

A Case Study of What Experiences Contribute to The Ideas of Energy Held By Primary School Students in Trinidad and Tobago

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Abstract

This case study explored what experiences contribute to the ideas of energy held by 30 purposively selected primary school students from one primary school in Trinidad and Tobago. The 30 students were selected from across all levels of the primary system. The study used the Interview About Events (IAE) approach to explore students' ideas about energy and further to reveal what experiences have led to them having these ideas. During the IAE exercise, flashcards of events and items were shown to students to prompt responses from them and to initiate a semi structured interview. Their interview responses were used to gauge what experiences contributed to the ideas they had. The findings showed that students ideas were as a result of many different experiences but that these experiences could be grouped into one of three categories: hearsay experiences, incomplete understandings, classroom experiences. Most of the students at the lower primary levels held ideas about energy arising from either hearsay experiences or incomplete ideas, while many of the upper primary level students explained their ideas about energy by referring to their classroom experiences. This paper presents the findings of this small-scale exploration.

Key words: Energy, ideas about energy, students' prior experiences

Introduction

The Trinidad and Tobago education system can be described as a four-layered system – these are Early Childhood Care and Education (ECCE), primary schooling, secondary schooling and tertiary or higher education. Basic education is covered in the ECCE, primary schooling and secondary schooling layers. Primary schooling consists of seven years of core curriculum stratified across 3 different levels – pre-primary education (consisting of 2 years of schooling for 5-6 year old students), lower primary education (consisting of 3 years of schooling for 7-9 year old students) and upper primary education (consisting of 2 years of schooling for 10-11 year old students). Each level in primary schooling is called a 'standard' (which is similar to a grade level in the North American context, though the ages are different), so for example, lower primary schooling consists of standard 1, 2 and 3 and upper primary schooling occurs in standard 4 and standard 5. Secondary schooling is a 7-year course of study also stratified across 3 different levels – lower secondary, upper secondary and advanced level secondary. Each level in

secondary schooling is called a ‘form’. Figure 1 summarizes the education system in Trinidad and Tobago.

