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Understanding Alternative Conceptions: Constructivism and Nature of Science Approach

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Abstract

Science aspires to discover the universal and objective truth. In this regard, scientists formulate postulates, hypotheses, theories, and laws to completely understand how things work in the universe. However, sometimes, there are certain ideas by students or even adults that do not fit into these theories and laws which are termed misconceptions or alternative conceptions. In this paper, I contend that alternative conception is a crucial factor in the development of learning and that there must be no drastic shift by educators. Also, I relate alternative conceptions to the critical thinking of the learners. Constructivist Theory, Model of Educational Reconstruction, Nature of science, Kuhn's Paradigm Shift, Popper's Theory, and some personal notes as important topics to truly understand alternative conceptions are discussed.

Keywords: *Misconception, Alternative Conception, Constructivism*

Introduction

> "The most incomprehensible thing about the world is that it is comprehensible."
> Albert Einstein

Fundamentally, we live in a world of complex things that cannot be easily understood. To make these complex things comprehensible, learners generally devise their way of thinking to explain phenomena albeit non-adherence to the laws and theories of science. They make their own ideas and understanding from their experiences in an attempt to achieve comprehension. As Pragle (2010) argued,

> It is our nature as human beings to understand how everything fits into place. These understandings will consist of whatever makes sense to us. Everyone on this planet makes assumptions about the way the world works; these assumptions are a way to ease the frustrations of living in a complex world (p. 37).

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These assumptions that do not match with what is scientifically correct in many terms are identified by educators in many terms such as false conceptions, preconceptions, misconceptions, or alternative conceptions. Many studies have shown that alternative conceptions exist in schools and are ingrained in many branches of science like biology, chemistry, physics, earth science, and even mathematics.

The ideas that do not match with accepted scientific knowledge are termed as "alternative structures," "misconceptions," "alternative conceptions," "pre-concepts," "common sense concepts," "inadequate understanding," or "spontaneous information," among many others (Aslan & Demircioglu, 2014). Initially, misconceptions have been the common term for these ideas; however, many educators believed that using this term implied that students had done something wrong when in fact they just do not have enough knowledge or thinking to ascertain the scientific truth behind that topic. In this case, educators choose alternative conceptions to refer to them than "mis"conceptions. Further, "mis" in misconception gave an impression of error or incorrectness when in fact the student just only gives his/her interpretation or own understanding of the problem or situation which is not reputable.

Students have their ideas about basic science concepts at the onset of formal science classes. Science concepts are not that well-learned in a standard classroom. Acisli and colleagues (2012) listed that the main source of difficulties is the abstract nature of science concepts, teacher-centered applications, and traditional teaching strategies. Narjaikaew (2013) stated that teachers' alternative conceptions in science bring forth students' alternative conceptions.

Many studies have shown that alternative conceptions of students in major branches of science such as biology, chemistry, mathematics, and physics exist. Studies show that biology concepts such as cell, genetics, evolution, ecology, mitosis and meiosis, are prone to alternative conceptions (Ozcan et al., 2012). Even mathematics which is considered the language of science does not escape from the alternative conception of students as shown in their understanding of radicals as studied by Ozkan (2011). Alternative conceptions in Physics topics like heat and temperature (Alwan, 2011), open and short circuit concepts (Hussain et al., 2012), manufacturing concepts like electricity, electromagnetism (Serrano et al., 2013), and light (Djanette & Fouad, 2014) are well studied. A broad spectrum of papers tackling alternative conceptions in different topics of earth science can be easily accessed (Dove, 1998). This is the same case with chemistry as the central science (Garnett et al., 1995).

