When “doing with understanding” fails: Addressing the misconception issues in primary science student (pre-service) teachers

Noraini Binte Abbas and Tan Chin Kwang

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When “doing with understanding” fails: addressing the misconception issues in primary science student (pre-service) teachers

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Abstract

“I do, I understand” is a quote used to support the “hands-on” approach to teaching science. However, learners do not always “understand” the science ideas the same way as scientist do just by doing science. Both hands-on activities and minds-on approaches are essential for student-centred learning. Numerous studies have highlighted the insidious effect of teachers’ and students’ alternative conceptions in science. Teachers’ alternative conceptions are commonly seen in the science test papers that teachers’ construct and the terms & analogies used during science lessons. These teachers are actually “victims” having been exposed to such faulty ideas themselves when they were students. The conceptual change approach shines a light to one way of breaking this vicious cycle of misconceptions.

This is a qualitative case study, conducted with primary science pre-service teachers, addressing common misconceptions cited in previous literature on topics related to energy. There are many topics in the 2008, Singapore primary science syllabus, that are related to energy. This paper has 2 purposes:

(1) To highlight the common alternative conceptions of student teachers in primary science on topics related to energy
(2) To devise a strategy to develop pre-service teachers “critical eye” in detecting misconceptions in both their students and lessons.

This study highlights how the conceptual change approach can enrich both the student teachers’ subject matter knowledge and pedagogical content knowledge.
Introduction

Hands-on science activities have long been touted as a great way to teach science.

Experienced science teachers are often aware that messing around does not equal to learning science concepts. Discovery learning, in which students invent or discover the proper science concepts through hands-on experience, which was once a popular notion now turned out to leave students to discover less than expected. We should not ignore the fact that students’ minds are not *tabula rasa* but laden with over-generalisation, heuristics and misconceptions (Vosniadou & Ionnades, 1998). Children and adults alike, usually adhere to some very well defined alternative framework about the science concept which play a very crucial role in learning.

This study draws from conceptual change, social constructivist and andragogy theory to seek the answer to the following questions:

- What are the common alternative conceptions related to the topics on energy?
- How can the knowledge of these common alternative conceptions enhance student teachers’ ability to be more discerning of the science content they select for instructional purposes?

Both children and adults who are able to express their alternative conceptions about things make better conceptual development than those ideas that are not explicit. Without addressing directly false beliefs of our learners from the very start, they will derive very little benefit from the experimentation and demonstration in their laboratory work as they will only observe those aspects which support their own theory (Pine, K. et al, 2001).

Theoretical Basis

This study draws from conceptual change and social constructivist research and social andragogy literature. According to Posner, Strike, Hewson and Gertzog (1982), conceptual change requires four pre-requisites:
1. The learner must be dissatisfied with currently held conceptions.
2. The alternative conception must be intelligible.
3. The alternative conception must appear plausible.
4. The alternative conception must appear fruitful.

This study implements this conceptual change model within a social constructivist context. Social constructivism supports the notion that learning occurs within a social context.

Andragogy examines the way adults learn compared to pedagogy, the way children learn. It is the art and science of helping adults learn. It is based on four crucial assumptions about the characteristics of adult learners that are different from the assumptions about child learners (Knowles, 1984).

Adults are self-motivated and need to be involved in the planning of their learning. They learn from experiences and they are most interested in ideas or concepts that have relevance to them. They learn better from problem-centred ideas. Adults are also more practical and prefer to focus on the aspects of a lesson most useful to them in their work. Seldom are they interested in knowledge for its own sake.

Since this study involves student teachers, we are dealing with adults. Therefore, there was a need to create a kind of cognitive dissonance to motivate the student teachers to bridge their alternative conceptions closer to the accepted scientific ideas. Thus, in the intervention phase of this study, learning begins with an analysis of chains of causes and results. This is followed by introducing the “language of science ideas” and giving opportunities for the student teachers to discuss their knowledge and define the differences between their alternative ideas and the scientific ideas.
Learning as Conceptual Development

Learning is seen as the process of changing mental models of the world. These mental models help them interpret and make sense of new experiences. Many researchers tend to focus on the ways each individual develop and change their mental models. Some researchers point out that such individual construction of knowledge does not take place in isolation but it must be influenced by the social and cultural settings within which individuals are located (Soloman, 1987; Edwards & Mercer, 1987)

The difficulty for science educators lies in the persistence of such misconceptions despite attempts to alter them so that they accord with formal scientific explanations of the world. As a result personal knowledge and scientific knowledge may become compartmentalised. Solomon (1983) has referred to the discontinuity that exists between the symbolic world of school and the personal world of the child. The latter has persistence because it confers meaning to the real world. It has social value and can be used in communication with others. Several researchers have developed teaching and learning strategies which take account the conceptual change theoretical perspectives. Driver & Bell (1986) review the implications of constructivist perspective on learning for teaching science.