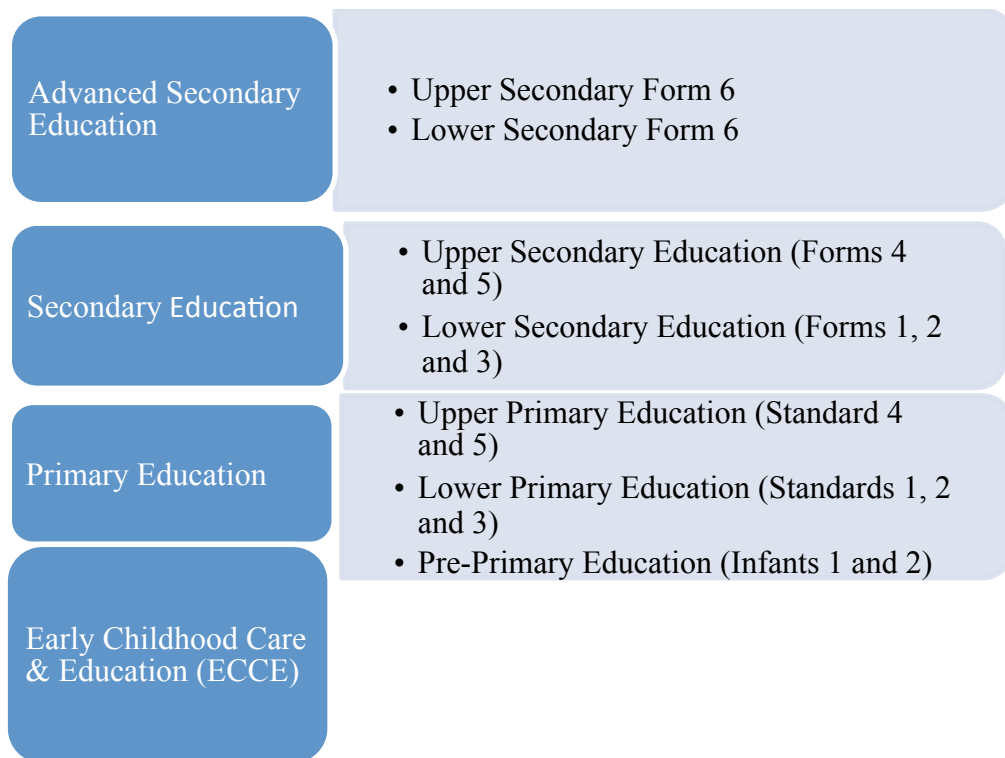


Figure 1: Education System of Trinidad and Tobago

All students in each level; in both primary schooling and secondary schooling; are expected to achieve the same learning outcomes as prescribed by the official curriculum documents that articulates content and guides instruction at each level. The content at each level builds on what was dispensed at the lower levels so that more information is progressively presented and more complex analyses are used as students move from level to level. The body of knowledge targets skills and learning processes, but also addresses values issues to some extent. The science content in primary schooling covers eight areas that are: (1) Living things and their survival, (2) Life and environment, (3) Matter and its properties, (4) Force and motion, (5) Energy, (6) Earth science, (7) Space and astronomy and (8) Nature of science and technology.

This work is situated in the primary schooling context; specifically across the lower primary and upper primary years of schooling; standards 1 – 5. During those years, teaching and learning about energy for primary school students in Trinidad and Tobago emphasizes forms and sources of energy and to a lesser extent simple energy transformations. Teachers are encouraged to use the constructivist approach and to that end their lessons on energy always seek to elicit students’ existing ideas about energy. This is usually done through whole class questioning at the start of each lesson. The absence of a rigid structure in the way students’ prior knowledge is solicited makes it difficult for even the class teacher to say with any degree of certainty what experiences may have led to the ideas of energy held by students. Teachers have some speculations of what these experiences might be, but are unable to empirically report on these.

The purpose of this work was to explore and hence gauge what ideas about energy are held by a group of primary school students in Trinidad and Tobago and further to reveal what kinds of experiences may have led to them holding these ideas. All the students involved in this work were familiar with the term energy from informal experiences either at home, at school or through interactions in the community. Because of the relatively wide age range of the sample, (7 – 11 years) and their corresponding varied degrees of formal classroom exposure, their experience and understanding of the term energy varied according to the level of the primary school system they were at.

Despite formal classroom teaching about energy; which is compulsory at each level of the primary school system; teachers often complain that only few students are able to look at familiar everyday situations and events involving forms, sources and transformations of energy and to explain these by referring to scientifically sound learning and understandings. Teachers claim to be baffled at times by the explanations students provide and admit that they are unsure of what experiences may have led students to conjure up the ideas they have about energy. A common example in Trinidad and Tobago is that many students, when shown a picture of, or, an actual example of a 1.5 volt cell and asked what type of energy is supplied by the 1.5 volt cell would respond by saying the cell supplies electrical energy. Many of them seem not to recognize that the cell supplies chemical energy transformed into electrical energy when the cell is connected in a circuit, example, placed in a radio or in an electric toy. The students seem to associate the cell with electrical energy instead of chemical energy even though content on energy sources might have been covered to some extent in previous learning.

Observations like this one and many others seem to suggest that; without or even after some exposure to formal science instruction on the topic; students' ideas about energy concepts and further their constructed understandings of various aspects of energy are not always scientifically sound. This concern is what motivated the current work. The aim was to determine what ideas about energy are held by primary school students but more importantly to reveal what experiences would have led to the ideas held by these students. In light of this concern, the following 2 research questions guided the approach adopted in this work:

1. What are primary school students' ideas about energy?
2. What experiences have contributed to the ideas of energy held by primary school students?

An exploration of students' ideas on this topic (energy) and specifically students' experiences leading to their ideas has not been undertaken in this context before and in that regard, this work is significant. It will provide some insights about what students' experiences influence the ideas they hold about this science topic. This work will therefore be instructive for primary school science teachers, as it will alert them to considerations that should be borne in mind when they plan for instruction in this topic. In spite of the limitations set by the small sample, the findings of this work will add to the existing literature on the important role of students' prior experiences and of the need to explore these prior experiences when teaching in the classroom.