Aslan and Demircioglu (2014) argued that the determination of an alternative conception is very important but eliminating it is the best. Many authors believe that these alternative conceptions will contribute negative effects on the process of learning. They

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contend that it only contributes to the factors that disrupt the formation of correct concepts and learning. They believe that this type of conceptions should be addressed first before developing the lesson since these are difficult to change. They share the same belief that alternative conceptions should be eradicated. There is evidence that alternative conceptions affect the understanding of the natural phenomenon. Studies have shown that students oppose the efforts in changing their alternative conceptions of certain topics (Djanette & Fouad, 2014). The stronger their alternative conceptions of a topic, the stronger that they resist the accepted scientific knowledge that creates a conceptual barrier limiting or preventing the learning to happen. This is in consonance with the study of Pfundt and Duit (1991) that alternative conception is truly resistant to change and strongly influences new learning. From these studies, they share the same results that students' alternative conceptions may come from their individual experiences which is why its foundation is strong. Additionally, students make another conception from this alternative conception creating other false conceptions. These erroneous understandings are believed to interfere with the learning of the new concept.

However, Smith and colleagues (1993) and Maskiewicz and Lineback (2013) have opposing views. They believed that alternative conceptions should not be replaced, overcome, or removed. But instead, alternative conceptions should be viewed "as resources for refinement, rather than obstacles requiring replacement, which this model of student thinking may lead to more effective pedagogical strategies in the classroom" as these authors suggest.

Constructivist Theory and Model of Educational Reconstruction

In understanding alternative conception, questions like "What do students understand'' and "how do students conceptualize" are very important. In a constructivist approach, students "discover and transform information, check new information against old, and revise rules when they no longer apply" and in this context that students are in the center of these processes (Bada, 2015). They are actively constructing their own knowledge.

Constructivism allows the students to construct their own knowledge for a deep appreciation of things in the world. This constructed knowledge is called concepts, ideas, or theories (Chan et al., 2020; Chhabra & Bajeva, 2012). However, through this constructivism, alternative conception produces prior knowledge that does not conform to the scientifically aligned facts. It is in this context that teachers try to resolve alternative conceptions by replacing these concepts through conceptual change. Smith, Blakeslee, and Anderson (1993) defined conceptual change as the significant learning of concepts that involve replacing or reorganizing students' prior knowledge to accommodate new ideas.

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In identifying and processing alternative conceptions, educators used different methods. The conceptual change approach used by teachers in alternative conceptions includes animations, explanatory models, refutational texts, analogies, computer-assisted instructions, group workings, learnings, and a few others. In identifying alternative conceptions, educators used open-ended questions, interviews, multiple-choice tests, concept maps, and others (Djanette & Fouad, 2014). Many studies have been done to eliminate these alternative conceptions since many believe that this prior knowledge is only a hindrance in creating a new one.

However, Smith et al. (1993) believed that these approaches of teachers toward alternative conceptions do not conform to constructivism. They argue that it contradicts a basic premise of constructivism that prior knowledge or pre-concepts is the prime resource of having new knowledge and replacing, reorganizing, or eliminating these alternative conceptions will not result in a piece of new knowledge. As Maskiewicz and Lineback (2013) explained in their paper, Smith et al. (1993, p. 353) stressed that,

> The central tenets of constructivism emphasize the foundational role of prior knowledge in learning, and students learn by transforming and refining their prior knowledge into more sophisticated forms. Learning, from this perspective, is not the replacement of one concept or idea with another, but instead is a slow refinement of existing knowledge with relatively stable intermediate states of understanding preceding conceptual mastery.

The authors added that although the practical findings of the alternative conception research are legitimate and important, the approaches and assumptions about learning are in conflict with the basic principles of constructivism. They contend that learning must be seen as the process of adapting prior knowledge and alternative conception must be viewed as a resource for building sophisticated and complex scientific understanding.

From this viewpoint, the Kattman Model of Educational Reconstruction was grounded. Within this model, teaching uses the students' conception to bridge the gap between a science subject matter and their respective alternative conceptions. In this model, three components should be accounted for such as "design of learning environments," "clarification and analysis of science content," and "investigation into students' perspectives. In applying this model, determination of students' alternative conceptions and consideration of the revealed conceptions in teaching approaches are used. A constructivist teaching sequence is used in this strategy. It is composed of three phases as stated by Franke and colleagues (2013) to wit:

> The first phase (orientation) is followed by a discovery phase of the students' conceptions (elicitation of ideas), and a subsequent restructuring phase of the

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selected conceptions (restructuring of ideas) follows. During these phases, a process of clarification and exchange takes place, where single conceptions are put in conflict with each other to allow the construction of new conceptions. These phases are followed by the application of the new conceptions (application of ideas) as well as by an assessment of the changes which may have resulted (review of change in ideas). The consequent comparison of the new and old conceptions concludes the constructive teaching sequence (p. 17).