BACKGROUND

What is energy?

The most common usage of the word “energy” in English is in the realm of literature (Elkana, 1967). The concept on energy only became meaningful through the establishment of the principle of conservation of energy in all its generality.

When students come to school, they will already be familiar with the word energy. They would have encountered the word when it is used in advertising and the media in connection with food. Some food labels claim that they can ‘replace lost energy’. Fuel companies used the word energy as a pun such as ‘energy is our business’ or ‘energy for life’.
In fact, many studies have shown that children do not differ greatly in their use and understanding of the term energy from the majority of adults. Most people do understand the term ‘energy’, however, it is the lay meaning and not the true scientific meaning. The lay meaning might include:

- A close association between notions of energy and other terms such as force, power, energy etc
- A notion that energy is a concrete matter, for example, plants get their energy from the sun which changes into plant matter.
- A popular view is that energy makes things happen and is used up. This is in systems where the total energy is the same before and after transfer occurs.

Energy is indeed an important concept yet it is an elusive one (Driver, et al, 1987). From the scientists’ point of view, there is a more precise meaning to energy:

“Energy is a mathematical principle and there is a numerical quantity that does not change when something happens. Energy is not a description of a mechanism or anything concrete” (Feynman, 1963).

Therefore, scientists’ understanding and control of these processes often involves sophisticated theoretical quantitative models involving energy. However student teachers are not pursuing to become scientists. They are more interested in the practical aspect of their life such as matters related to healthy eating, weight watching, fuel bills and petrol consumption. To understand these matters or to even teach matters, student teachers will need to have an understanding of energy that goes beyond the lay meaning with all its vagueness and ambiguity. However, the scientific meaning is not practical and helpful to most student teachers in the domain of their everyday problems.

**Importance of Science Content Knowledge in conceptual development**
Since the introduction of the Primary Science curriculum with a special emphasis on inquiry for Singapore, primary school students are now required to study experimental and investigative science which include topics on Life sciences and Physical sciences. All these are concepts which the students will have previously experienced in some form in their daily lives. The role for the primary school teacher is to organise the students’ alternative conceptions into coherent concepts which are both accurate and explicit.

The introduction of scientific inquiry to the 2008 national curriculum led to a focus on raising standards of primary science teachers’ subject knowledge as a central tenet in the quest to push scientific inquiry in schools. Good teachers not only know their content but they know things about their content that make effective instruction possible. Undoubtedly, good teachers are reflective practitioners. They listen to their students’ voices and scaffold their ideas in a developmental process. The knowledge that teaching adults need in order to teach science is very different from the knowledge that ordinary adults need in order to do science. The origins of alternative conceptions have been examined by many researchers.

Among the sources of alternative conceptions suggested are the following:

- From the use of perceptual thinking. Students’ explanation of scientific phenomena are dominated by what is immediately perceptible (Driver, 1985)
- From diagrams or statements in textbooks (Blosser, 1987)
- From everyday experience and observation (Strauss, 1981) and
- From teachers and student teachers (Osborne & Cosgrove, 1983)

Local research has shown that Singapore student teachers are not immune to the problems of alternative conceptions that are related to basic scientific phenomena. Several areas of teachers’ alternative conceptions range from life science and physical science concepts that were taken from a pool of primary science assessment items (Boo & Ang, 2004). Despite ensuring that student teachers meet the minimum entry requirement for science in the teacher
training institution in Singapore, local research of primary school science teachers in Singapore have shown that they were still weak in their basic scientific phenomena. Securing student teachers’ conceptual understanding in science may require considerable conceptual changes, especially when they encounter abstract phenomena such as heat, electricity and light.

