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Does Conceptual Change Process of Instruction Promote Scientific Understanding of Biological Evolution?

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ABSTRACT

This study investigated the teaching experiences of secondary science teachers on biological evolution to promote conceptual change among their students. Descriptive phenomenological analysis was employed to explore the lived experiences of teachers (n=12) via a semi-structured interviews with the participants. Thematic analysis revealed six stages of conceptual change process of instruction of biological evolution, namely recognition, reinforcement, relevance, restructuring, reflection, and enrichment. These stages facilitated gradual conceptual change among students; however, students did not completely develop a sophisticated understanding of evolutionary concepts due to strongly held inherent beliefs and biases by their teacher and the lack of mastery of the concept. Strengthened teacher preparatory program, content enrichment, pedagogical retooling, availability of manipulative and audio-visual materials, and the supportive collegial group will help capacitate teachers to effectively and competently teach evolution.

Keywords: teaching evolution, conceptual change process, Philippine education, science education, Phenomenological study

INTRODUCTION

Teachers are the agents to develop scientifically-literate citizens and they are "the missing link" (Brooks, 2001) that connects scientists' thought processes on evolution and that of the general public's resistance and the lack of knowledge of the concept (Newport, 2006). While it is no longer an issue as to the provision of evolution in the curriculum, its inclusion is not a complete guarantee that it is taught accurately in the classroom (Hermann, 2008; Hildebrand, 2008) despite the theory being regarded as the most plausible and scientifically-accepted theory based on evidence (Moore & Cotner, 2009; Hildebrand, 2008). Biological evolution instruction presents special challenges among science teachers (NAS, 2004) because standards alone are not enough to ensure the accurate teaching of evolution in classrooms (Moore & Kraemer, 2005). The inconsistencies and mismatch of teaching approaches in the delivery of the lesson from the teacher to the learner (Banet & Ayuso, 2003) and the influence of the learners' external environment (Clores & Limjap, 2006) account to these challenges. It puts teachers at the center as one of the major sources of misconceptions aside from the reference textbooks (Clores & Limjap, 2006). The content and manner of teaching the concept are likely to be influenced by the nature of the subject and by inherent teachers' belief and subjectivity towards the subject matter (Balan, 2015; Moore & Cotner, 2009).

Increasing scientific reports have described the upsetting predicaments faced by teachers teaching evolution. There is no in-depth and integrative delivery of instruction with other scientific disciplines, which limits a deeper and more relevant understanding of concepts because it is compartmentalized (Yasri & Mancy, 2016). There is also an observed avoidance of the topic due to fear of conflicting personal beliefs and religious orientation as evidenced by its placement in the curriculum causing it to be either skipped, or rarely and superficially discussed (Rutledge & Warden, 2000; Hildebrand et al., 2008; Hermann, 2008). Alters and Nelson (2002) purport that if inadequate and flawed instruction continues to be practiced using conventional approaches, science education remains to be less effective and full of biases favoring only for a particular group. Education researches underscored the need to employ methodologies that foster student engagement and comprehension through active participation, critical thinking, contextualized interdisciplinary approach, and strategies that promote conceptual change (Sheppard & Prischmann, 2003).

A new fertile research area in science education for the past decade is on the

epistemic cognition and beliefs of teachers and how it translates to their teaching practices (Buehl & Fives, 2009; Lunn, Brownlee, Ferguson, & Ryan, 2011; Chinn, Buckland, and Samarapungavan, 2011). One of two definite ways to promote change in the epistemic belief of an individual is through conceptual change strategies by engaging the individual to a higher-order thinking (Lunn Brownlee, Ferguson, & Ryan, 2017), inducing cognitive conflict through constructivist strategies and exposure to conflicting explanations (Rodrıguez & Cano, 2007) which essentially involves higher-order thinking (Lunn Brownlee et al., 2011). Facilitating conceptual change to occur among students through engaging teaching practices is a great role of teachers (Hewson, 1992) by utilizing effective instructional strategies that makes use of students' prior knowledge as a foundation in building new scientifically correct concepts (Tunnicliffe, 2006). With all the preceding need of constructivist-based instruction, it is a vested interest of this study to find out how teachers facilitate conceptual change on misconception-enriched science concepts (i.e., biological evolution) to their students despite the strong and varied cultural and religious background.

