Educational Innovation & Practice

CONTENTS

PAPERS

Conceptual Understanding of Genetic Phenomena by Higher Secondary School Students: A Case of Samtse Dzongkhag

KARMA DORJI, PEMA TSHERING, RAJ KUMAR CHETTRI AND LOBZANG DORJI

Abstract

Reasoning across genetic phenomena entails the students to map the mechanisms that are prevailing across ontologically distinct levels of biological organisations. Growing body of empirical research have shown, however, that many students leave the school often with little or no understanding of how genes confer their effects at macro-level via protein mediated mechanisms. Therefore, an exploratory case study was carried out to investigate students' reasoning ability of genetic phenomena involving seventy three (n=73) class XII students majoring in biology. Data were collected by means of questionnaire and analyzed based on the approaches of multiple code based analysis. The key findings include that high school students have no knowledge about: i) biological role of genes, ii) functions and the biological role of proteins, iii) casual mechanistic expression of genes via protein mediated mechanisms, and iv) connectivity between proteins and genetic diseases. The results, overall implicate Bhutanese educators and teachers to articulate the concepts of genetic phenomena with carefully designed domain specific heuristics and domain specific knowledge.

Key words: Genes, Proteins, Traits, Genetic phenomena, Domain specific knowledge

Introduction

Genetics is the center piece of modern biology and understanding genetics is an essential aspect of scientific literacy. Since the inception of double helix molecular model of Deoxyribonucleic acid (DNA), a growing body of research into genetics has given birth to myriad of scientific and technological innovations that are widely applied across the spectrums of everyday life. In light of its ongoing popularity and increasing relevance, today, genetics as a scientific discipline has become an important topic that everyone needs to understand (Duncan, Freidenreich, Chinn, & Bausch, 2011; Duncan & Reiser, 2007; Kılıç, Taber, & Winterbottom, 2016; Mills Shaw, Van Horne, Zhang, & Boughman, 2008; Rotbain, Marbach-Ad, & Stavy, 2006; Tsui & Treagust, 2007).Therefore, across the board of high schools, it is placed as one of the compulsory topics within biology education, relating to the details of cell structures, genetic entities, cell divisions, and laws of inheritance. With this rationale, students at the end of compulsory education are anticipated to graduate with broad and in-depth ideas that explicate unified biological mechanisms prevailing within an individual or across the generation (Banet & Ayuso, 2003; Chattopadhyay, 2005; Chattopadhyay, 2012; Duncan, Rogat, & Yarden, 2009; Lewis & Kattmann, 2004; Lewis & Wood-Robinson, 2000; Venville & Donovan, 2007; Venville, Gribble, & Donovan, 2005). One such idea is the genetic phenomena that underlie the mechanisms embodied across the ontologically distinct levels of biological organisations.