**Purpose of the study**

The purpose of this study is to present a qualitative account of the findings on the responses for a science diagnostic questionnaire that was given to 147 student teachers from the Diploma and Postgraduate programmes. It also reports on a case study of how one of the researchers used this information to develop her student teachers’ “critical eye” in sieving out the different types of alternative conceptions in science that they might encounter in their daily life. In today’s generation, much content knowledge can be obtained through the internet. Therefore, this skill to be discerning about accurate science information for science teachers to obtain is crucial to curb the spread of these alternative conceptions.

The science diagnostic questionnaire was implemented at the beginning of the intervention stage to elicit student teachers’ prior knowledge on the topics related to the energy concept. This was followed by the open-discussion to bring in the element of social constructivism with the intention to promote a greater clarity in student teachers’ understanding on the energy topics. The items set require the student teachers to consider applying their knowledge on energy in their relevant and realistic contexts.

One problem with the traditional teaching is often that a teacher educator assumes that the student teachers arrive with an open mind with no prior knowledge. This is not the case. Every student teacher would have constructed their own meaning on the energy concepts which would have been useful to them and have been firmly established. The traditional
teaching only results in new ideas being assimilated to these prior ideas producing unintended meanings. Many student teachers may not even be aware of their alternative conceptions.

In this study, our focus was on the application aspects of the concept of energy. To apply their understanding of energy, they need not know the abstract, formal mathematical relations.

**Methods**

**Instrument**

One of the aims of this study is to develop a science diagnostic instrument to elicit the alternative conception from the student teachers. We designed a diagnostic questionnaire that consists of 11 items after researching on the topics related to energy. The items were crafted based on our research through informal consultation with a number of primary school teachers, review of some science examination papers set by primary school teachers and content analysis of several alternative conceptions’ literature review on children’s and teachers’ alternative conceptions on topics related to energy concepts.

From this analysis, we were able to identify the major scientific concepts that both teachers and students were struggling with.

The diagnostic questionnaire covered the following topics related to the theme on “Energy”:

<table>
<thead>
<tr>
<th>Topics related to “Energy”</th>
<th>Number of questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEAT ENERGY</td>
<td>4</td>
</tr>
<tr>
<td>ELECTRICITY</td>
<td>1</td>
</tr>
<tr>
<td>FORMS AND SOURCES OF ENERGY (Energy Conversion, photosynthesis)</td>
<td>2</td>
</tr>
<tr>
<td>LIGHT ENERGY</td>
<td>4</td>
</tr>
</tbody>
</table>

We intentionally focus on everyday phenomenon, language and situations and the answer choices are closely modelling students and teachers’ alternative conceptions. Approaches that draw on everyday experiences and focus upon the uses of energy were strongly recommended based on the several studies done on alternative conceptions (Driver, et al, 1994). We used a two-tier science questionnaire to elicit the alternative conceptions of student teachers on the concepts related to energy which include both life science and
physical science topics. The eleven items in this questionnaire are base-lined to the Singapore Primary Science Syllabus introduced by the Ministry of Education in 2008.

**Subjects and setting**

This study was conducted with a group of 147 student-teachers who are attending lessons in Pedagogy of primary science. The participants comprise of student teachers from a broad multicultural population and their ages ranges from 20 to 45 year old. They came from both the Diploma and the Postgraduate diploma programmes.

The intervention for this study was implemented during a science curriculum studies lesson. This course addresses the pedagogy aspect of primary science. However, we believe that pedagogy would only be effective if the student-teachers’ subject-matter knowledge is brought up to par. As stated by the findings from Hashweh (1987) and Sanders, Borko and Lockard (1993) which highlighted the importance of pedagogical content knowledge that link pedagogy with subject matter knowledge.

In this study, we refer to pedagogical content knowledge as the knowledge about how to help particular students understand ideas such as heat energy, photosynthesis and using the best analogies, the best demonstration and the best activities in which to involve the students. To us, pedagogical content knowledge refers to subject matter knowledge package with the knowledge of pedagogical skills and context of the place.

