


Effects of Cognitive Conflict Instructional Strategy on Students' Conceptual Change in Temperature and Heat

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Abstract

The purpose of this study was to investigate the efficacy of cognitive-conflict-based physics instruction over the traditionally designed physics instruction on students' conceptual change in heat and temperature. The subjects were 249 senior secondary II students from 2 schools purposively sampled from 12 secondary schools. The 2 schools sampled had well-equipped laboratory, experienced physics teachers, and two intact classes. One of the intact classes in each school was assigned to control group. In one school, there were 70 subjects for experimental group and 60 for control group, while in the other school, there were 60 for experimental group and 59 for control group. Both groups were taught by the same teacher, and this lasted for 6 weeks of intensive treatment. The experimental group received cognitive-conflict-based instruction, while the control group received traditionally designed physics instruction. The instrument for obtaining the data was thermal concept evaluation (TCE). Students in both groups were pretested using TCE to establish their level of initial understanding of heat and temperature. At the end of the treatment, the same test was administered as posttest. The data generated from the TCE were analyzed using frequency and chi-square statistics, indicating that the level of understanding of heat and temperature was significantly dependent on the treatment. Based on the findings, some recommendations were made.

Keywords

misconceptions, understanding, cognitive conflict, heat and temperature

Introduction

The Nigerian Federal Ministry of Education (FME; 2008) regards physics as a crucial subject for effective living in the modern age of science and technology. The curriculum indicates that every student needs to be given an opportunity to acquire some physics conceptual knowledge, theory, principles, and skills, which are enshrined in the objectives of physics education in the *New Senior Secondary Physics Curriculum* (2008). The objectives of teaching physics to Nigerian students are to (a) provide basic literacy in physics for functional living in the society, (b) acquire basic concepts and principles of physics as a preparation for further studies, (c) acquire essential scientific skills and attitudes as a preparation for technological application of physics, and (d) stimulate and enhance creativity.

Attainment of the above objectives requires a teacher who uses learner-centered teaching approaches as learning takes place when the learner is actively involved during teaching and learning interaction. Hence, the challenge before a teacher is how to bring about meaningful teaching that will engender meaningful learning (Novak, 2002). In so doing, the teacher needs to take into consideration the learner's

prior knowledge, which anchors the new knowledge (Limon, 2001). Hence, the idea that every learner constructs his or her own concept/knowledge and comes into the classroom with existing conceptions, which may be in consonance or otherwise with the scientific conceptions or paradigm, is an established fact (Baser, 2006; Foster, 2011; Ivowi, 2011; Lee & Byun, 2011).

In science, learning of concepts can occur under three different conditions (Chi, 2008). First, a student may have no prior knowledge of the to-be-learned concepts, although they may have some related knowledge. In this case, prior knowledge is missing, and learning consists of adding new knowledge (Chi, 2008). Second, a student may have some correct prior knowledge about the to-be-learned concepts, but that knowledge is incomplete. In this incomplete knowledge case, learning can be conceived of as gap filling. In the third

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condition, a student may have acquired ideas, either in school or from everyday experience, that are “in conflict with” the to-be-learned concepts (Vosniadou, 1994). The prior knowledge that is in conflict with scientific knowledge is called misconception (Chi, 2008).

Misconceptions are false beliefs in one’s mental model. Misconceptions are also incorrect ideas about a concept or belief. Misconceptions originate from prior knowledge of everyday experiences or ones obtained from school. Some misconceptions have been found to be not only resistant, but also persistent to change. These categories of misconceptions are called robust misconceptions (Chi, 2008; Lee & Byun, 2011). That is, robust misconceptions are resistant and persistent to change.

Misconceptions may originate from category mistakes. Category mistakes occur when a learner mistakenly assigns concepts into wrong lateral or ontological categories (Chi, 2008). A lateral category is a category occupying different branches of the same tree, while an ontological category is a category between different trees. Category mistakes account for robust misconceptions (Chi, 2008). This implies that a category mistake once it gets registered into a learner’s mental framework results in a wrong or flawed mental model. That is, students think of some concepts from different ontological categories from those assigned by scientists. This suggests that conceptual change must involve an ontological change in the student’s cognitive structure.

The structure of a conception may vary considerably from a relatively amorphous collection of ideas with no strong connection to one which is interrelated and possesses a large measure of internal consistency. Therefore, developing a solid base of knowledge about students’ conceptions should be instrumental to providing a framework for considering the learning processes involved in changing students’ conceptions, as well as providing a framework for designing instruction that facilitates the expected changes.