FRAMEWORK

There are various views of authors on the definition of conceptual change. Research on how student's prior knowledge influences learning was first introduced by Piaget in his assimilation and accommodation theory. In 1992, Posner and his colleagues introduced the classic learning model called conceptual change. It consists of four-level framework of dissatisfaction, intelligibility, plausibility and fruitfulness. Hewson (1981) has further expanded the model by adding reconcilability as the fifth condition that triggers the person to be dissatisfied with the strongly-held concepts and undergo conceptual capture or conceptual exchange of the concept to be considered. Hewson (1992) interprets conceptual change as a manifestation of growing awareness of an individual's diverse and strongly held conceptions of natural phenomena. It is knowledge construction that takes place within a context and social interactions. This movement in learning is closely linked to a constructivist-epistemological view. The more recent development of conceptual change is considered to be more inclusive because it addresses the dynamics of teaching and learning processes more comprehensively (Duit & Treagust, 2003). Meanwhile, Vosniadou (2009) describes conceptual change as an approach that delves on a way of learning a particular subject matter such as science concepts that require significant restructuring or reorganization of existing knowledge and not merely adding up to what is already acquired. Conceptual

change-oriented instructional design is recently considered to be more efficient due to constructivist orientation. The idea should be translated in the instructional practice but the problem is that majority of teachers are not updated and are not equipped of the latest trends in education because the transmission way of teaching predominantly exists. Some researchers posit that students view on the "ways of teaching" as a kind of pedagogy that serves as transmission of content expert sources to relatively passive recipients (Hewson, 1992; Duit & Treagust 2003; Vosniadou, 2009). Hence, it is noteworthy that through investigating teachers' views and their instructional behavior in a process of conceptual change, sound instructional decisions can be made.

OBJECTIVES OF THE STUDY

The present study is conducted to describe teachers' instructional process of evolution theory with a salient emphasis on their perceptions of the concepts and pedagogical beliefs and how it influences, their approach in teaching, which will ultimately lead to conceptual change. This study aimed to provide a framework of conceptual change-based instruction that science teachers and educators can use to teach biological evolution, especially in the context of newly-implemented curriculum and predominantly religious populace. The entire research process centers on the question, "How do science teachers teach biological evolution that fosters conceptual change on their students?"

METHODS

This study primarily aimed to describe the individual experiences of public school science teachers teaching biological evolution (here onward termed as evolution) in the new K to 12 curricular frameworks. Such a premise of analysis and data collection requires phenomenological analysis as an inductive approach.

Twelve purposefully-selected Biology teachers who have taught evolution in high school who are implementing the K to 12 science curricula were the source of data. A vital aspect of this study is the general understanding that these teachers have rich cultural and religious milieu reflective of their students. In the old curriculum, science concepts were offered in a discipline-based approach (i.e., General Science is for first-year high school; Biology is for second-year high school). With the shift in the curriculum to K to 12, concepts are now offered in a spiral progression. This competency is also a prerequisite for the higher concepts in Biology. The selection criteria for sampling were as follows: (1) he/she must

have an undergraduate degree in natural sciences or science teaching (BS Biology or BSED major in Biological Science or allied course, respectively); (2) must have taught evolution for at least three (3) years; and (3) must be a Science teacher for at least three (3) years. The sample size was twelve (n=12) secondary school science teachers in Cebu City, Philippines.

The instrument utilized in this study is mainly the interview guide composed of six semi-structured questions. Interview protocol (Creswell, 2013; Jacob & Furgerson, 2012) has been adhered to in asking questions and in recording answers during a qualitative interview. The instrument is content validated by three experts (two are content experts, while the other one is method expert).

There were two rounds of the interview conducted. The first round was the interview proper, while the second shorter round was for any questions missed during the initial interviews and clarifications of the transcribed initial interview (Jacob & Furgerson, 2012). The second round of interviews also served as member checking of the participants if they have agreed to the transcripts. Interviews were recorded via electronic means, which approximately lasted for almost an hour or more for each of the participants. Participants were debriefed with the interview questions in order for them to provide clearer, substantial, and relevant information. The interviews were manually transcribed and translated and kept safe. Access to data is limited and is made available to the participants whenever they like. During the actual interview process, participants were requested to share and narrate their perceptions of the concept of evolution, experiences, difficulties, struggles of teaching biological evolution.

Verbatim transcripts collected through the semi-structured interview with the participants served as the dataset. Interview responses were answered in either vernacular or English language. The researcher analyzed the transcripts to preserve the voice of the participant's narrative accounts of his/her lived experiences in teaching evolution. Data collection and analysis happened consequently and is anchored on the analytic process of Colaizzi (1978) for descriptive phenomenological analysis. The text data obtained from the interview were coded using both descriptive coding and in vivo coding method and were manually analyzed for themes for a more intimate and detailed exploration of the response. The themes organized were emergent from the participant's transcripts. Teacher's teaching experiences are looked into in terms of the manner on how he/she delivered the lesson on biological evolution to the students. Member checking, expert validation, and bracketing of the researcher's own biases and presuppositions were observed to establish the trustworthiness of the whole research process.