In this model, approaches to alternative conceptions are hinged on constructivism.

Nature of Science, Popper's Theory, and Kuhn's Paradigm Shift

What may be true now may not be true tomorrow. That is the nature of science. As defined by Lenderman, Lenderman, and Antink (2013), the nature of science refers to the "epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge." Koksal (2011, p. 198) listed the aspects of nature of science as:

> a) Scientific knowledge is theory-laden; b) Scientific knowledge is tentative; c) Observation is different from inference; d) Scientific knowledge is based on evidence and observation; e) There is no hierarchy among hypothesis, theory, and law; f) Laws and theories have different roles in science; g) Scientific knowledge is embedded in social and cultural context; h) Science is a way of knowing; i) There is no universally accepted one way to do science; j) Creativeness and imagination are also important to produce scientific knowledge; and k) Scientist is not objective when s/he begins to study; or when s/he has a background.

From the perspective that scientific knowledge is tentative, that there is no universally accepted way to do science, and importantly, that science is embedded in social and cultural contexts, are where the alternative conceptions come in. It is logical to think that these alternative conceptions from the students may be the facts of science in the near future. Science is not absolute. Even Kuhn himself argued that science, as viewed in one paradigm, has a tendency to make a paradigm shift. Kuhn argues that knowledge may emerge which will refute the previous knowledge which may lead to a paradigm shift. This paradigm shift will create an era befitting and acknowledges this new facet of knowledge.

In chemistry, a famous paradigm shift is from Phlogiston's theory to Lavoisier's Chemical Revolution. The 18^{th}-century chemists believed that from the phlogiston theory, substances or matter, in particular, contains "phlogiston" and ash. That is why, in

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combustion, ash will be left since the phlogiston will vanish or go with the natural environment. The easy concept and the observable explanation of this theory are the reasons why it was widely accepted and popular at that time. However, this theory was flawed when it was proven that the weight of some metals burned is heavier than the initial. Lavoisier's experiments proved that this is because some metals react with the components in the air and mix with it; hence, the product weight is heavier than the initial weight. The component of this air is later confirmed as oxygen. This Lavoisier experiment paved the way for an important law in Chemistry, the Law of Conservation of Mass.

The acceptance of Lavoisier's Chemical Revolution took almost 20 years. During this time, Lavoisier's idea of phlogiston was believed as an alternative conception. If the educators are faced with replacing this alternative conception, then the non-existent "phlogiston" is still a famous notion today. It is in this context that one must think of alternative conceptions as a guide in developing scientific knowledge as Maskiewicz and Lineback (2013) asked that "if learning is the process of adapting prior knowledge, and misconceptions [alternative conceptions] are viewed as unproductive and must be replaced during instruction, then what would students use as resources for building more sophisticated scientific understandings?" Hence, alternative conceptions play a significant role since they can lead to the paradigm shift as proposed by Kuhn which contributes to the progress of science. Further, identifying, acknowledging, and putting alternative conceptions in debates may be done so that a well-analyzed, well-thought, and crystal-clear understanding of the concept could be made.

As explained, scientific knowledge may change as the nature of science is changing over time. It is temporal. Thinking that these alternative conceptions may be the true conceptions in the future is not absurd. Alternative conceptions should therefore be taken as alternative views of the scientific understanding.