In the Nsukka Education Zone, students have been found to have a number of misconceptions about current electricity (Madu, 2004), elasticity (Agumuoh, 2010), and force and motion (Ugwuanyi, 2012). A literature review revealed that students in other parts of the world possess misconceptions about heat and temperature (Yeo & Zadnik, 2001). As students hold misconceptions related to mechanics and electricity and other concepts related to physics, the researchers predict that the students in this educational zone may equally have misconceptions in heat and temperature. The current study investigates this and seeks to determine whether a particulate teaching approach may affect the level of misconceptions.

Research Question

Research Question: How significant is physics students’ conceptual change, taught using a cognitive conflict approach, compared with the traditional physics instructional (TPI) strategy?

Hypothesis

Null Hypothesis 1: The physics students’ level of conceptual change is significantly independent of the treatment (conflict instructional strategy and TPI).

Theoretical Overview

Students’ Conceptions of Heat and Temperature

Acquiring the concepts of heat and temperature poses many conceptual challenges to students, which often means that students fall back to their alternative conceptions (ACs). This is because heat and temperature are not directly observable quantities (Leura, Otto, & Zitzewitz, 2005). Yeo and Zadnik (2001) list ACs held by students about heat and temperature, such as heat is not energy, heat and temperature are the same, the use of skin and touch methods determines temperature, heat rises, the boiling point is the maximum temperature, and there is no limit to the lowest temperature attainable. In the same vein, students think of heat as physical objects, such as hot molecules or a material substance such as “hot stuff” or “hotness,” as indicated by phrases such as “molecules of heat,” or expressions such as “close the door, you’re letting all the heat out” (Wiser & Amin, 2001). Another misconception is that heat can be contained as if it was an object like marbles (object category), or a substance such as sand or water. In either case, heat is misconceived as a kind of entity, whereas from a scientific point of view, heat is seen as a process rather than an entity. For example, heat or the sensation of “hotness” is the speed at which molecules jostle: The faster the speed, the “hotter” the molecules feel. Thus, heat is “hot molecules” or “hot stuff” (an entity), but more accurately, the speed of molecules (process category; Chi, 2008). Technically, the term *heat* is a noun, but refers not just to the total energy of molecular motion in a substance, but to the transfer of energy as a result of a temperature gradient or differences. That is, heat is defined as “the transfer of energy,” or energy in transit from one hot object, or substance to another colder object or substance, and therefore heat is a process. The use of a noun to represent a transfer process, and defining heat as the transfer of energy, which is also a noun, is unfortunate (Chi, 2008). Noting this confusion, it is not surprising that Baser (2006) indicates that misconceptions in heat and temperature are not peculiar to students, and that also scientists have difficulties applying their scientific knowledge related to heat and temperature to everyday situations. For example, scientists give different answers to a question on the relative insulating properties of aluminum foil and wool (Baser, 2006). To overcome such problems of misconceptions, students should be presented with learning situations that would bring about a change in their belief system. Hence, this change in their belief system has been regarded as conceptual change.

Overview of Conceptual Change

Conceptual change, according to White and Gunstone (1989), is a principle or belief change, a change in a meta-physical belief. Westbrook and Rogers (1992) defined conceptual change as a process of using instructional strategies to bring children's thinking into line with that of scientists. Conceptual change in this study is taken to be a student's change in reasoning patterns on moving from one level of understanding to another. That is, tracing the movement of a student from one level of understanding to another. That is, tracing the number of students who move from PU to sound understanding (SU) or from an AC to a PU or SU. Hence, conceptual change is viewed from the social context.

For instance, Tobin (1992) states that conceptual change is a social process by which students make sense of their experience in terms of extant knowledge. As all learning occurs in a social milieu, all learning is inherently social. By extension, conceptual change is primarily brought about by way of thinking about learning, that is, it is something that a learner does as an intentional act, rather than something done by a teacher (P. W. Hewson, 1992). So, in summary, conceptual change is a change or modification or rejection of one's conceptual beliefs when presented with an anomalous situation.