RESULTS AND DISCUSSION

It is the goal of this study to describe how the teachers promote a conceptual change of the misconception-laden topic on biological evolution through their instruction. Analysis of data revealed six stages of conceptual change process of evolution instruction (see Figure 1) that were common among the participants: (1) recognition; (2) reinforcement; (3) relevance; (4) restructuring; (5) reflection; and (6) enrichment.

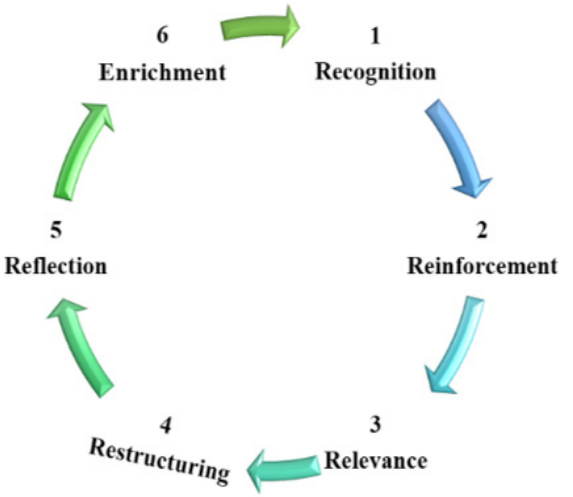

Figure 1. Stages of Conceptual Change Process in Teaching Biological Evolution

The Recognition Stage: "I need to know what my students already know."

In teaching evolution, it is commendable to draw out students' alternative conceptions and allow them to question, argue, make clarifications about the evidence and the theory itself so that they will be the ones to dispel their misconceptions or restructure their existing ideas. Some participants encouraged argumentation and questioning, while others were defensive of their personal theistic view by putting a disclaimer or shutting down students' clarifications. It is forwarded by science education researchers to let them inquire about the scientific topics by asking questions with no right or wrong answers and let them conclude by themselves. When teachers consider the alternative conceptions of the learner, one is acknowledging the voice of the learner. For instance, Noel assumed and asked students regarding their prior knowledge so he would know where and how to structure his lesson.

His observation was that students had varied prior knowledge, which were either incomplete or faulty brought about by half-baked instruction early on. Other students had completely no idea about evolution. Students shared the same prior conception about evolution, which they associated with a mere morphological transformation of organisms. Therefore, students have had evolution education in their elementary grades, but it was not coherently understood, and its mechanism was not profoundly established in their mind.

> "*I always ask them about a topic, if they have learned that one during elementary or they have a schema about that so, I ask them some ideas and let them explain what they have learned so I can gauge where I should get in. Some had no idea, some had a partial ideas, and there are few who were familiar with the topic. We need to gauge them, so no one will be left out especially, those who have no prior knowledge at all. It is a must to refresh then explain to them again. Students have naïve knowledge like animals evolved from land-based to reptiles or those fishes from underwater that developed wings later on. Those are the only ideas they have about evolution which is more on the changes in morphological features."* (Noel)

On the other hand, Rollie has assessed students existing knowledge through diagnostic assessment and the same findings with Noel that there is scarcity of evolution knowledge among them. If there were traces of conceptions, it was more of misconceptions and scientifically incorrect ideas. The association of evolution to "man came from apes" statement remained pervasive, and this report is significantly informing the field that misconceptions continuously exist up to the present time and is handed down from teachers to students and is shared widely to the community at large.

> *"I start with the foundation concepts before I introduce the topic. I started testing their prior knowledge by giving them pretest or pre-assessment or diagnostic test on how far they have learned about evolution but sad to note based on the result, they had no prior knowledge. I do it because it is a little bit deeper, and it requires a strong foundation of basic concepts. Their idea is that we evolved from apes. That is all they knew and heard about."* (Rollie)

Teachers were challenged in teaching evolution because of the intuitive knowledge that students bring into the class and this seemed to be prevalent among the new generation of learners. Diagnosing students' prior knowledge

towards a particular science concept is essential to foster an active and enabling learning process. Cassie had students who were doubtful about the validity of the theory and its supporting evidence. Despite its atmosphere, she still accommodated their alternative conceptions as an opportunity to promote underlying tenets of evolution. Cassie's poor evolution education experience when she was a student reminded her to avoid the cycle of miseducation.

> "*They are also skeptic about it. They are doubtful about the validity of the evidence as to who traced it. For instance, the fossils of dinosaurs, they are doubtful on the sufficiency of a bone to illustrate the whole picture of extinct organisms. So you have to patiently explain it to them, so they will not experience what I had when I was a student."* (Cassie)

During her evolution teaching, Jenny recounted the challenges she faced due to the influence of external force to the understanding and acceptance of students on evolution. External force here pertains to the controversy magnified by the fake news circulated the social media platform, of which students have direct and easy access to enrich their knowledge on evolution. Fortunately, she seemed not to be threatened by this scenario and instead found it to be an opportunity to challenge students' perception of evolution and understanding science's nature and processes in general.