**Procedures**

This study presents a constructivist approach to the teaching of concepts on energy. A constructivist mode of teaching science assumes that learning involves a rational interaction between new conceptions and the learners’ prior ideas. This mode is slower and involves discussion, debate and re-creation of ideas. The intervention stage consists of 3 phases: before, during and after teaching/learning. First, we administered the diagnostic questionnaire to elicit the alternative conceptions of the student teachers. After the diagnostic questionnaire has been
implemented, the student teachers would discuss and debate their answers. The details of the procedures are stated below:

- Student teachers are grouped in groups of 4 to 5. A recorder tabulated the results for each group.
- Each group will compare and then justify their answers
- Group members in each group come to a consensus on the answers
- One of the researchers, who is also the tutor for these tutorial groups, discussed the answers with her student teachers and tried to bridge the ideas towards the scientific views.

After the discussion, each student teacher will analyse their alternative conceptions and reflect on the possible sources for their alternative conceptions. Then, each group will be allocated 2 items to work on. In their groups, they are to create activities to address the possible alternative conceptions for the items they are assigned to.

This is followed by a sharing session and some feedback sessions. Crafting out activities usually require the student teachers to do some research to sieve out the different ways of representing the concepts to address the alternative conceptions. It is during this stage and during the sharing sessions that student teachers’ display a development in their pedagogical content knowledge as they struggle with the idea of content representations. The intervention phase include modelling to the student teachers strategies of analyzing learning tasks and activities to ensure that they emphasized on conceptual development.

After the lessons, the student teachers were asked to reflect on their learning process by penning down their thoughts and insights on alternative conceptions. It was during this reflection that issues related to sourcing out accurate information for teaching surfaced. These issues were discussed and a model of analysing information was created from this discussion.

**Identified common alternative conceptions**

The diagnostic questionnaire was useful in highlighting the gaps that the student teachers needed to fill in order to be more proficient in teaching the theme on Energy.
The collated responses from the diagnostic questionnaire showed a general trend in alternative conceptions of the student teachers regardless of the programme they were in. This reveals that there are some mental models that are shared among many student teachers. Despite coming from different backgrounds and exposed to different programmes, many alternative conceptions were not only common but have similar reasons given (similar sources of alternative conceptions). In this paper, we would be discussing items that have less than 50% correct.

**Q1.**

<table>
<thead>
<tr>
<th>Answer Key: B2</th>
<th>Reason</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>A</td>
<td>33.6</td>
<td>0.0</td>
</tr>
<tr>
<td>B</td>
<td>2.7</td>
<td>48.6</td>
</tr>
<tr>
<td>C</td>
<td>2.7</td>
<td>0.0</td>
</tr>
<tr>
<td>D</td>
<td>0.7</td>
<td>0.0</td>
</tr>
<tr>
<td>Nil</td>
<td>1.4</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>41.1</td>
<td>48.6</td>
</tr>
</tbody>
</table>

Table 1. Percent of Responses For Each Answer and Reason For Q1

**Q1.** A metal ruler and a wooden ruler of the same size are placed in a room for 24 hours. Which of the following are the possible temperatures of the metal ruler and wooden ruler after 24 hours if the room temperature is maintained throughout at 25°C?

<table>
<thead>
<tr>
<th>Wooden ruler</th>
<th>Metal ruler</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) 25 °C</td>
<td>21 °C</td>
</tr>
<tr>
<td>(B) 25 °C</td>
<td>25 °C</td>
</tr>
<tr>
<td>(C) 28 °C</td>
<td>25 °C</td>
</tr>
<tr>
<td>(D) 21 °C</td>
<td>25 °C</td>
</tr>
</tbody>
</table>

Which one of the following is a reason for your answer above?

(1) The metal ruler feels colder than a wooden ruler as it is a conductor, so it will lose more heat than the wooden ruler.

(2) The metal and wooden ruler should be of the same temperature as the room.

(3) The metal ruler is a conductor so it will conduct more heat from the environment.

(4) The wooden ruler is an insulator so it will lose more heat than the metal ruler.
Item 1 is related to the topic on heat and temperature. The most common alternative conception for this item is A1. Despite the emphasis on the difference between heat and temperature, many student teachers are confused between the reason for the metal ruler to feel cold and the temperature of the metal ruler.

One possible cause of this particular alternative conception could be due to their everyday encounter of cold things such as ice water that has a temperature lower than the surrounding. They might misinterpret the term conductor of heat for metal as referring to being able to lose heat quickly to the surrounding. Even when some did have the accurate idea that good conductor such as metals are able to conduct heat away from our hands, they still believe that it will affect the temperature of the metal ruler.

