpt #13: The heated water weighs more because heat has weight and occupies space inside the water (Form 3/Female/Student # 68).

Excerpt #14: Heat exists like air inside the heated body (Form 3/Male/Student # 3).

The following excerpts illustrate the pre-kinetic conceptions expressed by students:-

Excerpt #15: Heat is a form of energy inside the water so the weights are the same (Form 1/Female/Student # 15).

Excerpt #16: When a body is heated, heat exists as an energy wave inside the body (Form 3/Male/Student # 26).

Kinetic conceptions can be illustrated by the following typical responses:-

Excerpt #17: Heating cannot increase the weight of water. It only increases the disturbances of molecules of water (Form 3/Male/Student # 118).

Excerpt #18: Heating increases the temperature of a body. The heat energy exists as the kinetic energy of molecules of the body (University/Female/Student #12).

Alternative conceptions in students' responses on this concept were noted. A notable one was that heat has weight and occupies space. This is illustrated by excerpt #13 above. Others expressed that heat occupies space between the molecules of the heated body:-

Excerpt #19: When an object is heated heat exist in the empty spaces between its molecules (Form 1/Female/Student # 108).

A number of students expressed the conception that heat resides on the surface of the body only:-

you touch it feels hot (Form 1/Female/Student # 38).

Conceptions where heat is thought to exist as an energy wave within the body were observed (see excerpt # 16 above). Other students expressed that heat is used up as work done to change the texture of the body for example:-

Excerpt #21: When heated, the heat makes the hard molecules of an object soft and since softer things weigh less, the heated water will weigh less than the cold water (Form 1/Female/Student # 21).

For some students, heat is absorbed by the molecules of the heated body and stored, as illustrated by the following excerpt:-

Excerpt #22: After a body is heated heat enters the particles of the body and is stored in the particles (Form 3/Female/Student # 67).

A notable misconception by those who expressed kinetic conceptions was that heat initiates vibrations of the particles in a heated body-:

Excerpt #23: When an object is heated, the molecules start to vibrate and the object becomes hot (Form 3/Female/Student # 179).

4.2.3 Students Conceptions of Thermal Expansion

Item Number five required students to explain the process of expansion of matter caused by heating. The conceptions held by students are presented in table 12.

Table 12: Distribution of Students Conceptions of Thermal Expansion Among Three Levels of Intellectual Development in Numbers and Percentages of Totals of each Level.

		Conceptions		
Level	N_i	Caloric	Pre-kinetic	Kinetic
Form One	257	61	125	71
		23.7	***48.6***	***27.6***
Form Three	220	19	127	74
		8.6	***57.7***	***33.6***
University	67	4	13	50
		6.0	***19.4***	***74.6***

Note: Percentage values of N_i are in bold italics

The distributions of conceptions were further presented in the bar chart. (figure 6).

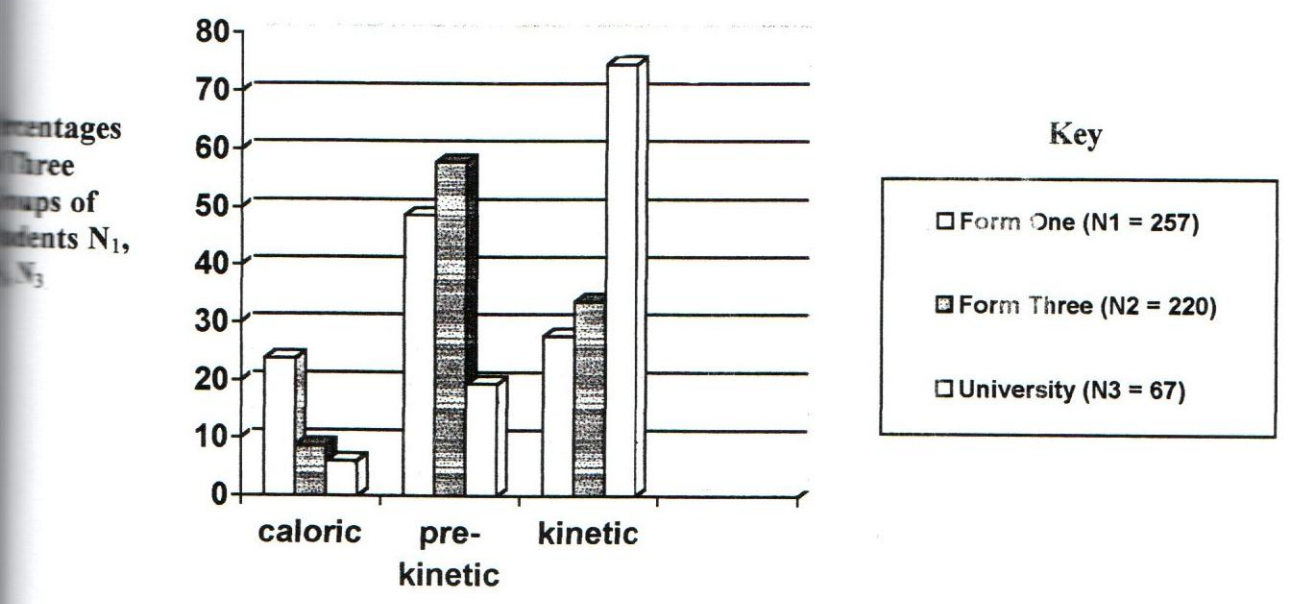


Figure 6:

Distribution of students' conceptions of thermal expansion among three levels of intellectual development.

It can be noted from the bar chart (figure 6) that majority of students in Form One and Form Three levels expressed pre-kinetic conceptions (48.6% and 57.7% respectively) while the majority of University students expressed kinetic conceptions. The percentage of caloric conceptions was highest in Form One level (23.7%) followed by From Three (8.6%) and least in the University level (6.0%). The reverse was true for kinetic conceptions (University – 74.6%; Form Three – 33.6%; Form One – 27.6%). The University level had the least percentage of pre-kinetic conceptions. Further analysis was done to establish whether the distribution of these conceptions was independent of the students' level of intellectual development and the results are given in table 13.

Table 13: χ^2- Test Analysis of the Distribution of Students' Conceptions of Thermal Expansion Among Three Levels of Intellectual Development.

	Conceptions				
Level	Caloric	Pre-kinetic	Kinetic	χ^2-value	P-value
Form One	61	125	71	174.6	0.00
Form Three	19	127	74		
University	4	13	50		

($\chi^2_{Tab} = 9.49$, df = 4, $\alpha = 0.05$)

Results in table 13 show that the chi-square value obtained ($\chi^2_{Cal} = 174.6$ df = 4) is higher than the critical value ($\chi^2_{Tab} = 9.48$) at the 0.05 level of significance. This indicates that the distribution of the conceptions was not independent of the students' level of intellectual development. The distribution of students' conceptions of thermal expansion according to gender is presented in table 14.

Table 14. Distribution of Students' Conceptions of Thermal Expansion Between Gender for Form One and Form Three Levels.

		Conceptions		
Level	Gender	Caloric	Pre-kinetic	Kinetic
Form One	Male	33	77	39
	Female	28	58	32
Form Three	Male	13	78	43
	Female	6	49	31

To determine whether the distribution was independent of gender or not at each level, χ^2-test analyses were done. The results are presented in table 15 below.

Table 15: χ^2– Test Analyses of the Distribution of Students' Conceptions of Thermal Expansion Between Gender for Form One and Form Three Levels.

		Conceptions				
Level	Gender	Caloric	Pre-kinetic	Kinetic	χ^2-value	P-value
Form One	Male	33	67	39	0.04	0.98
	Female	28	58	32		
Form Three	Male	13	78	43	0.69	0.75
	Female	6	49	31		

($\chi^{22}_{Tab} = 5.99$, df = 2, $\alpha = 0.05$)

Results in Table 15 show that the chi-square values obtained ($\chi^2_{Cal} = 0.04$ for Form One level and $\chi^2_{Cal} = 0.69$ for Form Three level) were both less than the critical value ($\chi^2_{Tab} = 5.99$) for 2 df at the 0.05 level of significance. This indicates that the distribution of the conceptions was independent of students' gender.

The following excerpts represent some of the students' responses that expressed caloric conceptions:-

Excerpt #24: When the body is heated it expands because heat enters and pushes out the body (Form 1/Male/Student # 6).