Posner, Strike, Hewson, and Gertzog (1982) developed a "Conceptual Change Model" (CCM) which has two components: The first is the condition (dissatisfaction, intelligible, plausible, and fruitfulness [DIPF]) to be met (or not met) for a learner to experience conceptual change. Dissatisfaction is a state of dislike for an old concept, which will pave the way for the learner to assimilate the new one. Posner and colleagues (1982) considered the phase of conflict generated by dissatisfaction with the existing concepts as a first step to achieving conceptual change. In this phase of dissatisfaction, students realize that they need to reorganize, restructure, or change to some extent their existing ideas or concepts. It seems that to change something, an individual needs to recognize the need for a change and to be willing to do it (Limon, 2001).

In intelligibility, the learner knows what the concept means and understands the terms symbols and syntax of the mode of expression. Here too, the learner constructs or even identifies a passage or theoretical propositions. For example, students with the naive conception that heat and temperature are the same will, at this point, understand that they are not really the same and, in addition, know why.

Plausibility is the state of believing in something on the grounds that it is true. At this stage, according to Hewson and Hennessy (1992), the learner believes that the concept is true and consistent with other conceptions accepted by the learner.

Fruitfulness occurs when a newly accepted conception/idea can solve previously insoluble problems, or suggests new possible directions or ideas. The new conception

becomes fruitful and accommodation of it seems fruitful (Hewson & Hennessy, 1992; Posner et al., 1982).

Posner and colleagues (1982) summarized the CCM by noting that learning proceeds smoothly when the learner meets the conditions for conceptual change. For example, when a learner encounters a new concept that conflicts with his or her conceptual beliefs, the learner may first feel dissatisfied, but then on checking the intelligibility of that concept, its plausibility and fruitfulness, the learner accepts it by replacing the old wrong concept. Without this, the learner rejects the new concept.

The second component of conceptual change is a person's conceptual ecology. Conceptual ecology may be seen as the learner's previous knowledge, or the alternative cognition of the learner. Conceptual ecology provides the context in which the conceptual change occurs. It influences the change and gives it meaning. Conceptual ecology consists of many different forms of knowledge, the most important of which may be epistemological commitments (e.g., to consistency or generalizability), metaphysical beliefs about the world (e.g., the nature of time), and analogies and metaphors that might serve to structure new information (P. W. Hewson, 1992). However, to understand the conceptual change components requires an instructional model that can stimulate and enhance students' conceptual change. This is because some instructional models have been found to be defective in changing students' concepts in science. Examples of such models are traditional teaching methods (e.g., the lecture method).

Generally, the literature has shown that traditional instruction, which does not take into account the existing beliefs of students, is largely ineffective in changing students' naive scientific ideas (Baser, 2006; Eryilmaz, 2002; Yeo & Zadnik, 2001). However, conceptual change research has led to the development of a variety of teaching methods and strategies which encourage students to actively reflect on, and evaluate, their existing knowledge (Yeo & Zadnik, 2001). Among others, one such strategy is a cognitive conflict instructional (CCI) strategy.

Overview of Cognitive Conflict

Cognitive conflict is a perceptual state in which one notices the discrepancy between one's cognitive structure and the environment (external information), or among the different components (e.g., the conceptions, beliefs, substructures, etc.) of one's cognitive structure (Lee & Kwon, 2001).

Cognitive conflict in classical theory is a "revolutionary" process believed to make learners either accept the scientific conception by dissatisfying them with their AC or retaining their conception if unable to satisfy the conditions for the scientific conception. Cognitive conflict occurs when a student's mental balance is disturbed by experiences (referred to as "anomalous data") that do not fit into their current understanding (Foster, 2011).

The cognitive conflict strategy involves (a) identifying students' current state of knowledge; (b) confronting students with contradictory information that is usually presented through texts and interviewers, thus making explicit the contradiction, or guide the debate with the student or among peers (small groups or the whole classroom); and (c) evaluating the degree of conceptual change between the students' prior ideas or beliefs and a posttest measure after the instructional intervention (D. W. Hewson & Hewson, 1984). To understand cognitive conflict, knowledge of the cognitive conflict process model is imperative. The reason is because it explains the stages in which cognitive conflict occurs and how to resolve the generated conflict(s).