A famous statement "All Swans are white" used by Popper in solidifying his view will support this case. To disprove the hypothesis that all swans are white, a black swan must be observed. According to Popper, the truth or knowledge must be verified or refuted to arrive at a solid conclusion. Popper argued that science should attempt to disprove a theory, rather than attempt to continually support theoretical hypotheses. Thus, an alternative conception about facts, knowledge, or truth may be considered as a counter hypothesis that could be verified which if proven false may justify the absoluteness of this fact, knowledge, or truth. Hence, outright dismissal of an alternative conception may hinder in justifying this knowledge.

From this context, teachers must use alternative conceptions for the students to think critically. As Demirhan and Koklukaya (2014) stated that for individuals to make appropriate decisions, "they must develop habits of seeking out multiple views and learning

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how to look at each critically." Alternative conceptions could contribute to the improvement of critical thinking. Hudgins and Edelman (1988) defined critical thinking as "one of the aspects of thinking, which is accepted as a way of overcoming problems and facilitates the way of reaching the information in our lives."

Alternative Conceptions in Science Pedagogy

Studies in science education have found that both children and adults frequently hold common sense views that come from their investigations into the physical world and perceptual experiences. One may argue that one's thoughts are built on broad abstractions derived from everyday experiences. They provide explanations for specific circumstances and provide answers to specific queries or issues in daily life using this contextual knowledge. Children's or even adults' alternative conceptions frequently run counter to the impersonal scientific models and are substantially different from scientific conceptions. According to different researchers, students' alternative conceptions may continue to influence their science learning even after they have been introduced to scientific models in formal training.

In fact, according to studies, deeply ingrained intuitive or commonsense beliefs are most persistent and cannot be entirely replaced by scientific beliefs through science education. Instead, the scientific model could coexist with different views. Student beliefs will have a direct influence on science instruction and the capacity of science teachers to assist their students in developing a better knowledge of conventional scientific models. On the same hand, conventional science education frequently fails to foster a solid comprehension of approved scientific models in students and tends to dismiss their own thoughts and opinions. In science education, it is crucial to acknowledge students' common-sense concepts as well as the methods in which they use them to understand scientific and technical events.

I agree with some philosophers and educators that some concepts are palpable in nature and must not be given time and must be rejected instantly, but the question will be what criteria will be considered so that the concepts per se will not be wrongly rejected since it may emerge as truth in the future. That is why in my teaching, I did not dismiss any conceptions developed by my students. Instead, I treat them as radical ideas wherein if proven as truth, will add to the contribution to the body of knowledge. Take, for example, an instance where a formula in mathematics (Natividad, 2011a; Natividad 2011b; Natividad, 2012; Natividad, 2013; Natividad, 2016) that I, myself, developed was scrutinized by my student and proposed an alternative. At first, her idea appeared flawed and her understanding of my work is different, however, I encouraged her to work with this alternative conception. From this collaboration, we were able to verify the truthfulness of her radical idea, publish it (Natividad & Policarpio, 2013), and now part of a body of

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knowledge in mathematics. This is the same case with my students in chemistry wherein a publication was generated (Natividad et al., 2014) from their alternative conception of my earlier paper concerning carotenoids (Natividad & Rafael, 2014).

Thus, I contend that it is vital that proper handling of alternative conceptions of students become an integral part of the pedagogy of science teachers. If educators can effectively use alternative conceptions as an effective tool, then effective individuals and critical thinkers are coming alive.

Conclusion

Students are likely to hold on to preconceived ideas even contrary to science. Science teachers may try to eliminate or replace these alternative conceptions for them to introduce new learning and concepts. Even though some studies revealed that indeed, eliminating alternative conceptions through different approaches helps the students to truly learn the lesson, one cannot deny the possibility that the students may stick with this alternative conception since this is already part of their lived experiences and is difficult to unlearn.

Studies revealed that treating these alternative conceptions as a partner for building scientific understanding may lead to an effective strategy for teachers to foster a better understanding of scientific knowledge. This is not absurd to think since the nature of science dictates that scientific knowledge is not permanent as supported by the paradigm shift of Kuhn. Alternative conceptions could also help in the critical thinking of students. It is imperative therefore for the science teachers to understand how the students learn and how these alternative conceptions develop to be in cycle.

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