Q3.

<table>
<thead>
<tr>
<th>Answer</th>
<th>Reason</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>A</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>B</td>
<td>2.7</td>
<td>1.4</td>
</tr>
<tr>
<td>C</td>
<td>0.0</td>
<td>0.7</td>
</tr>
<tr>
<td>D</td>
<td>8.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Nil</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>11.0</td>
<td>2.1</td>
</tr>
</tbody>
</table>

Table 3. Percent of Responses For Each Answer and Reason For Q3

Q 3.  Peter, Sharin, Faridah and Devi were observing a plant that they had planted a month ago. It had grown bigger and heavier. Each of them made a statement trying to explain how the plant got its energy to grow. Whose comment do you think is correct?

(A) PETER: The extra weight came from carbon dioxide in the air. The plant got its energy from fixed carbon dioxide.

(B) SHARIN: The extra weight came from air, water and sunlight. Sunlight was the source of energy for its growth.

(C) FARIDAH: The extra weight came from water. The plant got its energy from the water it took in from the roots.

(D) DEVI: The extra weight came from the fertilizer that was placed onto the soil. The plant got its energy from the mineral salts from the soil and the fertilizer that was placed in the soil.
Which one of the following is a reason for your answer above?

(1) Energy comes from the plant’s food. Substances from the soil such as mineral salts and fertilizer are sources of food for the plants.

(2) Energy comes from the plant’s food. Water is the source of food for plants.

(3) Energy comes from the plant’s food. Sunlight, carbon dioxide and water are all sources of food for the plant.

(4) Energy comes from the plant’s food. Sugar and starch are the sources of food for plants.

Item 3 is related to the topic on photosynthesis. The most common alternative conception for this item is B3. Despite the emphasis on photosynthesis process during primary and secondary science education, many student teachers were confused mainly because the item had ascribe to the word ‘food’ instead of restricting the meaning to those substances which plants manufacture.

One possible cause of this particular alternative conception could be due to “naive ideas” student teachers tend to bring into the classroom from their everyday knowledge. Since the word ‘food’ was used in the item, they tend to think of food the same way as humans consume food. They most likely associate the raw materials plants need for photosynthesis as food instead of the sugar or starch produced by the plant as a source of energy for the plant.

The source of this alternative conception might have been derived from the idea that plants obtain their food from the environment in the same way as an animal that is the food is ready-made.

Q7.

<table>
<thead>
<tr>
<th>Answer</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Nil</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.7</td>
<td>2.7</td>
<td>0.7</td>
<td>0.0</td>
<td>0.0</td>
<td>4.1</td>
</tr>
<tr>
<td>B</td>
<td>22.6</td>
<td><strong>25.3</strong></td>
<td>7.5</td>
<td>0.0</td>
<td>0.0</td>
<td>55.4</td>
</tr>
<tr>
<td>C</td>
<td>10.3</td>
<td>12.3</td>
<td>12.3</td>
<td>0.7</td>
<td>0.7</td>
<td>36.3</td>
</tr>
<tr>
<td>D</td>
<td>1.4</td>
<td>0.7</td>
<td>2.1</td>
<td>0.0</td>
<td>0.0</td>
<td>4.2</td>
</tr>
<tr>
<td>Nil</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>35.0</td>
<td>41.0</td>
<td>22.6</td>
<td>0.7</td>
<td>0.7</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 7. Percent of Responses For Each Answer and Reason For Q7
Mary places a cardboard with a hole measuring 7mm in diameter between a frosted light bulb and an A4 size white screen. The diagram below shows the hole touching the middle of a frosted light bulb. When the bulb is lighted up, she moves the screen to position A and then to position B.

Which one of the following best describes Mary’s observation on the screen?

(A) The screen is fully illuminated. No observable change is noticed when the screen is moved.

(B) A small spot of light with its outer parts dimly illuminated is observed. It becomes smaller in size as the screen moves to position A and gets bigger as the screen moves to B.

(C) A small spot of light with its outer parts dimly illuminated is observed. It becomes bigger in size as the screen moves to position A and gets smaller as the screen moves to B.