Energy is an all-pervasive phenomenon not only in science but also in everyday living because we are continually exposed to it in various forms. As a consequence of its common usage, notions of energy have mushroomed to encompass a whole set of meanings in everyday life that are sometimes in conflict with scientific world-view notions of energy (Kruger, 1990;

Duit & Haeussler, 1994; Mann, 2003). In attempting to reveal what ideas of energy students in this work hold, a consideration of the mental model theoretical frameworks articulated by Johnson-Liard (1983) and Gentner and Stevens (1983) is necessary. Johnson-Liard (1983) suggests that students' ideas are constructed as "analogues of the world as perceived or conceptualized" based on formal and informal experiences. Gentner and Stevens (1983) argue that mental models leading to ideas and notions that students hold are related to their knowledge level of the world and how the world works and that based on their existing knowledge level, students construct ideas by negotiating existing knowledge and past experiences with new knowledge, understandings and experiences they encounter as the learning process occurs. Corpuz and Rebello (2011) have suggested that both theories – perceived analogues of the world and ongoing knowledge construction of the world – are valid and that these two operate to varying extents at each level of schooling to determine the way primary school students develop ideas and understandings. The assumption in this work is embedded in the mental model combination adopted by Corpuz and Rebello (2011) which is that a combination of students' knowledge and experiences from both formal and informal settings lead to the ideas they hold.

Harrer, Flood and Wittmann (2013) in following up on seminal work done by Watts (1983) have suggested that students' ideas about the concept of energy are as a result of prior experiences either inside or outside the classroom and while the nature of nor the impact of these experiences are fully known, it seems clear that they are derived from the following types of interactions:

- A range of informal everyday experiences,
- Formal (current and past) classroom experiences, or
- A combination of formal and informal experiences.

Harrer et. al. (2013) reported further that in older students, formal classroom experiences were largely responsible for the science ideas they held while the ideas held by younger students were as a result of their everyday experiences.

Visual prompts provided by Chin (2001) in work done with primary school students to elicit what ideas they held on a number of science concepts including energy, revealed that such interventions provide a window into students' minds thereby allowing teachers to recognize what understandings and ideas about science topics/concepts students hold dear. The findings indicate the oftentimes students ideas about science concepts are as a result of both formal classroom experiences and informal experiences about the topic that may be known to the students, the latter being more influential in the ideas held by younger students. Chin (2001) suggested further that the insights teachers gain from the use of such prompts are pedagogically useful in that they can be used to tailor classroom instruction and activities which can be used to monitor changes in students' ideas and hence to enhance teaching effectiveness in the classroom.

The pervasive, frequent and common use of the term energy is what Hammer, Goldberg and Fargason (2012) say contribute to a variety of non-worldview ideas about the concept of energy held by young students. Expressions like "burning energy" and "saving energy" are used very loosely in many everyday settings and these instill ideas into the minds of young persons that suggest energy is tangible rather than transient. Other experiences which lead to the development of ideas as a result of only partial understandings of the application of energy in everyday events give rise to incomplete understandings of the concept, which Nordine, Krajcik, and Fortus (2010), advise if not corrected very quickly can make it difficult for students to make

linkages among other energy related concepts to arrive at scientifically sound and complete understandings in later learning.

Mann and Treagust (2010) have reported that most students bring with them to the classroom alternative conceptions or ideas of energy that were formed either in earlier learning or from everyday experiences. These alternative conceptions are oftentimes linked to different usage of the term energy either in combinations with others words (which conveys mixed meanings) or in the context in which the term is used (formal or informal setting).