Excerpt #25: When an object is heated it expands because heat has weight and it occupies space within the object (Form 3/Female/Student # 51).

Pre-kinetic conceptions can be illustrated by the following typical responses:-

Excerpt #26: When a body is heated its molecules expand occupying larger space and in the process the whole body expands (Form 3/Male/Student # 204).

Excerpt #27: The body expands because when it is heated the molecules that are in the body multiply and increase in number so the body increases (in size) (Form 1/Female/Student # 48).

Kinetic conceptions can be illustrated by the following examples:-

Excerpt #28: When an object is heated its molecules start to vibrate. This makes them occupy larger space and the whole body is observed to expand (University/Male/Student # 11).

Excerpt #29: When the heat is applied to a body, the molecules vibrate faster and this makes the body expand (Form 3/Female/Student # 112).

A number of alternative conceptions in this area were noted. For those students who expressed caloric conceptions, the argument was that heat has weight and occupies space (see excerpts # 24 and # 25 above). Alternative frameworks observed for the students

expressing pre-kinetic conceptions include those based on the model of particles of the body splitting or multiplying:-

Excerpt #30: When the body is heated the molecules of the body multiply and increase in number leading to expansion (Form 3/Female/Student # 46).

Excerpt #31: The body expands because the molecules that were there before heating divide themselves into many after being broken down by the heat (Form 1/Male/Student # 9).

For other students it is the individual particles of the body that expand, apparently employing macroscopic phenomena at the microscopic level (for example see excerpt # 26 above). Still others used the concepts of particle arrangement within the body, being altered by heating:-

Excerpt #32: Heating breaks the bonds between the molecules of the object. The molecules change their positions taking new ones further apart and the body is observed to expand (University/Male/Student # 17).

It must be emphasized that even where students' conceptions were categorized as kinetic, some of the ideas expressed did not conform to the scientific explanation of expansion. For example, a number of students expressed that it is heating that initiates the vibrations of molecules in the heated body. This is illustrated by the excerpt below:-

Excerpt #33: When an object is heated, its molecules start to vibrate. This makes them occupy larger space and the whole body is observed to expand (University/Male/Student # 34).

For other students it was not clear how increased particle movement due to heating leads to expansion:-

> Excerpt #34: Through heating particles vibrate to and fro faster. As more heating occurs their kinetic energy increases and they knock on each other leading to expansion (Form 3/Female/Student # 13).

4.2.4 Students' Understanding of Heat Transfer

Item number six required the students to explain the process of conduction of heat through matter. The distribution of students conceptions is presented in table 16.

Table 16: Distribution of Students' Conceptions of Thermal Conduction of Heat Among Three Levels of Intellectual Development in Numbers and Percentages of Totals of each Level.

		Conceptions		
Level	N_i	Caloric	Pre-kinetic	Kinetic
Form One	255	73	105	77
		28.6	***41.2***	***30.2***
Form Three	218	38	95	85
		17.4	***43.6***	***39.0***
University	67	8	18	41
		11.9	***26.9***	***61.2***

Note: Percentage values of N_i are in bold italics

Figure 7 represents a bar chart that illustrates the distribution of the conceptions for the different levels.

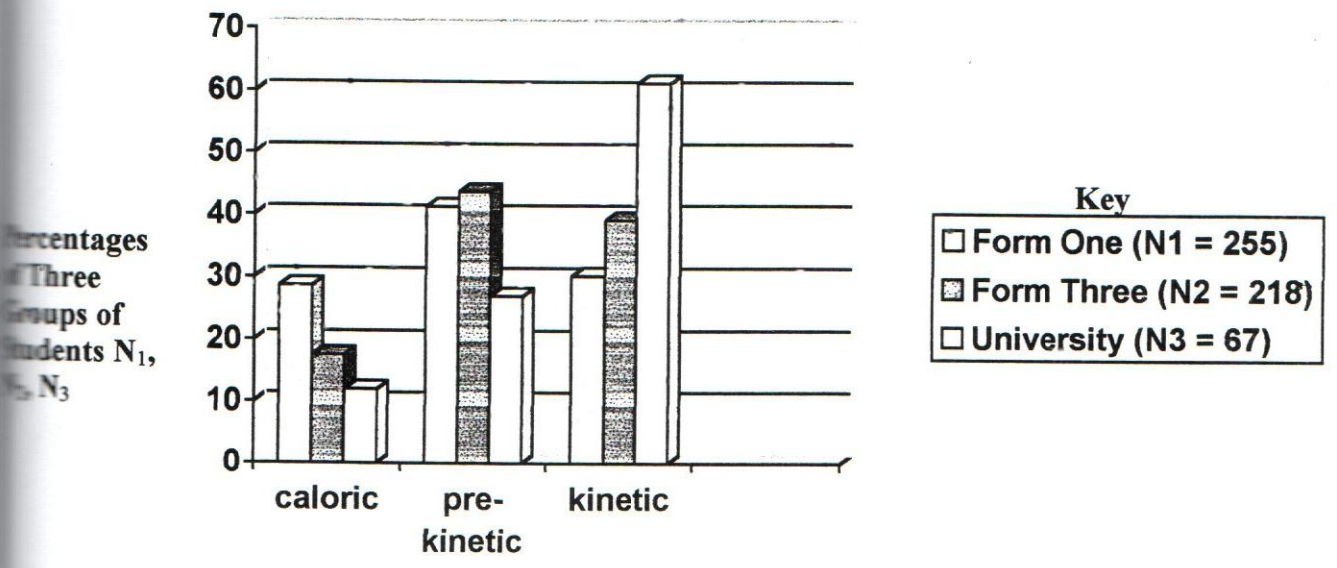


Figure 7:

Distribution of students' conceptions of thermal conduction among three levels of intellectual development.

The bar chart (figure 7) shows that the majority of Form One and Form Three students expressed pre-kinetic conceptions (41.2% and 43.6% respectively). Majority of the University students expressed kinetic conceptions (61.2%). Majority of caloric conceptions were observed among the Form One students (28.6%) and lowest in the University (11.9%). Further analysis was done to establish whether the distribution of the conceptions was independent of the students' level of intellectual development. The results are given in table 17.

Table 17: χ^2- Test Analysis of the Distribution of Students' Conceptions of Thermal Conduction Among Three Levels of Intellectual Development.

	Conceptions				
Level	Caloric	Pre-kinetic	Kinetic	χ^2-value	P-value
Form One	73	105	77	27.5	0.00
Form Three	38	95	85		
University	8	18	41		

($\chi^2_{Tab} = 9.49$, df = 4, $\alpha = 0.05$)

From the results in table 17 the chi-square value obtained ($\chi^2_{Cal} = 27.5$) is higher than the critical value ($\chi^2_{Tab} = 9.48$) for 4 df at the 0.05 level of significance. This indicates that the distribution of the conceptions was not independent of the students' level of intellectual development. The distribution of students' conceptions by gender for Form One and Form Three Levels is presented in table 18.

Table 18: Distribution of Students' Conceptions of Thermal Conduction Between Gender for Form One and Form Three Levels.

		Conceptions		
Level	Gender	Caloric	Pre-kinetic	Kinetic
Form One	Male	40	62	42
	Female	33	43	35
Form Three	Male	22	59	51
	Female	16	36	34

Chi-square tests of analyses were done to establish whether the distribution of the conceptions was independent of gender for both levels. The results are given in table 19.

Table 19: χ^2 – Tests Analyses of the Distribution of Students' Conceptions of Thermal Conduction Between Gender for Form One and Form Three Levels.

		Conceptions				
Level	Gender	Caloric	Pre-kinetic	Kinetic	χ^2-value	P-value
Form One	Male	40	62	42	0.48	0.78
	Female	33	43	35		
Form Three	Male	22	59	51	0.22	0.89
	Female	16	36	34		

($\chi^2_{Tab} = 5.99$, df = 2, $\alpha = 0.05$)

Results in table 19 show that the chi-square values obtained ($\chi^2_{Cal} = 0.48$, for Form One and 0.22 and Form Three level) were both less than the critical value ($\chi^2_{Tab} = 5.99$) for 2 df at the 0.05 level of significance. This indicates that for these levels, the distribution of students' conceptions of thermal conduction is independent of gender.

Examples of caloric conceptions expressed by students are given below:-

Excerpt # 35: The other end of the rod feels warm because when the rod is heated, heat molecules flow from the region of high heat concentration to low heat concentration (Form 1/Male/Student # 184).