> *"Sometimes, I find it amazing that students also have their videos, but if you look at it you would know that it is fake, especially if the creationist created the video. So I asked them, 'what is the source of your video?" Who is the author?' because students would insist on showing it to you. I would say that it is the creationist who made it because it claimed that the evidence presented by the scientists such as fossils are all fake. I told them that books are more reliable compared to videos available online because you can even create your videos because that is what students are into now. We talked about the video they want to show, but then I tried to show them the real proof of the evidence that have been presented by scientists. There were still some who insisted of their views about it which lead to more debate. Nevertheless, this is a stimulating discussion because it encouraged critical discussion, so I kept telling them to look for more reliable sources. That is the role of the teacher."* (Jenny)

There were two accounts of teachers who have demonstrated a kind of instruction which fostered conceptual change. Both Cassie and Jenny did not inhibit students' epistemological knowledge nor coerce them to dismiss and replace their alternative conceptions of things. They allowed them to channel their doubts in the form of open inquiry. Jenny claimed to accept evolution theory but possess limited knowledge of the mechanisms of evolution whereas Jenny displayed a deep sense of understanding and knowledge but consistently denied acceptance of the theory. Despite the differences in their epistemological beliefs and knowledge, both teachers encouraged freedom for critical discussion to challenge their misconceptions and assess their stand. Teachers, however, have varying stances towards evolution. Some have displayed a high level of agreement and inclination whereas others showed a relatively high rejection and doubts, and some even profess outright denunciation, and it somehow influenced not just the kind of instruction but also the amount of evolution education provided.

> *"The evolution is a theory about the origin of life. One of the misconceptions of teachers is they tend to compare it with creationism, which is focusing on the origin of life. Evolution is not the theory focusing on the origin but on the changes that occur over time regardless of the origin. That is what I usually noticed for the misconception that they focused on the origin of life on the earth. Another misconception that students had was the idea that we came from monkeys then we became humans, and since we have become humans, we will no longer evolve, and so evolution stop which for me is wrong because based from what I can remember, humans are not current, I mean humans are still evolving into modern. I present them with my source then correct them of their misconception."* (Ferdie)

Educator's beliefs and attitudes stems from their own particular educational experiences. These experiences contributed to how educators evaluated their abilities in comprehending science phenomena and the capacity to teach science.

The Reinforcement Stage: "Making my lesson understandable and enjoyable."

Participants reported to having used technology-mediated instructional materials such as pictures, videos, and documentaries to support and to correct alternative conceptions and misconceptions of students. This helped them facilitate a lesson on evolution in an engaging way as opposed to explicit instructions without visuals at all. Their personal experiences when they were still learning it in the past,

and their learning style informed them of their practice through the use of enabling materials and activities. Teachers spent time and effort expanding his understanding and interest of the content through reading and watching documentaries and educational videos for content enrichment in providing thorough explanations, contextualized instructions, a variety of examples, and the ability to answer questions from students. The method of knowledge transfer and the content of instruction to students depend on the pedagogical knowledge of the teacher. Technology integration shapes today's instructional routine (i.e., the use of audio-visual equipment) in delivering lessons across all disciplines. Computer literacy has become an added value in teaching because the use of technology in teaching made the job more efficient, and the content of the lesson becomes more relatable to the students through the use of visuals. Hence, it is highly encouraged that teachers equip themselves not just of the pedagogical and content knowledge but also of technology-based skills. Generally, teachers became dependent on the use of visual materials for the following purpose: (a) complement their lack of understanding, (b) avoid insinuation of their stand on evolution, (c) preventing situation that will reveal their theological beliefs, and (d) foster interaction with the information shown by the materials.

> *"We had this online game, and the students were to play on their own where they can observe changes from this form to this form, its relatives, that kind of strategy. For readings, students had to look for journals about evolution, share it, and discuss it. In employing journal [reading], online games, and videos, we only had short discussion about the topic. I just gave an introduction, then they will do all the activities on their own."* (Shirley)

Moreover, representations of many types were offered by participants (e.g., concept maps, problems as models, videos, displays, step-by-step demonstrations, and pictures) and given emphasis in their teaching process. The significance of these representations to learning varies (i.e., to help students get a picture of the concept; to visualize it and remember it; to show how everything is connected; to retain more; to internalize more, and to bring home the message needed by visual learners). While these representations held various meanings to them, one shared idea is that a model facilitated students' thinking, and they are more engaged in the topic at hand. They see these representations as important element of teaching and learning process.