While not much work in this specific area is available in the Trinidad and Tobago context, Maharaj-Sharma (2011), in work that explored primary school students' ideas about the concept of an electric current revealed that many of the pre-existing ideas students come into the classroom with; at the primary level; are not entirely aligned to worldview scientific ideas but are in fact as a result of a range of informal experiences students encounter in their everyday interactions mostly outside the school context. Revealed in that work was the finding that these scientifically incomplete ideas can be transformed through effective classroom instruction in which teachers employ relevant and appropriately selected instructional methods and approaches to deliver science lessons.

Methodology

The current study proceeded via a naturalistic inquiry approach (Yvonna & Egon, 1985) conducted within a constructivist paradigm (Glaser, 2002). This approach allowed for multiple articulations of students' real life experiences derived from familiar social settings. Students' ideas about energy were elicited by way of semi-structured interview dialogue between the researcher and the participants (Ritchie & Lewis, 2003). The dialogue was prompted by visual stimulation through the use of flashcards and it was guided by students' responses as the researcher probed for students' understandings of and/or ideas of energy as well as what experiences would have led to the existing understandings/ideas (Chin, 2001). It was a small-scale study aimed at exploring the experiences of a small group of students to determine how their experiences influenced the ideas of energy they held. In view of the small sample size it is important to recognize that even though the findings derived will have implications only for the specific context of the study, they can be instructive for teachers in other primary schools; with similar school contexts; but cannot be generalized for all primary schools.

The sample of the study consisted of 30 students comprising of 3 boys and 3 girls from each standard, namely standards 1 to 5 from a school in sub-urban central Trinidad. This school was chosen because the principal and teachers had expressed concerns, several times, about the scientifically unsound ideas of energy and energy related concepts often times uttered by student. They expressed interest in facilitating a small-scale study to determine what factors and/or experiences may be responsible for students holding these ideas about energy. The six students from each class level were purposively selected by the relevant class teacher to participate in this study. The selection was done by drawing on the knowledge the teachers had about the students based on their interactions with the students and hence their knowing what were some of the ideas of energy these students held. Parental permission was sought for each of the selected students to participate in this work. Once parental permission was obtained, the nature of the research, specifically their expected role in the process was explained to the students. All the students indicated that they understood what was expected of them and they agreed to participate in the work.

Data collection involved the identification of students' ideas about energy using flash card prompts to initiate the semi-structured interviews, which proceeded via the use of the Interviews about Events (IAE) approach. Development of the IAE flash cards was based on the eighth step algorithm developed by Gilbert, Watts and Osborne (1985). A total of 22 flash cards were developed, each capturing energy in the context of work being done. The cards displayed various forms of energy in situations where work was being done. The cards were used to initiate a semi-structured interview in which students' ideas and their experiences leading to the ideas they hold were revealed. The semi-structured interview allowed for appropriate pausing, probing and prompting as the dialogue between the student and the researcher developed. The interview began with the interviewer showing the participant a flash card of a sample, a situation or an object such as a person skateboarding, a plate of food, a burning fire or a battery. The students were asked to explain what idea about energy was conveyed to them by the sample, situation or the object displayed on the card. The cards were shown to the students for as long as was necessary to get an initial response from the students. Once a response was obtained, the interview continued with the interviewer probing for further clarification, if necessary, or with questions related to the flash card to elicit from the students what idea of energy the flash card prompted for them. If the example involved simple energy transformation (for example an electric fan) students were prompted to explain the energy transformation occurring, if they could. Taking guide from the responses provided as the interview progressed, the interviewer/researcher probed for clarifications and needed extensions in attempts to determine on what experiences students' understandings and ideas about energy were based. This latter activity was done without any attempt to modify students' initial notions and was done specifically to determine what experiences would have led the students to develop the ideas held.

The interviews lasted about 15 minutes each and interviews were audiotaped to maintain authenticity. Verbatim transcription was done of all the interviews. The data analysis process involved coding the data, to allow for the emergence of broad labels which were reviewed and cross-checked against the raw data to allow for the data to be sorted into categories based on similarities. It was an ongoing iterative process in which the codes, labels and categories generated were constantly reviewed and refined. Member checking was the employed to establish trustworthiness of the findings. This involved taking the data (interview transcripts) back to the participants, and asking them to clarify responses and/or issues emerging from the analysis.