Lee and Kwon (2001) developed a three-stage cognitive conflict process model, which includes preliminary, conflict, and resolution. The preliminary stage represents a process in which a student who has belief in preexisting conception accepts an anomalous situation (e.g., experimental results obtained by a teacher) as genuine. If the students do not have a strong confidence in a well-formulated conception or if they consider the anomalous situation as deceptive, they do not experience cognitive conflict. Thus, the preliminary stage is the stage before cognitive conflict (Lee et al., 2003). In this model, the cognitive conflict process occurs when a learner (a) recognizes an anomalous situation, (b) expresses interest or anxiety about resolving the cognitive conflict, and (c) engages in cognitive reappraisal of the situation. For instance, when learners recognize that a situation is incongruous with their conceptions, they become interested in or anxious about this situation (Lee et al., 2003). Relating this to heat and temperature, where a student, who originally believes that a sense of touch can be used to measure the temperature of a substance, now observes through an anomalous experiment that the sense of touch does not reliably measure temperature of a substance, the student becomes interested or anxious about the situation and now cognitively reappraises his or her previously held misconceptions and accepts the scientific conception of the use of thermometer to measure the temperature of a body. The resolution stage is an external response behavior (Lee et al., 2003). Response behaviors include ignoring, rejection, uncertainty, exclusion, abeyance, reinterpretation, peripheral and theory change.

The purpose of this study was to investigate the efficacy of CCI strategy over the TPI on students' conceptual change in temperature and heat. Specifically, the study intends to determine the effects of CCI strategy on students' conceptual change in physics.

Method

Design and Area of Study

The design of the study was a quasi-experimental design. Specifically, a nonequivalent control group design was used for the study. In this type of design, the researchers cannot

randomly sample the research subjects, but treatments are randomly assigned to the research subjects.

The study was conducted in the Uzo-Uwani Local Government Area with 12 secondary schools. The choice of the Local Government Area was borne out of the fact that earlier research has shown that students in the area have a number of misconception problems in physics, especially in the areas of force and motion (Ugwuanyi, 2012), and electric current (Madu, 2004). Hence, the researchers wanted to investigate whether the students in the zone equally held misconceptions in heat and temperature, or are physics misconceptions peculiar to force and motion and electric current?

Sample

The subjects were 249 senior secondary II students from two schools, purposively sampled from 12 schools in the area of the study. That is, the sample size of this study was 249. The reason for the choice of the 2 schools purposively selected was these 2 schools enjoy common characteristics that are not present in the other schools. These characteristics are well-equipped physics laboratory, experienced physics teachers, and two intact classes.

Instrument

The thermal concept evaluation (TCE) instrument was used for both the pretest and posttest to measure students' conceptual change in their understanding of heat and temperature. The instrument was originally developed by Yeo and Zadnik (2001) and adapted by the researchers. TCE has been proven valid in real-life application by researchers (Baser, 2006). TCE originally had 26 items with four choices, although some items had five choices. For each item, there was no correct key (i.e., no right or wrong answer), but each of the options had an answer that exposed the learner's alternative or scientific conceptions. For this study, each response in TCE was scored at four levels (3-0), where 3 was assigned to scientific conception (i.e., SU), 2 to transitional conception (PU), and 1 and 0 to an AC or no conception (NC), respectively. The scientific conception represented the most preferred and acceptable response. Transitional (partial) conception showed a learner's abandonment of his or her naive conception, while an AC represented a naive conception. An example of a TCE question was as follows:

- On a stove is a kettle full of water. The water has started to boil rapidly.

The most likely temperature of water is about (a) 88°C, (b) 98°C, (c) 110°C, (d) [None of the above answers could be right].

Give a reason for your answer.

-
- Five minutes later, the water in the kettle is still boiling. The most likely temperature of water is now about (a) 88°C, (b) 110°C, (c) 98°C, (d) 120°C.

Give a reason for your answer.

The researchers modified the original instrument by requesting the students to give the reason for their answer. This aimed at finding out the student's reason for the option preference and to enable the researchers to determine qualitatively the nature of the learner's conceptual change. The researchers made all the options of the instrument uniform (i.e., four options [A-D] for each of the items of the instrument). Also, the researchers changed all the foreign names such as Lee, Pam, Mel, Zack, and Jan used in the stems to familiar local names such as Obi, Chinasa, and Ada.

The instrument was subjected to trial testing using 20 students from one school in the Uzo-Uwani Local Government Area that was not among the sampled schools in the study. This was to avoid bias and test-wise effect on the subjects.