"I have videos, and then the bio-interactive that I shared with you. There are also videos with accompanying activity sheets, so that is what I gave them as an activity then discussion. I allowed them to watch or find more videos." (Jenny)

Teachers see their role as a provider of stimuli that promote interest in the lesson. Jenny, for example, recognizes the power of questions and its impact on the teaching and learning process as a vehicle for inquiry. She also valued the power of visuals, especially to capture the attention of students that are hard to engage. Such technique resonated with her reflections and experiences on her learning as a child and her pedagogical belief that visuals help students learn complex concepts. Leandro's experience mirrored that of young and novice teachers whose initial teaching experience were more of the college-type approach and spoon-feeding of the concepts, bearing in mind the belief that students will absorb whatever concepts given to them without acknowledging their alternative conceptions. As a result, he admitted that students were bored, disengaged, and struggled to grasp the input, especially for those who are not inclined to science. Through constant reflection, he became conscious of his passive teaching style and had improved to a more constructivist approach through the use of familiar examples and pictures. This improvement in his pedagogy made him feel better and competent as a teacher. Similarly, Rollie believed in the complementary and supplemental effect of visuals like videos and familiar pictures in his instruction. Teachers opined that the use and exposure of concrete and manipulative materials and tasks facilitate evolution instruction better.

"We have this video about the expedition of Charles Darwin on the Galapagos Islands, so I showed them the video and I solicited information about the topic. After that, I unlock some terms for them to at least be familiar as we go along with our topic because some terms in the books are technical, and students seemed to be unfamiliar with it. When I introduced to them the documentary about Charles Darwin, it was then they slowly appreciate and grasp the information about evolution. I printed photos for them to compare the structures and functions of those homologous and analogous parts. I usually did it as a group to encourage peer discussion and peer mentoring." (Rollie)

One participant whose pedagogical belief rests on the realistic observations through field trips and active teaching and learning process expressed disappointment when the moratorium for the field trip was implemented. He

witnessed the transformative effect on the attitude, interest, and understanding of field exposure to the students and the ease in teaching science concepts on the part of the teacher. On the other hand, Shirley, who is teaching in a science-oriented school, considered the use of concrete and manipulative materials and activities as helpful tools in teaching selected concepts in evolution.

> *"There are evidence that can be presented to the students. For instance, if you showed to them about the evolution of bacteria on how they developed resistance to the antibiotic, students can understand, and they even commented that it is indeed possible for evolution to happen because the evolution of bacteria is fast-growing. We had students who researched on the antibiotic resistance, so that is the example we give and ask them to read the works of the schoolmate. Sometimes, we give it to them as reading assignments then administer practical tests after which we compared it with evolution. It was indeed, effective. They understood about evolution that it is not just possible; rather, it is happening."* (Shirley)

Teachers also considered the learning style preference of students. When the learning style of the learner complemented that of the teaching style of the teacher, good learning outcomes happen. However, when it is mismatched, it breeds students to become inattentive, perform poorly, and become disengaged and lose interest in the lesson. Some teachers are intuitive and reflective, while others are keen on sensory perception. Paul, along with other participants, claimed that the majority of the students are visual learners. This perception towards the learning style of students reflected his learning style when he was also a learner. Similarly, Jay preferred activities and task that involves a lot of movement and games because he contends that learners learn best when they move around and enjoy and that learners are kinesthetically intelligent. It showed that regardless of the teaching style in teaching evolution, teachers' sensitivity to the needs of the learner and ambiance in the classroom mattered as it informed him/her to modify the approach and delivery of instruction to accommodate learner's learning style.

The Relevance Stage: "Bridging the Gap between learner's context and science concept."

The teacher used localized examples and situations that are relevant to students. Their approach is context-based and context-specific. What the teacher found meaningful and significant about the science concept is what was emphasized

in the delivery of the lesson. If the teacher found the concept irrelevant, there is likely a chance of skipping it, omitting it, or superficially teaching it in class. They also attempted to establish an atmosphere of objectiveness in the teaching of biological evolution by introducing and including the nature of science. Rollie oversimplified emphasis on evolution through a take-home line "survival of the fittest", which may have negative implications for the students' learning. He wanted to extract moral values from the lesson on the evolution, of which he believed that, when students see the values of the lesson, they will find it relevant to learn and apply in their daily life; however, this kind of teaching may mask the details of the mechanism of evolution. Micah had the same end goal of teaching evolution which is geared towards the appreciation of Divine Power. In spite of the superficial coverage of evolution, the participant seemed to be satisfied with their approach in light of the values and ethical considerations that students will bring home. There is no denying to the sphere of influence of the teacher's disposition to the kind of learning and attitude towards science that learners will develop. Just like the misconception of students and general public, evolution theory to these teachers is still unproven and is simply a science idea. In fact, to them learning the topic is necessary to strengthen the appreciation of Supreme Being. Most likely, this implicit creationism-based instruction is strongly influenced by what the teacher personally believes.