Results

Students' responses relating to each flash card, particularly the experiences they cited, were analyzed and it was found that while the specific experiences articulated by the students were wide-ranging and varied, that they could in fact be grouped into one of the three following categories:

- Students' ideas based on hearsay experiences
- Students' ideas based on classroom learning
- Students' ideas that reflect incomplete understanding

Many students at the upper levels (standards 4 and 5) had ideas and understandings about energy that they explained by referring to experiences they had from formal classroom settings. Experiences students cited to explain their ideas that drew on formal classroom experiences and

which led to them holding scientifically sound ideas were classified as ideas based on classroom learning. An example of this was the explanation that food contains chemical energy which when consumed provides the body with energy to perform daily activities. Some students (mostly at the standard 3 level) while citing classroom experiences in their explanations articulated ideas of energy that were not completely scientifically sound. Ideas resulting from explanations like these were classified as ideas based on incomplete understandings. An example of this was the explanation that an electric fan is a source of wind energy, without seeming to recognize that electric energy is the source of the wind energy generated by an electric fan.

At the standard 1 and standard 2 levels, most students used hearsay experiences (playtime chat, conversations and observations); mostly from the home setting; to explain their ideas of energy in the various flashcard prompts. An example of an idea resulting from hearsay experiences was that medicines provide energy to fight illnesses, which the students indicated is something she was told at home when she is ill. Interestingly though, two of the students in this group, when prompted by the flashcards, provided explanations for the ideas they had about energy; in the specific cases presented to them; which reflected more than hearsay experiences. One student for example, was shown a flashcard of a wood-burning fire and in her response said that,

'fire is giving heat energy.....which is coming from the inside the wood.....there is some energy in the wood....I know this from my teacher.....'

This explanation is not based simply on hearsay experiences, as the student seems to be clear about two scientifically sound ideas about energy: transformation of energy and chemical energy contained in a fuel (though she was unable to state the term chemical energy and was unable to use the word transformation). Her explanation was not based on bare informal experiences as she indicated clearly that she knew about some of this from her teacher. Explanations similar to this one were classified as being reflective of incomplete understandings.

Explanations for ideas held by students at the standard 3 level suggested that at this level, some students were still drawing on hearsay experiences to explain their ideas and understandings while some were providing scientifically sound explanations citing formal classroom learning experiences in their explanations. It seems that at this level the experience of formal science instruction served to initiate cognitive transition from hearsay into worldview. In the case of the six students at this level who were interviewed, three of them provided explanations for their ideas citing hearsay experiences while three cited formal science experiences in their explanations of the ideas of energy represented in the flashcards shown to them. Table 1 below summarizes the kinds of experiences students (from this group of 30 students) had that led to the ideas of energy they hold. Following the table are detailed explanations linking students' experiences and ideas at each level of the primary school (standard 1 to standard 5).

Table 1: Experiences that led to ideas of energy held by students

Class Level	Notion based on Hearsay		Notion based on Incomplete Understandings		Notions based on Classroom Learning	
	Boy	Girl	Boy	Girl	Boy	Girl
Standard 1	2	2	1	0	0	1
Standard 2	2	1	0	1	1	1
Standard 3	1	2	0	0	2	1
Standard 4	1	0	0	1	1	3
Standard 5	0	0	0	1	2	3

Standard One

At the standard one level, analysis of the data revealed that of the six students, four of them held ideas of energy types and energy sources that were based on hearsay experiences. One 7-year old boy at this level referred to his classroom experience when shown a picture of a lighting bulb and said that his teacher explained to him that the bulb is giving light energy and that the *'light energy comes from electricity.'*

While he was unable to provide further explanation to suggest that he understood the specific energy transformation occurring in this example, he did use the phrase *'...electricity energy is made to light energy...'*

It is suggesting that he had a basic understanding of a change occurring, which he did attribute to his exposure to formal classroom learning. One of the girls at this level could explain that the bulb was supplying light energy, but she was unable to provide any explanations to suggest that a transformation from electric energy to light energy was occurring. She was categorized as having notions of energy based on incomplete understandings.