Excerpt # 36: Heat flows from the source through the rod to the cold end (University/Male/Student # 61).

The following typical responses illustrate some of the pre-kinetic conceptions expressed by students:-

Excerpt # 37: Heat energy wave propagates through the metal rod to the cold end (Form 3/Male/Student # 165).

Excerpt # 38: The other end feels warm because heat is energy and can flow between matter that is a good conductor (Form 1/Female/Student # 131).

Kinetic conceptions in this area can be illustrated by the following typical responses:-

Excerpt # 39: Once the rod is heated atoms on that end acquire more energy and vibrate faster. These atoms pass their energy to adjacent atoms. This process is repeated until the atoms on the other end are vibrating faster (University/Male/Student # 29).

Excerpt # 40: Particles of the rod (electrons) get more energy and as they collide with others they pass heat energy to the other end of the rod (Form 3/Male/Student # 7).

Analysis of alternative frameworks on this concept indicated that most of those who expressed caloric conceptions used words in their explanations that implied heat as having material characteristics. Such words included heat moves, travels, flows and others, for example:-

Excerpt # 41: This is because heat travels through the rod from the source to the other end (Form 1/Male/Student # 133).

Excerpt # 42: Heat flows through the metal rod until it reaches the other end (Form 3/Female/Student # 120).

A number of students argued that heat has molecules and that these flow from a region of high to low heat concentration, for example: -

Excerpt # 43: The other end feels warm because heat molecules flow from high heat concentration to low heat concentration (Form 1/Female/Student # 159).

Yet other students expressed that just like a gas spreads to fill a container so will heat spread and fill the whole rod:-

Excerpt # 44: When heated on one end, heat starts to circulate and spreads to fill the whole metal rod (Form 1/Female/Student # 35).

Pre kinetic conceptions included alternative conceptions where students used the model of heat transfer by convection to explain conduction:-

Excerpt # 45: Molecules near the heated end move away from the heat source and are replaced by the cold ones from the other end. This way heat transfers throughout the rod (Form 1/Female/Student # 102).

Others explained conduction as the transfer of a heat wave or radiation within the metal rod:-

Excerpt # 46: When the end of the rod is heated, the heat radiation propagates through the rod to the cold end (University/Female/Student # 6).

The most notable alternative conception expressed under kinetic conceptions was the notion that it is heat that initiates the vibrations of molecules of the body. This is illustrated below:-

Excerpt # 47: As you heat the metal rod at the one end, molecules start to vibrate due to the heating and these vibrations are transferred to the neighbouring

molecules which also start to vibrate. This is repeated until the vibrations reach the other end (University/Male/Student # 53).

4.2.5 Student's Understanding of Change of State Caused by Heating

Item number seven required students to explain the process of melting caused by heating. Analysis of students' responses yielded the results shown in table 20 below.

Table 20: Distribution of Students' Conceptions of Melting Caused by Heating Among Three Levels of Intellectual Development in Numbers and Percentages of the Totals of each of the Three Levels.

		Conceptions		
Level	N_i	Caloric	Pre-kinetic	Kinetic
Form One	254	59	110	85
		23.2	***43.3***	***33.5***
Form Three	211	24	106	81
		12.6	***49.5***	***37.9***
University	65	7	14	44
		10.8	***21.5***	***67.7***

Note: Percentage values of N_i are in bold italics

The results were further represented in a bar chart (figure 8).

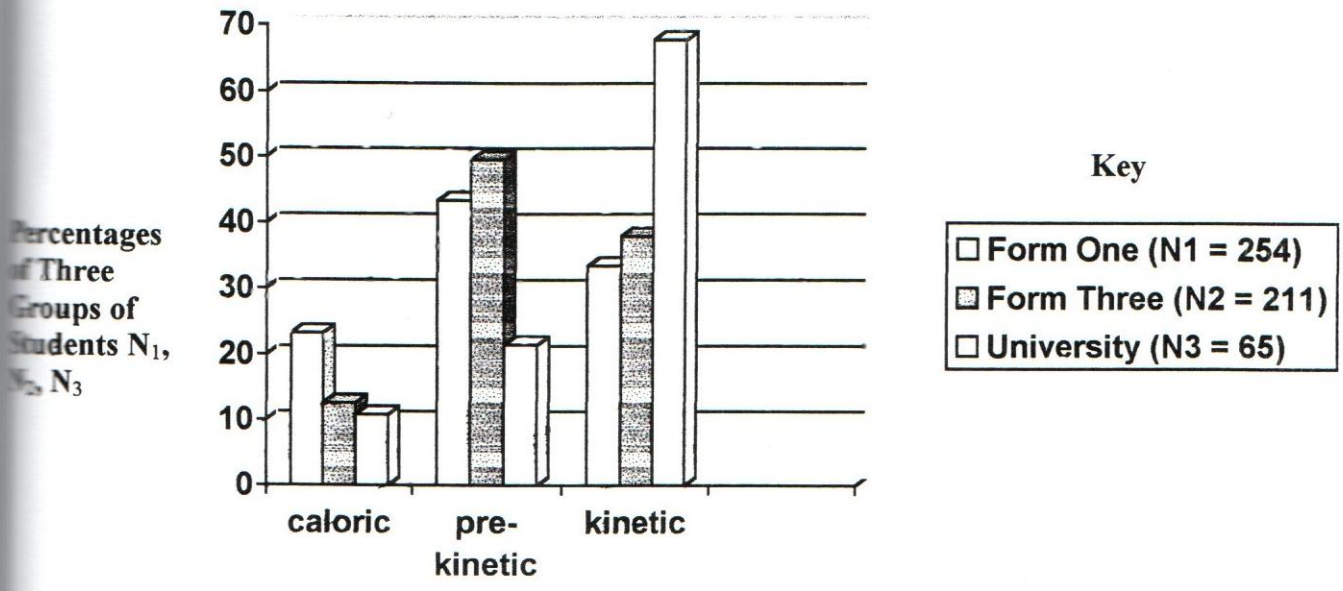


Figure 8:

Distribution of students' conceptions of melting caused by heating among three levels of intellectual development.

From the bar chart (figure 8) it is observed that majority of students in Form One and Form Three used pre-kinetic conceptions ((43.3%) and (49.5%) respectively) while majority of University students used kinetic conceptions (67.7%). The percentage of caloric conceptions was highest in Form One (23.2%) followed by Form Three (12.6%) and least in University level (10.8%). For kinetic conceptions, the highest percentage was at the University level followed by Form Three (37.9%) and lastly Form One level (33.5%). Form Three level represented the highest percentage of pre-kinetic conceptions, (49.5%) then Form One (43.3%) and lastly University level (21.5%). Chi-square test analysis was done in order to establish whether the distribution of the conceptions was independent of the students' level of intellectual development. The results are given in table 21.

Table 21: χ^2-Test Analysis of the Distribution of Students' Conceptions of Melting Among the Three Levels of Intellectual Development.

	Conceptions				
Level	Caloric	Pre-kinetic	Kinetic	χ^2-value	P-value
Form One	59	110	85	33.9	0.00
Form Three	27	106	81		
University	7	14	44		

($\chi^2_{Tab} = 9.49$, df = 4, $\alpha = 0.05$)

Results in table 21 show that a chi-square value of 33.9 was obtained. This value is greater than the critical value ($\chi^2_{Tab} = 9.48$) for 4 df at 0.05 level of significance. This indicates that the distribution of students' conceptions of melting caused by heating was not independent of their level of intellectual development. The distribution of students' conceptions of melting caused by heating according to gender for Form One and Form Three levels is given in table 22.

Table 22: Distribution of Students' Conceptions of Melting Caused by Heating Between Gender for Form One and Form Three Levels.

		Conceptions		
Level	Gender	Caloric	Pre-kinetic	Kinetic
Form One	Male	33	66	46
	Female	26	44	39
Form Three	Male	17	63	49
	Female	10	43	32

students' gender, chi-square tests of analyses were done. The results are presented in table 23.

Table 23: χ^2 – Tests Analyses of the Distribution of Students' Conceptions of Melting Between Gender for Form One and Form Three Levels.