> *"I highlight the essential concept of Charles Darwin that students must understand, which is "it is not the strongest and the most intelligent species that will survive but the one most responsive to change." I inculcate to them moral values about nothing in life is constant; although every now and then, things change, weather change, people change, but how you will survive depends on how you adapt to those changes. The same is true with organisms, they evolved based on adaptability in a particular environment and not have lived until today if they did not adapt to changing environment where they live. Similarly, the biggest lesson we learned is that we have to adapt to the changes that is happening around us. It is then that students started to be interested on how beautiful life is and understand why such thing appears the way it is, how life is really being conceptualized by whoever created like God perhaps or simply how things evolved. It is when they realize the importance of life, and all the things around us and we should not abuse them. It is also fulfilling for me that they learn that things change and we have to adapt to change for us to survive."* (Rollie)

In establishing the relevance of the lesson, teachers included the general connection between evolution and the real world such as biodiversity conservation, habitat loss, the development of antibiotic resistance among bacteria, among others. Some participants have shared personal reflections on the pedagogy used in teaching evolution, where concepts should be connected to visuals and hands-on activities. The breadth and depth of one's understanding of evolution are seen in the kind of examples one advances. For instance, Paul, who is a Nurse by profession and only had a Human Evolution course during his graduate studies, used the resemblance of physical features of offspring from the parents as a motivation to introduce evolution. Despite this meager representation, he was able to draw out interest from the students which reflected that establishing relevance of the lesson which is indeed pivotal to evolution instruction.

> *"I told them that look at yourself who do you have similarities with your parents, and they were interested about it. Before, my class used to be so boring, plainly lecture and copying and students are very passive and did not understand at all."* (Philip)

They also argued that for understanding to take place, it is necessary to provide activities and link it to something they have experienced as a frame of reference. Leandro has voiced out his disappointment with the limited basic knowledge of students which is supposed to be developed in the early years in education. The tendency for them is to keep on revisiting basic concepts otherwise contextualization is useless because students cannot relate to the examples given and its underlying concepts. Collectively, they underscored the need to contextualize teaching of evolution, i.e., by making the lesson, the examples, the materials, and task relevant to them and where students are, particularly their prior knowledge and their background.

> *"Actually, I used current events that they can relate to like epidemic diseases and who started it, those diseases caused by mutations. I teach some parts of Genetics superficially because it has been focused in Grade 10 curriculum but for me Genetics is one of the evidence for evolution, although it is a higher subject but it is interrelated to all other fields for the student to fully grasp. This is also to show to show that this is one of the evidence and it's up to them to take the credibility of it. In Biology, evolution is the concept that links everything, especially on my part. It is essential to understand evolution fully because it is a core topic on diversity that I am teaching in Grade 11. If they cannot grasp*

evolution, they cannot appreciate biodiversity and why species are presently so diverse. Majority of my discussions are on the different kingdoms, so they are all anchored on evolution so I have to teach clearly about evolution." (Shirley)

Participants also offered personal reflection in consideration of the essence in teaching evolution concepts. They accentuated the strong connection of evolution and its application in real life. An indication of higher cognitive process is allowing students to integrate and apply scientific principles and concepts to real-life problems such as in the field of medicine, implications of genetics development to policy, and other pressing environmental issues. Consequently, students realized that conservation of biodiversity, respect, and appreciation of life is the ultimate reason for learning evolution. This is the stage where consensus in learning evolution is resolved in light of the application of the concept to reality, connection with all the organisms both for extant and extinct species, and promotion of human welfare.

"First, I find the topic essential for understanding our environment and for appreciating the life that we have at present. I think that is also the main idea that I have to teach to the students that these organisms we have now were not the same as before so the changes it underwent through time was not easy. What we can do best is to preserve and learn about it for conservation purposes, so that we people will not be extinct since we are the reason of their extinction." (Marie)

The Restructuring Stage: "Time to shake up my student's mind."

The students were given freedom by the teacher to restructure old conceptions and new information received in order to empower students to own their learning. A participant recalled that during his class, there were students who were adamantly rooted in their religion-raised argument against the evolution concept by advancing the biblical story of creation. That student questioned the moral ascendancy of the teacher as though discussing evolution equates to a betrayal of one's religion. It has been a challenging situation to him. However, he allowed students to freely question him on religious matters and explained to him that science is more concerned about the pieces of evidence available and that learning evolution does not equate to neglecting and denying one's religious beliefs.