After the trial testing, the reliability of TCE was determined using Cronbach's alpha because this instrument had polytomously scored items (i.e., each item of the instrument had no preferred right or wrong answer). Using this formula, the internal consistency index of the instrument was calculated to be .79.

As the same TCE was used for the pretest and posttest, the estimate of temporal stability through the process of test-retest was carried out, and the scores of the two administrations, undertaken with an interval of 2 weeks, were correlated using Pearson's product moment correlation coefficient (r) and calculated to be .88. All internal consistency analysis was undertaken using Statistical Package for Social Sciences (SPSS) Version 15.

Experimental Procedure

In this study, two instructional approaches were used: an approach using the CCI model and a TPI approach. The applications of the two instructional approaches were the same in terms of their content, instructional objective, and evaluation. The only major difference between the two was that in the CCI approach, the three-step CCI approach was used stepwise. These three steps were as follows:

- Identifying students' current state of knowledge. This was carried out using pretest. In this case, TCE was administered to the students of the two groups (experimental and control) to determine students' preconceptions or naive conceptions related to temperature and heat;
- Confronting students with contradictory information, usually presented through texts and interviewers, so

as to make explicit the contradiction or only guide the debate with the student or among peers (small groups or the whole classroom), or by the teacher; and

- Evaluating the degree of change between students' prior ideas or beliefs and a posttest measure after the instructional intervention. Often, conflict might be induced by presenting information that clearly contradicts students' ideas, beliefs, or theories (Limon, 2001). The six steps were as follows:

- Identifying students' AC;
- Presentation of anomalous situation;
- Creation of cognitive conflict with the anomalous situation;
- Students' interactions with peers;
- Discussion/summary; and
- Evaluation of degree of change between students' prior idea and posttest measure.

These steps are tagged as IPCSDE.

In this approach, students formed groups of two. The teacher demonstrated an anomalous situation experiment to activate students' "alternative" conceptions. After this, students were requested to carry out the activity and obtain a result which would contradict with their previous conceptions and set students in cognitive conflict. The students were asked to discuss the results of the activity and also their previous ideas with their peers. This enabled the students to interact with each other, exchange their ideas, and discuss observations from the activity. Finally, the teacher collected their different ideas about the experiment, summarized them on the board, and discussed them with the whole class, whereupon correct ideas were determined and explained in detail.

The students in the second school were taught the same topics using TPI. The students in this secondary school were used as the contact group. Throughout this article, TPI refers to the following teaching strategy. The teacher used a lecture and discussion method to teach the concepts heat and temperature. The students studied the physics textbook on their own before the class session. The teacher structured the entire class as a unit, wrote notes on the blackboard about the definition of concepts, and solved a number of quantitative problems. The main principle was that knowledge resides with the teacher and that it was the teacher's responsibility to transfer the knowledge to the students. When the teacher finished the explanation, some concepts were discussed through instructor-directed questions. The teacher solved some chapter-end problems from the textbook on the blackboard. The classroom typically consisted of the instructor presenting the "right way" to solve the problems. The teacher assigned some chapter-end problems to students as homework. In the laboratory, TPI students carried out the experiments and made records in their laboratory manual. Before coming to the laboratory, students read the manual on their own and made

preliminary preparations, for example, wrote a theoretical framework of the experiment and answered questions about the theoretical base of the experiment. In the laboratory, they followed the manual to undertake the experiment, record and analyze data, obtain results, and accordingly write the report for the experiment.

Detailed lesson notes were written for the two groups following the CCI model and the TPI. The study lasted for 6 weeks as per the time duration stipulated in the new physics curriculum for the topics (FME, 2008).

Data Collection and Analysis

Data obtained from administering the TCE as a preconception test to the students to both groups in their respective schools were used to determine the students' naive or preconception related to heat and temperature. Thereafter, each teacher administered the TCE as a conception test after 4 weeks to the two separate groups. Conceptual-trace analysis (CTA) was used in measuring specific type of change or conceptual shift of the students in temperature and heat, testing the research hypotheses at the $p < .05$ level, that is, tracing the movement of students from one level of understanding to another conception (understanding). In determining the specific level of changes in students' knowledge, the following criteria were adopted to classify the responses:

- SU (or Sound Conception)—Such responses indicated that students seemed to have acquired an integrated scientific perspective. They were able to restructure their ideas and gave a coherent explanation of the phenomenon.
- PU (or Transitional Conception)—Such response indicated that students seemed to have merely a partial knowledge of the phenomena/concepts. Although ideas were not verbalized in an integrated way, some understanding was evident.
- AC—Students gave just one simplistic, incorrect viewpoint. Generally, students gave a linear explanation rather than seeing a number of factors as being responsible for the phenomenon. These responses indicated a lack of understanding about the phenomenon or concept.
- NC—Students failed to formulate an answer. They sometimes admitted that they had some exposure to the information but could not assess it, that is, the students' reasoning was contrary or irrelevant response, or no response.