		Conceptions				
Level	Gender	Caloric	Pre-kinetic	Kinetic	χ^2-value	P-value
Form One	Male	33	66	46	0.71	0.70
	Female	26	44	39		
Form Three	Male	17	63	49	0.12	0.93
	Female	10	43	32		

($\chi^2_{Tab} = 5.99$, df = 2, $\alpha = 0.05$)

Results in table 23 show that the chi-square values obtained for both the levels (χ^2_{Cal} = 0.71, and 0.93 for Form One, Form Three levels respectively) were both less than the critical value of chi-square (χ^2_{Tab} =5.99) for 2 df at 0.05 level of significance. This indicates that the distribution of students' conceptions of melting due to heating was independent of students' gender.

The following excerpts represent some examples of students' responses that expressed caloric conceptions on this concept:-

Excerpt #48: When the butter is heated, the heat is going to pass through the butter molecules and turn it into liquid form (Form 1/Female/Student # 120).

Excerpt #49: Heat particles bombard the butter molecules leading to broken bonds between the molecules. This makes them free molecules and butter melts into liquid (University/Male/Student # 5).

The excerpts below represent some of the pre-kinetic conceptions expressed by students:-

Excerpt #50: The absorbed heat energy breaks the bonds between the butter molecules and butter melts (Form 3/Female/Student # 58).

Excerpt #51: The heat radiation absorbed by butter breaks the bonds between its molecules. Molecular forces are broken and butter turns to liquid state (University/Male/Student # 38).

Kinetic conceptions can be illustrated by the following students' responses:-

Excerpt #52: When warmed the heat energy makes the solid butter molecules to drift further apart. This leads to melting (Form 1/Male/Student # 134).

Excerpt #53: Heating increases the kinetic energy of the butter molecules. As more heating occurs the vibrations are so much that the bonds holding the molecules are weakened further. Eventually they become free to move about and solid butter is then observed to melt (University/Male/Student # 17).

Analysis of alternative frameworks in this area indicates that although a large number of students have the idea of latent heat of fusion, the interaction of heat energy with the molecules of the matter that leads to melting is not clearly understood. In the category of those students who expressed caloric conceptions some have the alternative conception

that heat 'exerts' pressure from inside leading to expansion and melting. This is illustrated by the excerpt below:-

> Excerpt #54: When the butter is warmed, the heat enters into the butter and pushes it from inside. The butter expands and when the pressure is so much it melts (Form 1/Male/Student # 221).

Some students also expressed the misconception that heat is matter with its own chemical properties. On heating the 'heat substance' reacts with the particles of matter to change the state of matter. For examples:-

> Excerpt #55: When the butter is heated, the heat particles react with the butter molecules to produce liquid butter (Form 1/Female/Student # 103).

A number of students expressed the misconception that it is the chemical bonding of the melting substance that is altered, for example:-

> Excerpt #56: As butter absorbs the heat energy the bonding of the molecules of butter change. This makes butter to melt (Form 3/Male/Student # 7).

The alternative conception that expansion and finally melting of solids is due to 'stretching' of the bonds between the molecules of the solid were relatively common, for example:-

> Excerpt #57: Heating makes butter to expand and as more heating occurs, there is further stretching of the bonds leading to melting (Form 1/Female/Student # 58).

A notable alternative conception among the students who expressed kinetic conceptions was the idea that the molecules of the body are stationary at first and only after heating commences do they start vibrating. This is illustrated by the following typical response:-

Excerpt #58: Initially before heating the molecules of butter were closely packed together. When warmed the molecules start to vibrate and the bonds between them weaken. This makes them drift further apart and melting occurs (University/Female/Student # 40).

4.3 Students' Metaphorical Heat Conceptions

The second part of the study aimed at establishing whether cultural beliefs in form of metaphors concerning heat exist in students' explanations of everyday life experiences. The QICBSCH and the interview were used to collect data from Form One and Form Three students in mixed, day secondary schools in Nyandarua District (see sections 3.6, 3.7 and 3.8). The data was analysed for each item in the questionnaire and is presented as follows:

1. The frequency (and percentage) of students subscribing to the categories of behavioural and biological changes (see section 3.6).
2. Examples of typical responses for each of the categories. At least one response is given. For each excerpt the code name of the student is given using the format described in section 4.2. The responses are quoted directly with only minor modifications to make outsiders' reading possible.
3. Excerpts from interview data to support the responses of those subscribing to the categories of behavioural and biological changes.

Item number 1 required the students to either agree or disagree that the term 'hot' can be used to describe an angry person and if in agreement, to explain their answer. The distribution of the types of responses given by the students is given in table 24.

Table 24: Distribution of Students' Responses on the Use of the Term 'Hot' to Describe an Angry Person. (N = 494).

Category or Response	*Frequency*	*Percentage*
Behavioural Changes	268	54.2
Biological Changes	119	24.1
Negative	86	17.4
Non-respondents	21	4.3

From the results in table 24, 78.5% of the students were in agreement. Of these 69.3% subscribed to behavioural changes while 30.7% subscribed to biological changes. Those who were in disagreement comprised 17.4% while those who did not respond to this item comprised 4.3% of the students.

The following is an example of typical response of those who subscribed to behavioural changes:-

Excerpt #59: Yes! I would say Njoroge is 'hot' because at the moment he is shouting and quarrelling his neighbour he is in a hot temper. He can even end up fighting him (Form 1/Male/Student # 110).

This student was further probed using the interview:-

Interviewer: How did you know this? Is it something said in your culture?

Student: In Kikuyu, a person who gets angry easily is described as *"nĩ mũhĩ ũ mũtwe"* (he has a hot head).

Interviewer: So Njoroge is one such person.

Student: Yes

An example of a students' response categorized as subscribing to biological changes is illustrated below:-

Excerpt #60: He can be said to be 'hot' because when someone gets annoyed or angry, you see him sweating as he talks, so he is hot (Form 3/Female/Student # 126).

Student (Form 3/Male/Student # 18) who expressed a similar response was interviewed:

Interviewer: You say Njoroge can be described as 'hot' because the temperature of his blood has risen due to the anger in him. Do you mean to say, his blood is now hot .....?

Student: Um ..... Not exactly, what I want to mean is that because of the anger in him, he ..... appears to be hot ..... not the normal heat that can burn but .....

Interviewer: (Interjects) ..... Some other kind of hotness?

Student: Yes .... Um ... you see because of the anger in him, he is not at peace within himself, ... His heart is pumping faster .... he is hot.

4.3.2 Cow on Heat

Item number 2 required students to either agree or disagree that a cow which is on heat can be described as 'hot' and if in agreement to explain their answer. The distribution of the types of students' responses is given in table 25.

Table 25: Distribution of Students' Responses on the Use of Term 'Hot' to Describe a Cow on Heat (N = 494).

Category or Response	*Frequency*	Percentage
Behavioural Changes	245	49.6
Biological Changes	116	23.5
Negative	101	20.4
Non-respondents	32	6.5

The results (table 25) show that those in agreement comprised 73.1% while those in disagreement comprised 20.4% of the students. Non-respondents to this item comprised 6.5% of the students. Of those in agreement, 67.9% subscribed to behavioural while 32.1% subscribed to biological changes.

The excerpt below illustrate an example of students' responses categorized as subscribing to behavioural changes:-

> Excerpt #61: Yes, it can be said to be 'hot' because when cows are on heat they become restless and keep on mowing and mounting over others. It does not settle (Form 1/Female/Student # 30).

The above student was followed with the interview:-

Interviewer: You say the cow can be described as 'hot' because it keeps on mowing and mounting others ..... Is that true?

Student: Yes, um .... The cow is not settled at one place, it moves about ..... abnormally.

Interviewer: This renders it the description of being 'hot'

Student: ah ... Yes, I would say so.

Interviewer: Is this expressed in your culture?

Student: Er .. yes, such a cow is said to 'have a heat' *(ĩ na ũrugarĩ)*, ... not a heat that can burn, but it makes the cow behave abnormally.

The following response was an example of those categorized as subscribing to biological changes:-

Excerpt #62: Yes, the cow can be described as 'hot' because it is being disturbed by its body. Its temperature is high, so it can be said to be hot (Form 1/Female/Student # 120).

The student was later followed with the interview:-

Interviewer: You said the cow's temperature is high. Is that so?

Students: Yes, the cow is burning with desire, this makes its temperature high.

Interviewer: A cow is a mammal ..... so if its temperature were to be higher than normal it would be sick!