Standard Two

Three students at this level (2 boys and 1 girl) held notions of energy that were categorized as being based on hearsay experiences as they used phrases like *'...energy is power...'* and *"...a good rest gives you lots of energy..."*

to explain their understanding when prompted by the relevant flashcards. When probed further to determine what experiences led to them having these ideas they said that it was what their

'friends' and 'parents always say.'

Two other students; one boy and one girl; provided explanations of the flashcard prompts presented to them by referring specifically to examples they were introduced to by their teacher in science lessons. For example, in response to the flashcard showing a plate of food, one student said

'food is a source of chemical energy which can change to other energy when we eat it....so that we can do work...'

This student made specific reference to learnings in the classroom that led to her having this understanding. At this level there was also one student, a girl, whose explanation for the electric fan prompt was categorized as a notion held based on incomplete understandings. She said that

'the electricity created the breeze' and when probed further to explain how the 'breeze' was produced she said that she 'did not know.'

Standard Three

None of the students at this level explained the concept of energy to suggest that they had incomplete understandings. From among the six students at this level, 3 of them (1 boy and 2 girls), explained their understandings of energy based on the flashcard prompts (a plate of food, a battery and an eagle in flight), by referring to hearsay understandings. Also at this level the 3

other students (2 boys and 1 girl), referred to explicit classroom learnings and experiences to explain the prompts presented to them on the flashcards.

Standard Four

At this level, 4 students (2 boys and 2 girls) explained their flashcard prompts; which in this case were a child eating a banana and a lighting flashlight; by referring to explanations provided to them in the classroom by their teachers. Their explanations in all cases indicated a sound understanding of the concept of energy and also of the specific transformations occurring in each case. One student at this level (a boy) explained that a battery was a

'storehouse of electrical energy' and indicated that he had heard his older siblings describing a battery as 'a powerhouse.'

This explanation was categorized as based on hearsay experiences. One other student at the standard 4 level (a girl) explained that an electric fan

'produces wind energy'

but when probed further to gauge what idea of energy she held, she spoke about energy being necessary to do work but when guided back to the specific example of the fan and wind energy; of which she spoke; she was unable to provide further explanations of what is energy what is meant by wind energy. Further probing led her to say that [referring to wind energy] it is what she had heard

'other people saying about a fan.'

Standard Five

Five out of the six students at this level explained the flashcard prompts presented to them by referring to explicit classroom learning experiences. In all cases these students spoke confidently about explanations given to them by their teachers about types of energy, energy sources and also about simple energy transformations in items such as a flashlight and a steaming kettle. One student at this level (a girl), explained a lighting fireplace by saying that the fire was 'creating heat energy.' Despite several attempts at probing she did not seem to recognize the role of the wood, in terms of energy, in the fireplace. In other words, even while drawing on her classroom experiences she did not seem to recognize that the wood was a source of chemical energy. She seemed to have known that the fire was a source of heat energy, but could not convince in any of her articulations that an energy transformation resulted in the heat energy being produced by the fire. Her explanation for this example was categorized as based on incomplete understandings.

Discussion

The findings of this small-scale study seem to align closely with the conclusions arrived at by Harrer, Flood and Wittmann (2013), suggesting that the ideas of energy held by students in the Trinidad and Tobago context seem to evolve as students move through primary schooling from the lower to the upper levels. Revealed herein is the implication that at the lower primary levels, students' ideas about energy are determined to a large extent by informal knowledge and hearsay experiences. As students move to the higher levels of the primary school, the influence of formal classroom science learning seems to trigger a renegotiation of ideas which, Hammer et. al (2012), have shown often leads to varying degrees of idea transformation. The result is that by

the time students get to the final stages of upper primary schooling only a small number of them retain ideas about energy linked to hearsay experiences with the majority of them able to explain their ideas about energy by adequately referring to concrete classroom learning experiences.