(D) A small spot of light with its outer parts dimly illuminated is observed. No observable change in the size of the spot is observed when the screen is moved.

Which one of the following is a reason for your answer above?

(1) Light goes out in only one direction from each point on the bulb in a radial manner.
Light goes out in all directions from every single point on the bulb in an outwardly manner.

Light goes out in only one direction from each point on the bulb in a parallel manner.

Light goes out in only one direction from each point on the bulb in a converging manner.

Item 7 is also related to the topic on light. For this item there seems to be two common alternative conceptions B2 and B1.

One possible cause of these alternative conceptions is due to the “naïve idea” that light goes out in only one direction from each point on a light source in a radial manner rather than in all directions from every single point on the light source in an outwardly manner.

According to Bendall et al (1993) study, respondents possessed the ‘flashlight’ model of conceptualisation of light rays. They viewed light rays as representing
actual beam of light, like flashlight beams. Thus in their geometrical representations of the direction that light travels from a light bulb, they would tend to show only single lines going outward from individual points on the bulb. The study suggested that a lack of understanding that light from each point on a source goes out in all directions, is at the root of many students’ difficulties in understanding image formation (Galili et al., 1993).

In light of the aforesaid study, respondents would predict a small spot of light (option B) rather than a large area of illumination (option A) for this question since they do not think of light from each point on the bulb going out in all directions.

Q9.

<table>
<thead>
<tr>
<th>Answer Key: B3</th>
<th>Reason</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Answer</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>A</td>
<td>4.8</td>
<td>0.7</td>
</tr>
<tr>
<td>B</td>
<td>7.5</td>
<td>0.0</td>
</tr>
<tr>
<td>C</td>
<td>0.0</td>
<td>2.1</td>
</tr>
<tr>
<td>D</td>
<td>1.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Nil</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>13.7</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Table 9. Percent of Responses For Each Answer and Reason For Q9
Q 9. A group of students was discussing about the processes in the water cycle. All of them agreed to the following statement that “Steam would condense when exposed to a cooler environment” however they could not decide what happened during condensation.

Which of the following statement best describes your explanation for this phenomenon?
(A) Absorbs heat from the environment
(B) Gives heat to the environment.
(C) Does not exchange heat with the environment
(D) Absorbs and emits heat with the environment at the same time

Which one of the following is a reason for your answer above?
(1) For condensation to occur, water vapour needs energy. Once the liquid water is formed, energy is given out as a by-product of the process
(2) Condensation is a physical reaction and not a chemical reaction, so no heat is taken in or given out.
(3) The process of condensation will release energy as the gaseous state of water requires more energy than the liquid state.
(4) The process of condensation requires energy to change the gaseous state of water to the liquid state of water.

Item 9 is also related to the topics on heat specifically related to processes such as condensation, evaporation etc. The most common alternative conception for this item is A4. Less than 50% of the student teachers chose the correct answer. The purpose of setting this question was to determine if student teachers could make the link between heat and the processes in the water cycle. For water to evaporate it needs to absorb energy from the surrounding so that when it condenses, it gives off energy to its surrounding. More than 50% of the student teachers chose the inaccurate option. One possible reason for this alternative conception was due to the confusion or surface understanding student teacher has on energy transfer in the condensation process. Even-though this process take place every day in nature or even at home, there is still confusion about the case in which a matter gains or losses energy.

Another interesting observation to note from this data is not 17% of the student teachers who got their answer (chose option B) but chose the wrong reasons 9reasons 1 and 4 instead of 3). Therefore, although these student teachers had chosen the correct answers, they do not truly
understand the concepts related to condensation and are unable to explain this concept accurately to their students.

In real life, student teachers experienced condensation when steam or water vapour touches a cold surface. This gave them the idea that condensation is related to something “cold”. The scientific view that heat is released to the surrounding seemed counter-intuitive to their pre-conceived idea.

**Discussion**

If learners base their thinking on what they experience, then as science educators, we need to structure their experiences to challenge their erroneous beliefs. Alternative views of scientific principles if left unaddressed, they can co-exist with the new knowledge learnt and create a mishmash of fact and myth. However, if each learner is given the chance to test his or her idea on a concept such as energy, and finds its limits, then a deeper understanding, without the alternative conceptions can result.