Student: Um ... Yeah, but in this case it is not that the cow will be hot, ... what I mean is that it is being disturbed by the state it is in ..... So it keeps moving and becomes restless.

Item number 3 required students to either agree or disagree that a group of boys about to face the circumcisor during an initiation ceremony can be described as 'hot' and if so to explain their answers. The distribution of the types of students' responses is given in table 26.

Table 26: Distribution of Students' Responses on the Use of the Term 'Hot' to Describe Boys Involved in an Initiation Ceremony (N = 494)

Category or Response	Frequency	Percentage
Behavioural Changes	228	46.2
Biological Changes	137	27.7
Negative	87	17.6
Non-respondents	42	8.5

From the results (table 26), 73.9% of the students were in agreement while 17.6% were in disagreement. 8.5% of the students did not respond to this item. Of those who were in agreement, 62.5% gave explanations that were categorized as subscribing to behavioural changes while 37.5% were categorized as subscribing to biological changes.

An example of students' explanations subscribing to behavioural changes is illustrated below:-

> Excerpt #63: Yes, they can be said to be 'hot' because of the fear in them. They are very afraid of the circumcisor and are worried of the pain they are going to experience (Form 1/Male/Student # 198).

This explanation is supported by the responses of student (Form 1/Male/Student # 19) who was interviewed on this item:-

Interviewer: You say the boys can be described as 'hot' because they are very anxious and nervous, true?

Students: Yes, they have never gone through it (circumcision) before and they know it is a painful process.

Interviewer: So because of anxiety, you can describe them as 'hot'.

Student: Er, ... Yeah, but not that they are 'hot' as of high temperature but ..... I mean ..... (gesturing).

Interviewer: I see.

The following is a typical response categorized as subscribing to biological changes:-

Excerpt #64: Yes, the boys can be described as 'hot'. This is because they sweat even when it is cold because of fear (Form 3 Female/Student # 127).

The same student was interviewed on this item:-

Interviewer: You say the boys are 'hot' because you can see them sweating even when cold?

Student: Yes, ... they are afraid ..... they tremble with fear.

Interviewer: Fear makes them hot .....?

Student: Not that their bodies are hot as such .... What I mean is that they ..... do not have peace within themselves ..... Their hearts are pumping faster ..... so blood is flowing faster.

Interviewer: Is this why they sweat?

Student: Er..... yeah, they sweat not because of heat, but .... because of fear in them.

Interviewer: Do you have something like that in your culture ..... does your language describe as 'hot' somebody who is in fear?

Student: Er,.....let me see,....I don't see, but I think somebody in a bad situation is said to be not cool, ... *"ti mũ horo"*..... meaning he is not cool.

4.3.4 Childbirth/Labour

Item number 4 required students to either agree or disagree that a mother in labour can be described as 'hot' and if so to explain their answer. The distribution of students' responses is given in table 27.

Table 27: Distribution of Students' Responses on the Use of the Term 'Hot' to Describe a Mother at Childbirth (N = 494).

Category or Response	Frequency	Percentage
Behavioural Changes	119	40.3
Biological Changes	174	35.2
Negative	78	15.8
Non-respondents	43	8.7

It was found that 75.5% of the students agreed while 15.8% disagreed that the mother can be described as hot. 8.7% of the students did not respond to the item. Of those who were in agreement, 53.4% gave explanations that subscribed to behavioural changes while 46.6% gave responses subscribing to biological changes.

behavioural changes:-

Excerpt #65: Yes, she can be said to be 'hot'. I say so because in this situation the mother is very worried, even crying, because she is in a lot of pain (Form 3/Female/Student # 3).

The student was probed further in the interview:-

Interviewer: You've explained that the mother can be described as hot because she is worried and in a lot of pain, true?

Student: Yes,

Interviewer: So because she is worried and in pain, how does that lead to her being described as 'hot'.

Student: Because she is not alright; ... You see, when one is not in peace, she can be described as hot.

Interviewer: Is this something you learnt in school or you've learnt it as you grew?

Student: I learnt as I grew, ... that a bad situation is also a 'hot' situation ..... like the one the mother is in.

The following is an example of a response categorized as subscribing to biological changes:-

Excerpt #66: Yes, the mother can be said to be 'hot'. This is because she is undergoing a very sensitive process and this makes her blood flow faster (Form 1/Female/Student # 28).

The student supported her answer in the interview:-

Interviewer: You say the mother can be described as 'hot' because her blood is flowing faster, true?

Student: Yes, the heart is pumping faster.

Interviewer: So that makes her 'hot' or what?

Student: Not 'hot' as to increase the body temperature ..... I mean she is in a bad situation and so she is not at peace within herself.

Interviewer: Her blood flow is distrubed, you mean, ...?

Student: Yeah,.....something like that.

4.3.5 Bees Attack

In item number 5 the subjects were asked whether they would describe students under bees attack as 'hot'. If 'yes' they were asked to explain their answers. The distribution of students' responses is given in table 28.

Table 28: Distribution of Students' Responses on the Use of the Term 'Hot' to Describe Students Under Bees Attack (N = 494).

Category or Response	*Frequency*	*Percentage*
Behavioural Changes	256	51.8
Biological Changes	147	29.8
Negative	70	14.2
Non-respondents	21	4.2

Results (table 28) show that 81.6% of the students were in agreement while 14.2% disagreed that the students can be described as 'hot'. 4.2% of the students did not respond

to this item. Of the students in agreement, 63.5% subscribed to behavioural changes while 36.5% subscribed to biological changes:-

The following is an example of a student's response that was categorized as subscribing to behavioural changes:-

Excerpt #67: Yes, the boys can be described as hot. I say so because this is a bad situation as the students face the danger of being stung by the bees (Form 1/Male/Student #230).

The students was further probed using the interview:-

Interviewer: You describe the boys as hot because they are in a dangerous situation, is that true?

Student: Yes, that is true.

Interviewer: So according to you people in dangerous situations can be termed 'hot'?

Student: Yes, the situation is 'hot' itself.

Interviewer: In Kikuyu, do you have anything in your language or beliefs that implies this?

Student: Yes, we say a very bad situation is a 'hot' one ....*'nĩ kũhiũ mũno'*. So people in such a situation can also be said to be 'hot'.

The following is an example of a typical response classified as subscribing to the category of biological changes:-

Excerpt #68: Yes, the students can be described as 'hot' because as the bees sting them, their blood becomes hot due to the pain (Form 3/Male/Student # 108).

The student supported his answer in the interview:-

Interviewer: You say the bee stings make the blood of the students hot?

Student: Yes,....the stings are very painful.

Interviewer: How does the pain make the blood hot?

Student: Er.....I don't mean to say the blood becomes hot ..... what I mean is that the stings are very painful and so the student who is stung is very uncomfortable.

Interviewer: Then in that state you describe him as 'hot'?

Student: Um..... ya, we can say that.

4.3.6 Menstruation

Item number 6 asked the students whether menstruating girls can be described as 'hot' and if 'yes', they were asked to explain why they said so. The distribution of their responses is given in table 29.

Table 29: Distribution of Students' Responses on the Use of the Term 'Hot' to Describe Menstruating Girls (N = 494).

Category or Response	Frequency	Percentage
Behavioural Changes	199	40.3
Biological Changes	179	36.2
Negative	85	17.2
Non-respondents	31	6.3

Results in table 29 show that 76.5% students were in agreement while 17.2% were in disagreement that menstruating girls can be described as hot. 6.3% of the students did not respond to the item. 52.6% of those who were in agreement subscribed to the category of behavioural changes while 6.3% subscribed to biological changes.

The following excerpt illustrates a student's response categorized as subscribing to behavioural changes:-

Excerpt #69: A menstruating girl is in a very uncomfortable situation because those things (blood) may come out unexpectedly and they feel shameful (Form 1/Female/Student # 139).

Student Form 3/Male/Student # 61, explained that such girls can be described as 'hot' because they are very 'moody'. He was probed further in the interview:-

Interviewer: You've explained that the girls are very 'moody' at such times, so they can be said to be 'hot', true?

Student: Yes, ... they are always angry.

Interviewer: The anger makes them 'hot' or what?

Student: Er... not really, ...not that they are 'hot' as to have high temperature but they are ..... not comfortable.