Once all pretest and posttest responses had been assigned to one of the four categories, the researchers traced what changes that had occurred from the pretest to the posttest using chi square, this being a nonparametric statistic able to handle items at a nominal level (i.e., frequency and percentage).

Results

Test Results

It can be observed from the table that the pretest for both CCI and TPI groups showed the two groups were nearly at the same preconception state at all levels of understandings. The students in the CCI group had ACs and NCs, which accounted for 26.9% and 30.0%, respectively, while the TPI group had 27.7% and 28.6% for alternative and NC, respectively. This meant that the number of students who had AC and NC before instructions in CCI and TPI groups when summed together was 74 for CCI and 67 for TPI. However, after the treatment, it was observed that CCI group had a higher percentage in SU (37.7), a value greater than the TPI group with a SU of 24.3%. This meant that 20 students and 1 student, respectively, now shifted to SU in the CCI and TPI groups after instructions. Also, 34 and 44 students now had PU in CCI and TPI of heat and temperature, respectively. It can equally be seen that students' ACs still persisted in the two groups, that is, 28.5% and 27.7% for the two groups, respectively. This represents 37 and 33 students in both groups.

Also, 10 and 13 students still had NCs after instructional treatments. This finding confirmed the finding of Chi (2008) who found that students' ACs are resistant to change. This persistent and resistant to change is called robust misconception.

Testing the Hypotheses

Null Hypothesis: The physics students' level of understanding was significantly independent of the treatment (CCI strategy and TPI).

Data in Table 1 indicate that the students' level of understanding is significantly dependent on the treatment in favor of CCI, and thus the null hypothesis needs to be rejected.

Discussion

Student Justification Responses

Students' reasoning in responding to the example item was presented. Reasons given by most students in the experimental group to the first part of the item were that the "water just started to boil" and "the water has passed the boiling point." Students who gave these reasons failed to understand that water boils at 100°C. In the second part, most students gave their reasons as "there is an increase in temperature." These reasons implied that most students failed to understand that when water boils at 100°C any increase in the application of heat to the boiling water will not increase the temperature, but will result in breaking down the intermolecular forces between the molecules of water and thereby change the water into vapor.

The students in the control group gave reasons for their answers to the first part as follows: "The water may have

Table 1. Overall Conceptual Trace Analysis of Response of Students by Group and by Levels of Understanding on Pretest–Posttest Scores.

Treatments	SU	PU	AC	NC	Total
CCI pretest	29 (22.3)	27 (20.8)	35 (26.9)	39 (30.0)	130
Posttest	49 (37.7)	34 (26.1)	37 (28.5)	10 (7.7)	130
TPI pretest	28 (23.5)	24 (20.2)	33 (27.7)	34 (28.6)	119
Posttest	29 (24.3)	44 (37.0)	33 (27.7)	13 (11.0)	119

Note. () = Numbers in parentheses are the percentages. SU = sound understanding; PU = partial understanding; AC = alternative conception; NC = no conception; CCI = cognitive conflict instruction; TPI = traditional physics instruction.

Table 2. χ^2 Analysis of Response of Students by Group, by Levels of Understanding on Posttest Scores.

Treatment	SU	PU	AC	NC	Total	df	χ^2	p
CCI posttest	49 (40.7)	34 (40.7)	37 (36.6)	10 (12.0)	130			
TPI posttest	29 (37.3)	44 (37.3)	33 (33.5)	13 (11.0)	119	3	6.558	.000
Total	7	8	78	70	23	249		

Note. () = Numbers in parentheses are the expected frequencies. SU = sound understanding; PU = partial understanding; AC = alternative conception; NC = no conception; CCI = cognitive conflict instruction; TPI = traditional physics instruction.

impurities, which increase the boiling point”; “The water could boil below its boiling point”; “Because 98°C is close to the boiling point of water.” The responses implied that students regarded the boiling point of water as a consequence of impurities in the water.