Student teacher’s early alternative concepts about energy was not diagnosed and rectified in the primary and secondary years. Often a student can read, use or even listen to a statement in science and understand it using their everyday interpretation of the word. This interpretation may not be the one intended by the teacher. By the time they reach tertiary level, these ideas have become valid and valuable for them to understand their everyday world.

For example, in the questionnaire, question 3 deals with a basic idea in life sciences. What is food to the plant? Science teachers usually focus on the process of photosynthesis and highlight the materials used during this process. Thus, it is not surprising that many of our student teachers have the following believe:

“Food is energy for human beings, we consumed this food. So the food for plants must also be consumed. Plants consumed water and mineral salts from their roots. Fertilizer is also food for the plants.”
The presence and robustness of naive theories in the student teachers suggest that the teachers will derive less benefit from experimentation and demonstration, since they will only observe those aspects which support their own theory. The implication of this study highlights the importance of eliciting student teachers alternative ideas and using their ideas as the starting points or to design experiments which can directly address their false beliefs.

Item 9 in the questionnaire intended to elicit student-teachers’ alternative conceptions related to the water cycle processes. As many as 33.5% of the participants chose reason (4) to describe the process of condensation. This alternative conception highlights the missing connection of the knowledge student-teachers’ have such that they are unable to link the particulate theory to the theory of Thermodynamics and was unable to give the correct reason for their answer. This shines a light to the problem of learning science. Emphasis on facts had led to many students teachers knowing the answers but not comprehending the reasons behind the answers. Therefore their alternative conceptions had actually been mismatched with the true scientific ideas such that it cannot be revealed in the school science exams.

Soloman (1983) suggested that we should ask the learners to think of these ideas in two different domains of knowledge like in different “genres” and teach them to be able to distinguish between these two domains. Thus, learning through the conceptual change approach may lead us to consider the content of a science curriculum in a developmental way. At first, many student teachers might not have the necessary construct to have a complete understanding of energy. However, teaching should take into account and rely on student teachers’ more pervasive alternative frameworks. By adopting the principle of spiral curriculum, student teachers should be given the opportunity to re-visit this idea throughout the tutorial sessions even though the lessons to be taught were not explicitly related to conceptual change techniques. This will enable student teachers to develop the scientific
domain of knowledge concerning the energy concept and this could reinforce their ideas in a step by step manner.

In this study, conceptual shifts did not seem to occur instantaneously. It was preceded by a period of orientation and followed by a period in which concepts were explored further through personal reflection and reading. The socio-cultural environment was widely recognised as playing a critical part in learning and interactions between learners and tutor were crucial in stimulating discussion and focusing observation and investigation. Personal involvement in the learning process provided ownership and was seen as leading towards a better understanding. Overcoming resistance to conceptual change is clearly an ongoing struggle as both adults and children do not easily surrender their carefully constructed schemes to the onslaught of new evidence, no matter how convincing it seems.

The student teachers’ reflections have revealed a sense of empathy with a young learner who is learning primary science. Student teachers are made aware that they need to use a variety of strategies, including infinite patience and the willingness to let their learners “swim upstream towards an elusive understanding” before they can over the barriers of such alternative conceptions.

As adults, many student teachers became aware of their alternative conceptions to basic scientific concepts which they once thought they knew very well. Their overconfidence initially and humbled disposition later, gave them insights on the need to sieve the roots of these alternative conceptions their students might have. With such disposition, my approach to teaching would always be to ask students questions to elicit their ideas about the concepts and to explicitly state the foundational concept such as where is the source of heat, or from where did the heat come from and to where did it go and how does heat travel in an object or from one object to the next? All these questions will focus the student-teachers to the fundamental idea that heat travelled from a warmer region to a colder region.
Although learners in a state of cognitive conflict are known to express signs of curiosity, however when the conflict is beyond the learners’ zone of proximal development, it lead to frustration and even boredom (nonchalant behaviour). Many student-teachers were overwhelmed by the items related to light. Some of them were so utterly confused that they just gave up without truly thinking through the questions.

This study illustrates that in developing awareness of their own learning processes, it gave student teachers the opportunity to develop a more subtle knowledge of science subject matter. Understanding the “root cause” of their own misconceptions allowed these student teachers to map their development and consider its implication for practice. Student teachers are now more capable of generating in-depth pedagogical knowledge focused on awareness of the occurrence, and development of alternative conceptions and ways of challenging their students through investigation.