The following is an example of a typical response categorized as subscribing to biological changes:-

Excerpt #70: Yes, the girls can be described as 'hot'. This is because the process is accompanied by a lot of blood loss and is sometimes painful (Form 3/Female/Student # 160).

The student supported her response in the interview:-

Interviewer: You say there is a lot of blood loss and pain, and because of these the girl can be described as 'hot', is that right?

Student: Yes, there is a lot of blood movement in the body, because the heart is pumping faster.

Interviewer: So the girl is 'hot'?

Student: Yeah, we can say she is 'hot'.

Interviewer: Meaning her body temperature is higher than normal?

Student: No,..... this is not an illness, it is a normal process, only that it is sometimes painful.

Interviewer: So when you say she is 'hot' it does not mean her body temperature is high?

Student: No, its only that she might be in pain.

4.3.7 Active Person

Item number 7 asked students whether an active and hardworking person can be described as 'hot' and if 'yes' to explain why they said so. The distribution of students' responses is given in table 30.

Table 30: Distribution of Students' Responses on the Use of the Term 'Hot' to Describe an Active Person (N = 494).

Category or Response	*Frequency*	*Percentage*
Behavioural Changes	301	60.9
Biological Changes	110	22.3
Negative	61	12.3
Non-respondents	22	4.5

The results (table 30) show that 83.2% of the students responded in the affirmative while 12.3% responded in the negative. 4.5% of the students did not respond to the item. Of those who responded in the affirmative, 73.2% were categorized as subscribing to the behavioural while 26.8% were categorized as subscribing to biological changes.

The following is a typical response categorized as subscribing to behavioural changes:-

Excerpt #71: Yes, Kamau is a 'hot' boy because he is active everywhere. He works fast, runs fast meaning he is 'hot' (Form 1/Male/Student # 239).

On being interviewed, the student supported his answer:-

Interviewer: You say that because Kamau works hard and runs fast he can be described as 'hot', right?

Student: Yes....., he is sharp....., he can do many things in a short time.

Interviewer: In your language, is what you are saying supported?

Student: Um.... In Kikuyu we say such a person has hot hands ..... *'nĩ mũhiũ moko'.*

Interviewer: Would that mean that the temperature of his hands is high?

Students: No, ... it means they are quick.

The following student's response was categorized as subscribing to biological changes:-

Excerpt #72: Yes, Kamau can be described as 'hot'. This is because his brain is quick to co-ordinate all the things he can do within a short time (Form 1/Male/Student # 111).

The following excerpts illustrate her support of the answer in the interview:-

Interviewer: So if Kamau has sharp brain, he can be described as 'hot'?

Student: Er..... yeah, I would say so.

Interviewer: Can we therefore say that he has a 'hot' brain?

Student: Er..... Yes, we can say his brain is hot.

Interviewer: Do you say that in Kikuyu?

Students: What we say is that the person is hot, *'nĩ mũhiũ'*, meaning he is quick.

4.3.8 Impatience

Item 8 asked students whether an impatient person due to waiting for long time can be described as 'hot'. If 'yes' they were asked to explain their answers. The distribution of students' responses is given in table 31.

an Impatient Person (N = 494).

Category or Response	Frequency	Percentage
Behavioural Changes	291	58.9
Biological Changes	91	18.4
Negative	73	14.8
Non-respondents	39	7.9

From the results (table 31) it can be seen that 77.2% of the students agreed while 14.8% disagreed. Non- respondents in this item comprised 7.9% of the students. 76.2% of the students who replied in the affirmative gave explanations categorized as subscribing to behavioural changes while 23.8% were categorized as subscribing to biological changes.

An example of a typical response categorized as due to behavioural changes is illustrated below:-

Excerpt #73: Yes, Wambui can be described as 'hot'. This is because she is very restless and full of worry of what may have become of her friend (Form 3/Female/Student # 124).

The student was further probed with the interview:-

Interviewer: So because she is restless she can be said to be 'hot'?

Student: Er.....yes, she is uncomfortable and worried.

Interviewer: Is this supported in your culture, for example your language?

Student: Yes, ... when a person is not in a comfortable situation, he is said not to be 'cool' ..... *'ti mũ horo'*, I think this applies to Wambui.

An example of a student's response categorized as subscribing to biological changes is illustrated below:-

Excerpt #74: Yes, Wambui can be described as 'hot' because the worry in her makes her blood flow faster due to her heart pumping faster (Form 1/Male/Student # 111).

The following interview excerpts illustrate the student's support of his answer:-

Interviewer: You say Wambui's blood flows faster due to worry and because of this she can be described as 'hot', right?

Student: Yes.

Interviewer: How does the blood flow faster?

Student: I think, it's because the heart pumps faster.

Interviewer: And how does this make her 'hot'?

Student: The girl is not hot....., its only that she is in a bad situation that makes her uncomfortable.

Interviewer: So her blood flows faster?

Student: Er... she is disturbed and so she has no peace inside herself ..... the mind is agitated .....

4.4 Discussion of Results

4.4.1 Results of Students' Physical Heat Conceptions

From the analysis of students' responses in the QSPIH, results show that a low number of students subscribed to the caloric conceptions. Majority of the students in secondary schools subscribed to pre-kinetic conceptions while majority of the University students

subscribed to the kinetic conceptions. When the conceptions were scaled against the students' level of intellectual development, a significant value of chi-square at 0.05 level was obtained on all the concepts studied. This indicates that the distribution of the conceptions was not independent of the students' level of intellectual development. As such, hypothesis Ho2 that the level of intellectual development has no significant influence on students' conceptions of heat is rejected. This finding seems to be in agreement with that of Erickson (1980) where he found that students' conceptualization of heat and temperature increased with their level of cognitive development.

These findings could be interpreted as resulting from the interaction of biological and environmental factors as well as interventional inputs. Biological factors include those that show strong correlation with chronological age while environmental factors include the physical and social influences surrounding the student. Interventional factors include those planned learning experiences deliberately designed and forming the educative process. According to Baltes and Nesselroade (1979) interaction of these factors form the basis of cognitive development. Influences of environmental and interventional factors are time related meaning that the length of exposure to these factors may have significant consequences for the magnitudes of measurable outcomes.

The QSPIH also sought to analyse findings for male and female students separately to discern differences, if any, in students' physical conceptions concerning heat. The results show that when the conceptions are categorized in terms of the prevailing theories of heat namely caloric, pre-kinetic and kinetic, no major difference exists in terms of gender. A non-significant value of chi-square was obtained on each concept for both Form One and

Form Three levels. This means that hypothesis Ho3 that gender difference has no significant influence on students' conceptions of heat cannot be rejected at the 0.05 level of significance. This finding is in accord with that of Zietsman and Naidoo (2000) who found no gender differences on students' understanding of thermal properties of matter. The properties included heat and temperature, thermal expansion, heat transfer and change of state. The results are further supported by Baumert (1998) who concluded that understanding of physics concepts may have very little to do with gender but depends a whole lot on the contextual situation of the content.

Analysis of alternative conceptions showed that students at all levels have misconceptions on the concept of heat and the phenomena associated with it. The results showed that although there was relatively high frequency of responses described as kinetic and pre-kinetic as compared to caloric conceptions, the conceptions were mostly crude and intuitive. Carramaza et al. (1981) used the term 'naive' to describe such conceptions which would be applicable to many of those expressed by students in this study. It is worthy to note that even University students expressed such naive conceptions.

On the whole, the alternative conception that heat is caloric had the lowest occurrence. This suggests a divergence from the findings reported in the Western countries. Albert (1978), Erickson (1975,1979,1980), Tiberghien (1980) and Shayer and Wylam (1981) all reported evidence of extensive caloric thinking among school students. For example Shayer and Wylam reported that about 80% of their subjects aged between 13-18 years used caloric conceptions to explain heat. This is in contrast with the findings of Hewson

amongst school children. Harris (1981) suggested that the use of caloric conceptions in the Western countries could be a semantic problem in which the languages in these countries use words for heat which influence students to think calorically. Examples of such words include 'heat flows', 'heat travels', and others. It could be hypothesized that few caloric conceptions were observed because all the subjects in this study were Africans. Most of these students especially from the rural areas use English as a third language (after mother tongue and kiswahili in that order). The Kikuyu language which is commonly used by the secondary students in this study does not have words for heat which are suggestive of caloric notions. On the contrary, as discussed in section 4.4.2, the Kikuyu involve a connotative meaning of heat which is influenced by the presence of a metaphor concerning heat.