> *"They brought about creationism because it is the most common idea among the students. A student said that 'Sir, isn't it in the Bible it is stated that God created humans in His image and likeness so why should we believe in evolution? Aren't we Catholic, Sir?" So from that, I could say it is a controversial topic, but I just had to explain to them by saying that we did not neglect our religion; however, in science lessons, we had to base it on evidence."* (Paul)

The same open-mindedness in teaching evolution is manifested by Jenny, who encouraged critical thinking of the information available. This is despite the atmosphere of resistance coming from the students upon introducing the concept of evolution. She even admitted that one student questioned the necessity of including evolution in the curriculum and suggested further to not dwell in the lesson and to move on to the next topic. Undeterred, she saw the need to induce the scientific way of knowing through critical thinking among students to challenge their preconceived knowledge and beliefs but not in a manner that prescribes what to believe. She allowed the students' freedom to question, to process information, and even to the point of coming up with their theory or explanation. In this manner, students were allowed to go over their existing conceptions and reconsider the evidence that they will encounter. As they searched and indulged in intellectual discussion, they will come to the point of experiencing conceptual change. There is a caveat to this kind of freedom. Students might perceive the statement "you can make your theory" as a ground to accept that evolution theory is still not proven and is only a tentative explanation to a phenomenon.

Leandro views argumentation and intellectual discussion as instrumental in fostering conceptual change. To him, it is an avenue to discover students' thought processes to influence those students who seemed neutral in their position and are just weighing substantive and intelligible information to decide on accepting or rejecting evolution. He also experienced an instance where an in-depth discussion triggered students' conceptual restructuring as indicated by the "aha moment" from students. The kind of class interaction was intensely engaging. It can only mean that either student heard the concepts for the first time or their intuitive knowledge which they held too long to be true was dispelled and abruptly replaced with the overwhelming and plausible evidence.

> *"I admire intellectual discussion to the point that it almost becomes a conflict because for me it is an avenue for new learning and there are passive*

students whom we may not know are already processing information of which they become passive because either they did not know at all or because they understand already. To see someone who will negate is a spot interest. I really look forward to it and if ever there is, I would throw the question to the whole class, and we will discuss it further and also so that they can do their research and can have a debate or something like that later on because for me it is a new avenue for a new method of delivering concept so I welcome that kind of questions but so far it did not happen." (Leandro)

All participants offered an appreciation for peer conversation, sharing, and exchanges of ideas in science learning. Participants unanimously considered research, argumentation, and peer-based activities a means to foster student-centered instruction and minimizing teacher talk. One of the dynamics that participants valued most is when students engage themselves in conversations that promoted the exchange of ideas. They see the argument as a conduit to learning and an opportunity to explore students' ethics, morality, and emotions. When students started to debate among themselves, there is a conversation taking place where everybody's ideas are coming out, and this is a great learning tool. Learners also paid close attention when a concept has an emotional connection rather than factual things that goes with it because of the former affects learning outcomes positively.

"You can see if students understood the lesson through oral recitation than the written in which they can cheat. They can describe evidence of evolution and how the population of organisms has changed. I let them design a poster tracing the evolutionary changes of a specific species, but they have to research it first. I gave them time to share what they know about evolution, and I identify their misconceptions." (Ferdie)

Teachers seemed to agree on how to set the atmosphere in the classroom away from conflict and arguments. Most of the participants, like Abby, Marie, Shirley, and Ferdie, applied the disclaimer statement and reverse psychology technique as a means of preemptive conditioning so they can facilitate the restructuring of conceptions among students. Each of these teachers has his reasons for doing so. For instance, Marie, who claimed to be strongly religious and consistently denied acceptance of evolution theory applied preemptive conditioning in her evolution class. Marie had no choice in teaching evolution, even if it is contradictory to her religious beliefs because it is in the curriculum. However, she felt the need to state the disclaimer for fear of being able to persuade students to believe in

evolution and become an atheist. There was a deliberate obstruction of any attempts to question religion and science for fear of inducing debate, and her stand as a person will be revealed that will also influence students' perspectives.

> *"I did not experience that a student questioned me regarding that [creationism and evolution controversy] because I informed them ahead not to mix religion and science and that we have to set aside creationism because that is where we are rooted but let us not also limit ourselves with the facts that we need to learn so students do not anymore ask questions. I had to put a disclaimer because I am afraid students will have a debate about the origin of life and about seven day's creation, and for me, it is not appropriate."* (Marie)

Moreover, she tried her best to preserve students' faith, especially at that time when she was teaching in a catholic school. She also felt the pressure that she would be reprimanded for inciting contradicting belief system and lead students to question God and would ruin students' religious faith. Marie manifested discomfort in teaching evolution, and this scenario posed a detrimental effect on the quality of instruction and learning outcome resulting in shortened time allotment and non-verbal cues of resistance.

The Reflection Stage: "Pondering over What Happened in my Instruction."