Teaching science requires sensitive and informed pedagogic approaches that address the need of learners to make sense of the challenging ideas encountered in science education. It has potential for the teacher training context, to simultaneously nurture the development of both subject and pedagogy as part of an ongoing cycle of professional reflection learning.

During the intervention phase, many student teachers highlighted their concerns during the intervention phase of their worry in getting accurate information from the internet and from science resource books. There have been many studies that highlight the errors in conceptual knowledge in many resources that could affect the subject matter knowledge of these teachers. How do we develop the student teacher’s critical eye is sourcing out accurate information. If student teachers are aware of the common alternative conceptions, they would be able to discern the errors quickly. However, no one is an expert in all the science areas, so there will be times when teachers, especially student teachers or beginning teachers are at a lost as they cannot verify the accuracy of the information. We brainstormed with the student
teachers and came out with a model to help us be more discerning in sourcing out information. We followed the framework for assessment whereby there are 3 factors to look into before we use any information for teaching purposes:

1. **Validity**

Validity involve issues related to the source of information, the time period the information was written (this is very important for science information) and the credibility of the author who wrote the information as stated below.

- Ensuring that the research literature is from the latest scholarly writings or recognized or reliable research
- Verifying the information with people who are experts or a major in the area.
- Verifying the information from people who has worked or taught in the area.

2. **Reliability**

Science should always be viewed as tentative, subjected to change as new findings emerged. Due to this, it is vital for the student-teachers to ensure that the science information they obtained for their lessons are from the latest sources. The idea of ensuring that the information they sourced out turned out to be a valuable discussion. Student teachers became aware that since the source (where) of their information is the “changed variable” they needed to keep the other variables constant. For a more accurate comparison of content, they needed to ensure that the time period, baseline of the research and context of the research of their sources of information are the same.

3. **Utility**

There are many occasions whereby student-teachers do not understand the piece of information they were reading as there were too many jargons used in them. Instead of finding out the meanings of these jargons which are usually scientific terms, they tend to
guess the meanings of these terms. This led to misunderstanding of the ideas intended by the author of the literature.

We also learned during through this study that if there is no member in the group holding any conflicting view, no conceptual change would occur. If all the members in the group shared the same alternative conceptions at the beginning of the discussion, the same conception remained after the discussion. There is a need of at least one member of the group who understand the concept for the discussion to be effective.

During the intervention lessons, the student-teachers were shown the 4 aspects of meta-task mainly looking into the task, modality and complexity of the activities they had crafted using the conceptual change approach. Meta-task is a technique that helped the student-teachers view the conceptual change approach in a multi-dimensional view. By bringing in the different modality to address alternative conceptions, student teachers were able to see beyond the diagnostic test and lecture style of teaching. They became comfortable with the idea of cognitive conflict demonstrations, investigative research and even using concept cartoons as pictorial representation to address the alternative conception issues.

**Conclusion and implication for teacher education**

So, what is the implication of this study? This study was intended to delve into matters related to teacher education. Based on the findings of our pilot study, we suggest four ways that might assist student-teachers in addressing the alternative conception issues and they are:

1) Helping student teachers examine their pre-existing knowledge and beliefs for every theme in the primary science syllabus (Diversity, Cycles, Systems, Interactions & Energy)

2) Addressing the need to guide the student teachers to be discerning when using information from the internet or from books, magazines and journals. They could take
the simple steps to ensure the validity, reliability and utility of the resources of information they have selected for teaching.

3) Highlight to the student teacher the relationship between subject matter knowledge and pedagogical content knowledge.

4) Emphasize the importance of lifelong learning in updating content subject matter due to the nature of science. Science content is not static but rather fluid.

By eliciting alternative conceptions, student teachers gained some meta-cognitive and meta-task skills; the discussions developed their analytical and communicative skills, and gave them insights selecting suitable teaching resources for their science lesson. Conceptual shifts would take time, however, it would be beneficial to address this matter in teacher training as it would help them develop student-teachers in many areas from their subject-matter knowledge to their pedagogical content knowledge. For these reasons, we feel that it is worth the time invested in doing this research. However, more in-depth study with a bigger sample would be essential to verify the findings we had stated in this paper.

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