A number of students used empirical ideas at a macro level to model explanations at a micro level. Alternative conceptions involving particles splitting, multiplying and expanding were relatively common. While such conceptions were identified by Hewson and Hamlyn (1984) and Zietsman and Naidoo (2000) the researcher found no evidence of their existence among the students in the Western countries except for Erickson (1975) whose category called 'pre-kinetic view-points' seems to incorporate some of these alternative conceptions.

4.4.2 Results of Students' Metaphorical Heat Conceptions

Analysis of students' responses in the QICBSCH and the interview show that metaphorical heat conceptions are present albeit in varying amounts in students from Nyandarua District. These results can be viewed in the context of the students' cultural beliefs concerning heat. The social and economic life of Kikuyu people appears to have given rise to a metaphor concerning heat. The people in this region are predominantly small scale farmers. For this reason climatical conditions are of special concern to them and 'heat' pervades many aspects of their lives.

Among the Kikuyu people there is a belief that 'coolness is good' and the converse 'hotness is bad'. There is a popular Kikuyu greeting *"wĩ mũhoro?"* which means "are you well"? but directly translates as "are you cool"? On the other hand a volatile situation is described as 'hot'. This is exemplified by the popular Kikuyu phrase *"kũhiũhĩ te ta thathi wa nĩnyuko"*, which directly translates as the "the situation is as hot as the soup of a bony animal". This could be used to explain why most students described the people or animals in situations involving negative feelings such as anger, impatience and others as 'hot'.

The Kikuyu people associate the state of increased physical activity for example vigor to the concept 'hot'. A person who is quick with his hands is usually said to have 'hot hands' (*moko mahiũ*). There is also a popular saying among the people that *"werũ ũkwenda mbĩ a hiũ"*, which directly translates as "the wilderness requires a hot rat". It means that for survival one has to be very active. The Kikuyu word *"hiũha"* has two meanings; 'get hot'

and 'hurry up'. This logically fits with the kinetic theory of heat which involves increased random movement of particles of matter.

Whereas no direct causality can be attributed to this fact as far as the present study is concerned, it would appear that there is an inferential logical fit between the metaphorical conceptions and the high frequency response for pre-kinetic and kinetic conceptions expressed by the Form One and Form Three students. As noted by Shumba (1995), this could be one area where indigenous thought interacts in a manner complementary to the accepted scientific theory.

CHAPTER FIVE

CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

5.1 Introduction

In this chapter, the summary of the major findings is presented as well as the conclusions reached and the recommendations emanating from the results of this study. The educational implications of the study are discussed and suggestions on possible areas for further research highlighted.

5.2. Summary of the Major Findings

On the basis of the data analysis presented in Chapter Four, the following are the major findings arising from the study.

1. Students' physical heat conceptions, when categorized in terms of the early and contemporary theories of heat namely caloric, pre-kinetic and kinetic, are influenced by the students' level of intellectual development but not gender.
2. Students in all the three levels of intellectual development namely Form One, Form Three and Second year University held misconceptions on the topic of heat.
3. A cultural metaphor concerning heat exists in secondary school students of the Kikuyu ethnic community living in Nyandarua District.

5.3. Conclusions

A number of conclusions have been reached based on the results of this study. In respect to the hypotheses posited for testing, the findings of the study are in the affirmative that

students' physical conceptions when categorized in the context of the early and contemporary scientific theories of heat namely:- caloric, pre-kinetic and kinetic, are a function of the students' level of intellectual development but not gender.

The study also demonstrated that students have alternative frameworks on their conceptualization of heat. Though not very commonly expressed, conceptions that heat has material characteristics were noted in some students' explanations. Alternative conceptions such as those involving models based on observable physical phenomena at the microscopic level, for example particles of matter splitting, expanding or multiplying were expressed relatively frequently. Alternative conceptions involving kinetic heat theory for example heating initiating particle vibrations indicate that students have a misconceived model of the kinetic theory of matter.

The results concerning the metaphorical heat conceptions indicate that a particular heat metaphor exists among the secondary students of Kikuyu ethnic community living in Nyandarua District. According to the metaphor, the concept 'hot' is used to describe a condition concerning increased physical movement of the body or a change in behaviour of people or animals in a situation involving negative feelings for example anger, pain and sickness. These metaphorical conceptions are influenced by the students' cultural beliefs concerning heat.

5.4 Implications of the Study

Heat is a fundamental concept in physics and indeed in science education. The findings of this study raise a number of questions regarding the most appropriate way of presenting the concept to students. For example, at what level should the topic of heat be introduced to pupils? A look at the current syllabus indicates that the concept of heat is introduced to pupils in standard five (K.I.E., 2001). It may be difficult to explain the concept of heat to pupils at this level, for example Patel and Vasishta (2000) introduce the topic of heat with the remark that "it is difficult to say exactly what heat is but we can say something about what it does ....." (p. 121). The effects of heating on matter are not explained, for example according to K.I.E (2000), "When heat is applied to a body, the body becomes hot" (p. 106). No explanation is given as to what happens so that the body 'becomes hot'. Patel and Vasishta state that when matter is heated, it usually expands. No explanation is given as to how this happens. The danger of such scenario is that students may construct conceptualizations based on alternative frameworks. This is because according to Bar and Galili (1994) students do not make sense of new concepts in isolation but utilize already well formed prior understandings and if absent construct new ones.

During classroom instruction teachers need to take into account individual differences in students' prior conceptions on the topic of heat. This is because students ideas are diverse and are influenced by a number of factors, for example their underlying knowledge and cultural beliefs. Out of these prior conceptions, teachers need to identify those that are based on alternative frameworks so that they can be corrected before formal instruction.

Another educational implication points towards concept learning in physics education. The findings of this study indicate that the concept of heat is misunderstood by students even those at the University. This is illustrated by the kinds of alternative conceptions that were expressed by the students at all the levels. If one considers that the University B.Ed - science students involved in this study are shortly going to teach the concept of heat and the phenomena associated with it to students in secondary schools, one may well see the need to emphasize concept learning in teacher training institutions.

The results of students' metaphorical heat conceptions indicate that students belonging to the Kikuyu ethnic group in Nyandarua District and with caution to those outside Nyandarua District may be at a relative advantage in learning about the concept of heat when compared to their counterparts in the Western countries. This may be because their existing knowledge concerning heat is in some sense close to a kinetic view. This could well be due to the influence of a prevalent cultural metaphor involving the concept of heat. Unlike their counterparts in the Western countries these students do not have to unlearn outdated scientific notions of caloric heat before being able to acquire the contemporary kinetic view of heat. This is because features of their particular existing knowledge may be more easily reconciled with the kinetic theory of heat.

5.5 Recommendations

Based on the results of this study the researcher makes the following recommendations.

1. The physics curriculum should be reorganized so that pupils are introduced to ideas of kinetic theory of matter before the topic of heat is introduced to them. A

reasonable introductory level treatment of particulate nature and kinetic theory of matter in primary science could provide an ideal foundation on which ideas about the effects of heating on matter can be built.

2. There is need for the physics curriculum planners at the K.I.E and the education inspectorate to examine the educational materials in schools and in the market to ensure that they convey the right ideas about the nature of heat. This is because some materials especially text books written by authors from the Western countries contain words for heat which may convey caloric conceptions of heat. For example Murray (1991) uses the following remark to introduce the concept of heat: "In our everyday lives we recognize 'heat as something' which can be produced by a variety of methods ....." (p.122). The use of the words 'heat as something' convey caloric conceptions of heat.
3. Concept learning in physics should be given more emphasis in schools and in teacher training institutions. As suggested by Okere (1996) one possible way of reducing misconceptions held by students would be to emphasize misconceptions in schools' and teacher training institutions' syllabi. Teacher trainees would be exposed on the concepts, for example heat, that students find difficult to understand. In schools, physics teachers could allocate some periods for discussions where pupils are encouraged to talk physics.
4. There is need to integrate some aspects of indigenous cultural knowledge that interact in a manner complimentary to the accepted science into our school science curriculum. For example in this case students' cultural beliefs concerning heat identified in this study could be harmonized with the scientific view of heat so that students see science as part of their culture. As observed by Shumba

(1995), although we go to books for science, it may already be existing in our culture, only that it is not in written documents.