The findings of this work are instructive in the following ways.

Students are confident about the ideas of energy they hold and can openly and freely cite specific experiences – scientifically sound or otherwise – to show how these experiences have led to the ideas that they hold. Recognizing the value that students attach to their ideas and knowing the pedagogical soundness of students' prior experiences, it seems telling, as Maharaj-Sharma (2011) has suggested that methods of soliciting these from students should not be random or unstructured. In fact, a formalized method of, or instrument for, soliciting students' prior experiences and ideas might prove to be very useful for teachers as information derived thereof can be used to tailor relevant and meaningful instruction for presenting new materials to students. This might be a useful consideration for future work.

Experiences that reflect incomplete understandings, such as those emanating from this work, can be valuable teaching/learning stimulus because they are neither scientifically sound nor are they entirely scientifically unsound. They can be used at the start of lessons in creative scenarios or episodes which highlight the scientifically unsound aspects and which after formal classroom instruction can be revisited in educationally provocative ways to indicate to students how new knowledge and new learning can refine existing knowledge and understandings. Incomplete understandings can also be used to design groups activities, example problem solving activities, for use in the main body of science lessons to promote discussion about a topic or an idea through which students can be led to recognize the scientific deficiencies of their initial ideas and to realize how new scientific knowledge and learning can be used to bridge conceptual gaps. Though not discussed explicitly in their work, Mann and Treagust (2010) have alluded to this approach as a useful method to help students make cognitive shifts from incomplete to complete conceptual understandings.

One thing that is clear from this work is that the progressive development of science ideas through formal science classroom instruction in this particular primary school in fact scaffolds as students move from the lower to the upper levels of primary schooling. At the standard 1 and 2 levels, students' science ideas were mostly as a result of experiences within the hearsay domain, but as their exposure to formal classroom science instruction increased and advanced as they moved into higher classes, students explained their ideas by referring almost explicitly to formal classroom experiences.

It seems, as was discussed by Corpuz and Rebello (2011) that incomplete understandings are created from a blend of hearsay experiences and formal classroom experiences and represents a transition phase between both extremes. In other words, students' experiences leading to the ideas they hold span across a continuum from hearsay through incomplete to formal, which maps almost exactly onto the levels of primary schooling from standard 1 through standard 3 to standard 5. This continuum, Corpuz and Rebello (2011), attribute to a combination of two mental models, one linked to perceptions based on experiences and the other linked to ongoing knowledge construction. Further work is needed to reveal the specific link between mental models such as these and students' ideas of scientific concepts in the Trinidad and Tobago context.

The inferred transformation or evolution of students' ideas about energy; as suggested in 4 above, seems to be based on an experiential shift from hearsay experiences to formal classroom experiences, similar to the shift discussed by Chin (2001). This suggests that the science

instruction to which students in Trinidad and Tobago are exposed in the classroom may, to a large extent, be constructive in nature. There is a sense emerging from the findings here that when presented with new information [as students move from one level to another], students negotiate these in the context of existing knowledge and reconstruct knowledge [from learning in lower levels of schooling] to lead to new understandings.

The small-scale coverage of this work is inadequate for generalization, but has shown that students do in fact have ideas about science topics arising from three types of experiences. This work, it is hoped, will prompt researchers in the field to survey to an even deeper extent and across larger population sizes and for a wider range of science topics, what kinds of student experiences lead to the ideas students have about science topics before, and even during, exposure to formal science instruction in these topics. It is quite possible that there might be other kinds of experiences; not revealed in this work; that students may have that would lead to them developing particular ideas and understandings about science concepts. Dual ideas and understanding for example, of which Boutte Kelly-Jackson and Johnson (2010) speak, result from experiences that consist of a mix of formal understandings and familiar cultural beliefs and practices. This is indeed an area in which further work must be done to gain a more comprehensive picture of the link between students' experiences and the ideas they conjure in their heads as a result of these experiences. Understanding this link can be a useful consideration for science teachers when they plan science instruction and design science activities to create stimulating teaching and learning opportunities in the classroom.

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