In the second part, most students gave reasons as follows: “The time was increased; hence the boiling point must increase”; “The temperature of the water will reduce when the boiling point is reached”; “An increase in heat will increase the boiling point.” The students in this group failed to understand that heating of water does not depend on time, but on the quantity of heat supplied.

Conceptual Change

A significant change occurred in the number of students who shifted from one level of understanding to another as a result of the treatment. After the treatment in both groups, it was observed that the majority (70%) of students in the CCI group remained in, or shifted to, either sound or PU (see Table 2). In the TPI group, some students shifted their conception from AC/NC to either SU or PU. From all indications, it was observed that only 1 student shifted to SU, while 20 shifted to PU of heat and temperature.

The difference was taken to indicate that CCI provides an opportunity for students to take an active role in building their own knowledge by modifying their existing conceptions through the process of conceptual change. This is in consonance with the opinions of Pines and West (1986) that students’ active role in any instruction brought about the modification of their existing knowledge and subsequent changes. The study by Rollink and Rutherford (1993) revealed the efficacy of using language and conceptual change strategies in remediation of the ACs held by students

before formal physics instructions took place. They concluded that the use of a conceptual change strategy was effective in facilitating conceptual shift. In this study, there was an overall increase in the students’ ability to answer questions about the specific heat and temperature topics after the intervention. This implied overall that the students in the conceptual change group (CCI) had significant gains in their content understanding compared with those in TPI group.

The trace analysis indicated a large gain in responses moving into SU, as well as PU, from AC/NC. However, it was observed that students in the two groups differed in their shift from AC/NC to scientific understanding. This is not surprising, given that PU is a typical outcome of many different types of science instruction (Boujode, 1991). Although both types of instruction provided gains in achievement related to heat and temperature, the gain in the experimental group was statistically higher than that in the control group. It could be claimed that this difference could be attributed to the following properties: activation of students’ ACs, presentation of a situation that could not be explained with existing concepts, creation of cognitive conflict to deal with this anomalous situation, active construction of students’ non-knowledge, students’ interaction with each other to share their ideas about the anomalous situation and its possible solution, and the new conception seen as helpful to solve similar problems that could be encountered in the future. These were in agreement with the themes of both constructivism and conceptual change theory posed by Posner and colleagues (1982).

As shown from this study, conceptual change based on cognitive conflict was a powerful instruction technique to teach physics concepts. The difference between their ACs and scientist was explained. It was also revealed that there was a significant relative effect of the cognitive conflict

strategy and TPI on students' levels of understanding of heat and temperature in favor of the group taught through the cognitive conflict strategy. This means that 61.54% of the instrument items were found to be meaningfully addressed using instructional interventions in favor of the CCI group who obtained the highest frequencies and percentages in all items, while 38.46% of the items did not depend on instructional treatment. Empirical findings by others are in consonance with the findings of this study. For instance, Madu (2004) found that students' level of understanding is significantly dependent on instructional treatment in 80% of questions. Madu's finding has been validated by Agumuoh (2010) who found that students' levels of understanding depended on instructional treatment.

Also, trace analysis in this study revealed, based on students' levels of understanding, that students' misconceptions/AC/NC are resistant and persistent to change. This finding is in line with Chi (2008) and Lee and Byun (2011) who showed similar findings and called resistant misconceptions "robust misconceptions."

The result from the study showed that cognitive conflict initiated the first step in the process of conceptual change. The study further revealed that CCI promoted students' conceptual change more than TPI, that is, the CCI enabled students to experience conceptual shift more than a traditional approach. This implied that senior secondary school physics teachers would be enabled to understand that even though TPI saved time in terms of content coverage by the teacher, the way to resolve students' misconceptions is through the use of cognitive-based instruction with students involved in dealing with cognitive conflict.

Conclusion

The findings of this study show that students have misconceptions in conceptualizing temperature and heat, and that these misconceptions/ACs are resistant to change. CCI as a conceptual change pedagogy is significantly more effective in repairing these misconceptions as compared with the TPI. The null hypothesis is therefore rejected.

Recommendations

In line with the findings of this study, the researchers made the following recommendation:

Conceptual change instructions like cognitive conflict instruction should be adopted by science teachers, educators, and authors and publishers of science books. Science teachers should be trained on how and when to use conceptual change instructions like cognitive conflict instruction to foster conceptual change.

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