5.6 Suggestions for Further Research

The present study has explored the kinds of conceptions that students use to explain heat and its associated physical phenomena over the intellectual range from secondary up to University level and had highlighted some of students' alternative conceptions. The study has attempted to investigate the influence of the level of intellectual development and gender on students' conceptions when categorized in terms of the prevailing theories of heat which include caloric, pre-kinetic and kinetic. The study has also attempted to investigate the influence of cultural beliefs on conceptions of heat among students of Kikuyu ethnic community living in Nyandarua District. Areas that warrant further investigations include the following:

1. A more in-depth exploration to gain further insights into the students' conceptualization of heat in an attempt to establish how the alternative conceptions are formed.
2. It is likely that the subjects of this study who did subscribe to the caloric views of heat probably acquired these ideas in school as a consequence of learning in the medium of English and using materials like text books written in English. This hypothesis would be worth investigating.
3. An extension of the present study to cover physics teachers to explore their own ideas concerning the concept of heat. Such a study could also attempt to find out

students.

4. A quantitative study to investigate the effect of the cultural metaphor concerning heat identified in this study on students' conceptions of heat.
5. In addition, further research into the generalizability of the results concerning the existence of cultural metaphors concerning heat is recommended to cover other ethnic communities living in Kenya.

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APPENDIX A

SAMPLE SCHOOLS AND THEIR PHYSICS ENROLMENTS.

FORM ONE

SCHOOL	PHYSICS ENROLMENT		
	MALE	FEMALE	TOTAL
1. Mwenda Andu	20	18	38
2. Turasha	22	17	39
3. Karati	24	16	40
4. Mahindu	19	18	37
5. Gichungo	22	13	35
6. Gatimu	23	19	42
7. Kagondo	24	14	38
TOTAL	**154**	**115**	**269**

FORM THREE

SCHOOL	PHYSICS ENROLMENT		
	MALE	FEMALE	TOTAL
1. Turasha	19	6	25
2. Gitogo	16	12	28
3. Heni	13	10	23
4. Gichungo	9	3	12
5. Ngano	11	10	21
6. Githunguchu	9	5	14
7. Malewa	15	12	27
8. Kirima	16	10	26
9. Manyatta	14	7	21
10. Mirangine	15	13	28
TOTAL	**137**	**88**	**225**

APPENDIX B

QUESTIONNAIRE ON STUDENTS' PHYSICAL IDEAS ABOUT HEAT (QSPIH)

INSTRUCTIONS

- The purpose of this questionnaire is to find out your ideas about the concept of heat and its associated physical phenomena. Please attempt all the items in the questionnaire and give your best responses.
- You are reminded that this is not a test. The results will not in any way affect your grades in your normal school / University examinations.
- The responses you give will be treated with utmost confidence.

NAME : _____

SEX : Male ☐ Female ☐ (tick appropriately)

LEVEL : SECONDARY Form One ☐ (tick appropriately)

Form Three ☐

NAME OF SCHOOL: _____

UNIVERSITRY : B.Ed ☐ (tick appropriately)

B.Sc ☐

1. Explain in your own words what you understand by the term 'heat'.

2. A student asked by her teacher to describe the nature of heat said that "the molecules of heat are very small".

   (a) Would you agree with her statement?

   Yes ☐ No ☐ (tick appropriately)

   (b) If your answer to (a) above is NO give a reason.

   (c) How would you describe the nature of heat?

3. A student poured equal amounts of water in two similar beakers. He then heated one of the beakers for sometime. No evaporation took place and no air was expelled. His colleague suggested that the hot water weighed more than the cold water as the hot water 'contained heat'.

   (a) Is he right?

   Yes ☐ No ☐ (tick appropriately)

   (b) Give reasons for your answer.

   _____

   _____

   _____

   _____

   _____

   _____

4. When an object is heated for sometime it is observed to become hot. Explain in your own words how the heat acquired 'exists' in the object.

   _____

   _____

   _____

   _____

   _____

   _____

   _____

5. When heated an object is observed to expand, that is, the size of the object increases. Explain what heat does to the object so that this happens.

6. When a metal rod is heated at one end after sometime the other end feels warm. Heat is then said to be conducted from the hot to the cold end.
Explain how this conduction takes place.

7. When a piece of butter is warmed it melts, that is, it turns from solid to liquid.
Explain what heat does to the butter so that this happens.

APPENDIX C

QUESTIONNAIRE TO ASSESS INFLUENCE OF CULTURAL BELIEFS ON *STUDENTS' CONCEPTIONS OF HEAT (QICBSCH)*

INSTRUCTIONS

- The purpose of this questionnaire is to find out your ideas on the concept of heat. Please attempt all the questions and give your sincere responses.
- Answer ALL the questions in this questionnaire as truthfully as possible.
- The responses you give will be treated with utmost confidence. You are therefore requested to be honest in your responses.

NAME : _____

NAME OF SCHOOL: _____

SEX : Male ☐ Female ☐ (tick appropriately)

LEVEL : SECONDARY Form One ☐ (tick appropriately)

Form Three ☐

ETHINICITY: Kikuyu ☐ (tick appropriately)

Non-Kikuyu ☐

Note: Kikuyu ethnicity means both parents are of Kikuyu ethnic tribe.

Non-Kikuyu ethnicity means one or both parents are not of Kikuyu ethnic tribe.

1. Njoroge is very annoyed by his neighbor. He is shouting and gesturing at him angrily. Would you describe him as 'hot'?

Yes ☐ No ☐ (tick appropriately)

Explain why.

_____

_____

_____

_____

_____

_____

2. A cow on heat is usually very restless. Would you describe such a cow as 'hot'?

Yes ☐ No ☐ (tick appropriately)

Explain why you say so.

_____

_____

_____

_____

_____

_____

3. A group of boys are about to face the circumciser during an initiation ceremony. Would you describe the boys as 'hot'?

Yes ☐ No ☐ (tick appropriately)

Explain why.

4. Would you describe a mother in labour as 'hot'?

Yes ☐ No ☐ (tick appropriately)

Explain why you say so.

5. A swarm of bees invade a classroom full of students studying. The students run out helter skelter. Would you describe this situation as 'hot'?

Yes ☐ No ☐ (tick appropriately)

Explain why you say so.

6. Girls at puberty normally have menstruation. Would you describe a menstruating girl as 'hot'?

Yes ☐ No ☐ (tick appropriately)

Explain why.

_____

_____

_____

_____

_____

_____

_____

7. Kamau is a very active boy. If given some work he does it very fast. He is a fast runner and is also quick with his hands. Would you say that Kamau is a 'hot boy'?

Yes ☐ No ☐ (tick appropriately)

Explain why you say that.

_____

_____

_____

_____

_____

_____

_____

8. Wambui has been waiting for her friend for a long time. It is growing late and she has become very impatient. Would you say that she is 'hot'?

Yes ☐ No ☐ (tick appropriately)

Explain your answer.

APPENDIX D

SCORING SCHEME FOR QISPH

Item 1:

EITHER

Heat is energy in transfer 1

brought by temperature difference. 1

OR

Heat is the process of energy transfer 1

due to temperature difference. 1

Maximum score **2**

Item 2

(a) No 1

(b) (Definition of heat)

- Heat is energy in transfer due to temperature difference. 1
- Therefore its nature does not involve molecules. 1

Maximum score **3**

Item 3

(a) No 1

(b) (Definition of heat)

- Heat only affects the internal energy of molecules in a body. 1
- Has no effect on the mass/weight of a body OR does not affect the amount of matter in a body. 1

Maximum score **3**

Item 4

- Heat exists as internal energy 1
  of molecules/particles in a body 1

Maximum score 2

Item 5

- Heating increases magnitude of vibrations of molecules. 1
- The mean separation of molecules increases. 1
- The size of the body increases. 1

Maximum score 3

Item 6

- Molecules near the heat source vibrate more vigorously. 1
- Increased vibrations are passed to neighbouring molecules. 1
- The process spreads throughout the body. 1

Note: For metals energy is transferred by free electrons.

Maximum score 3

Item 7

- Heating increases energy of butter molecules. 1
- Vibrations are quicker and extend further. 1
- Sufficient heating gives molecules enough energy to become free (latent heat) 1
- Freedom of molecules allow them to flow over each other – makes solid butter turn to liquid form. 1

Maximum score 4

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