There is a significant level of discernment among participants towards the topic and way of teaching. Their instructional practices are usually reflections of their beliefs as to what constitutes effective methodologies. Ferdie, Marie, and Shirley have shared relatively similar pre-service experience in learning evolution, and unconsciously it shaped their teaching philosophy. Some participants (Shirley and Marie) have admitted having said a disclaimer statement regarding the validity of the theory and the freedom to stand by their religious beliefs. This conveyed confusion and controversy in science learning and affected the knowledge acquisition of the learner as well as their behavior of not taking the lesson seriously.

> *"I do not divulge my religion to my students. When I discuss evolution, I put a disclaimer that I will only talk about science, not on religion, so do not ask me anything about religion because I will not answer. I also do not insist on God rather, I respect what they believe. I put a disclaimer to avoid conflict with the students."* (Shirley)

They also revealed to have employed varied teaching strategies depending on the kind of students they have and the suitability of a specific strategy to the content. Through it, they felt a sense of efficacy and competence when students are engaged and interested in the activities and materials they provided. Overall, teachers use engaging strategies a means to promote conceptual understanding.

The Enrichment Stage: "I Have to Shape Up."

Pedagogical retooling and pursuit of advanced studies aligned with the specialization are important initiatives teachers found to be helpful in teaching evolution effectively. It is therefore imperative that teachers must organize and practice having a support group in school and continuously upgrade one's knowledge and skills in the field through capacity building activities for a better and more informed curricular and instructional decisions. Science teachers should enhance themselves professionally so that they will become even more effective and feel competent in promoting conceptual understanding of scientific concepts prone to ambiguous meaning-making. Unfortunately, teachers' cognitive structures of evolution reflected those of their students in which is a needs-based concept by Lamarck. Darwin's natural selection is masked by the faint association of adaptation and survival of the fittest as the central idea, but the underlying principle behind the mechanism is least understood. The relatively low acceptance and understanding of the evolutionary theory, along with the poor understanding of the nature of science, are likely the contributing factors to the well-documented de-emphasis of unifying themes in biology not only in the high school but also in the college level biology curriculum. It is implied in this investigation that the academic background of the majority of secondary school biology teachers is inadequate in equipping them the knowledge and skills to teach even the most basic principles of evolution as well as the coherent understanding of the works of science.

> *"I find it most difficult on how to explain the process. During my first teaching experience, I did not know how as I was struggling to teach it. There are students who ask me about evolution, and I will just be honest to them in telling I did not know the answer yet. Now, the difficulty is more on how to relate the lesson on students for them to understand, especially those who have no background knowledge about it."* (Philip)

The felt need of most teachers is more on the enhancement of knowledge and skills, especially on the latest updates and developments in evolution-related information and genomics. They wish to have a support on the accessibility of available lesson plans for teaching evolution with appropriate, varied, and effective teaching materials. They also expressed difficulty in looking for materials appropriate to match the student's cognitive level. Upon introducing the lesson on evolution, the majority of students were not prepared to receive the higher-level concept that progressed from the previous grade level because they have not understood it nor mastered it.

> *"How to make the students understand because, based on my experiences, I had students who are slow to learn, so I was thinking how to introduce the topic, considering that they have insufficient background knowledge because it is often skipped since it is the last topic. I feel like I am the first to introduce evolution and I find it hard to make them understand because I am confused about what should the target concept for them to know."* (Micah)

Teachers are cognizant of their duty to advocate facts and promote correct conceptual understanding of the fundamental mechanism of evolution to promote scientific literacy. Teachers felt pressured to pursue advanced studies in order to gain mastery of subject matter content for self-efficacy and appraisal of teaching performance. Another means where the teacher positioned herself as accountable for learning is through collegial coaching. Some teachers sought technical help and consultation with experts regarding the effective approach and strategies to teach evolution as well as the simplification of explanation of the concepts.

> "*For me, in order to equip the students, teachers must study and as much as possible pursue higher studies because what was learned in the past may not be the same at present. There are changes, so it is a must to read."* (Paul)

CONCLUSIONS

Teachers valued the voice of students by recognizing their alternative conceptions and elicitation of prior knowledge, which they found to be similarly flawed and inadequate. They have challenged students' existing conceptions through audio-visual materials, varied activities, manipulative materials, and visual representations and also put premium consideration to the students' learning style. Teachers' personal beliefs, pedagogical, and curricular beliefs conform to his teaching practice as a

result of the constant reflection of his practice. Their teaching experiences served an impetus for professional development, pedagogical retooling, and collegial support system to improve their perception, knowledge structure, and pedagogy.

Based on the findings, conceptual change process promote better scientific understanding of biological evolution among students, but caution has to be observed to better attain a considerable depth and breadth of concepts. Considering that "teacher factor" plays an important role in maximizing learning, adequate content knowledge and mastery of concepts are deemed necessary to meet the learning goals. The results of this study support the idea that teachers see the need to improve because of the role they embody as science educators who need to promote scientific literacy as well as a sense of accountability of the science concept they teach to their students.

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