Modern genetics extends classical genetics into the realm of molecular and cellular level that link genes with traits (Duncan et al., 2009). The association between genes and traits is manifested by the genetic phenomena embodied within informational level (genes) and the hierarchically organised biophysical levels-proteins, cells, and tissues (Duncan, 2007; Duncan & Reiser, 2007). According to domain specific heuristics of Duncan (2007) and Duncan and Tseng (2011), 'Genes-Code-for-Proteins and Proteins-are-Central or Biological Elements that Mediate Genetic Effects'. In the account of modern genomic perspective, genes are referred as the union of DNA segments that code multiple proteins (Gerick & Hagberg, 2007; Meyer, Bomfim, & El-Hani, 2013; Smith & Adkison, 2010). Thus, the informational content embodied in the informational level specify and order the sequence of amino acids-building block of proteins. Therefore, the structure and function of proteins form the basis of cells, tissues, organs, and the character where the elements at one level constitute the elements of progressive higher organizational levels as illustrated in Figure 1 (Alozie, Eklund, Rogat, & Krajcik, 2010; Duncan, 2007; Duncan et al., 2011; Duncan et al., 2009; Duncan & Reiser, 2007; Duncan & Tseng, 2011; Wood-Robinson, Lewis, & Leach, 2000; Tibell & Rungden, 2010).With mediating roles, proteins are chiefly involved in carrying out central roles such as formation of connective tissues, body defenses, enzymes, communication system, and body signals (Duncan, 2007; Duncan et al., 2011; Duncan et al., 2009; Duncan & Reiser, 2007; Duncan & Tseng, 2011), but, changes incurred in the aspects of proteins can ensue visible effects at the macro-level. For instance, for sickle cell anemia, a gene for hemoglobin molecule - a protein involved in the transportation of oxygen in red blood cells (RBC) has a mutation that alter the shape and function of globin protein which confer the RBCs to assume sickle like structure (Duncan et al., 2011; Duncan & Tseng 2011). However, a growing body of empirical research in last one decade have inferred these conceptual aspects perennially counterintuitive (Alozie et al., 2010; Bahar, Johnstone, & Hansel, 2000; Duncan, 2007; Duncan et al., 2011; Duncan et al., 2009; Duncan & Reiser, 2007; Duncan & Tseng, 2011; Kılıç, Taber, & Winterbottom, 2016; Lewis, Leach, & Wood-Robinson, 2000; Marbach-Ad & Stavy, 2000; Mills Shaw et al., 2008; Rotbain et al., 2006; Saka, Cerrah, Akdeniz, & Ayas, 2006; Tibell & Rungden, 2010; Williams, Montgomery, & Manokore, 2012; Wood-Robinson et al., 2000; Venville et al., 2005).

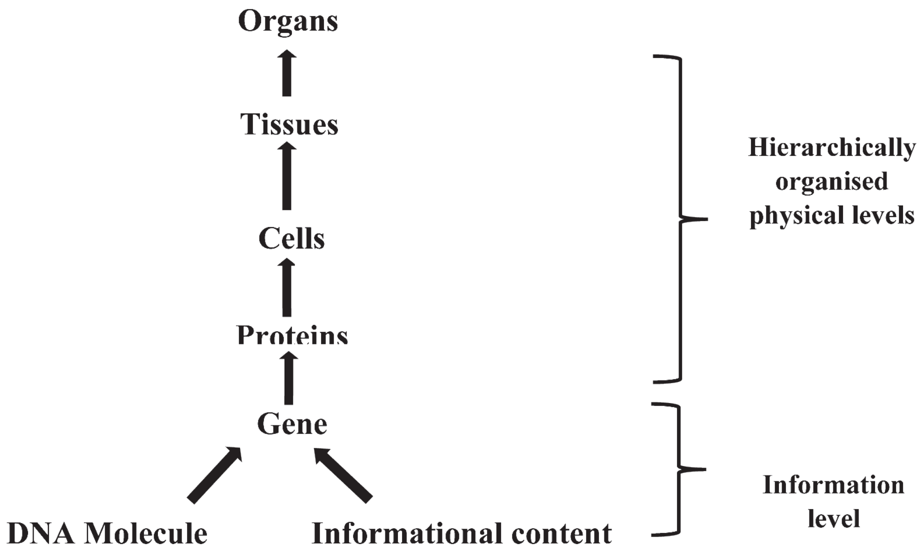

Figure 1. The informational and physical levels of genetic phenomena: Events at one level constitute the basis to form next successive higher level (Duncan, 2007)

With the ontological design, genetic phenomena is touted as one of the challenging domains of biological science replete with the ideas that are difficult to comprehend (Alozie et al., 2010; Bahar et al., 2000; Rotbain et al., 2006; Tsui & Treagust, 2007; Tsui & Treagust, 2003; Williams et al., 2012). In the account of domain general perspective, the perplexities surrounding genetic phenomena are believed to be inextricably anchored with the very nature of the scientific ideas underlying in the domain (Duncan & Reiser, 2007; Duncan & Tseng, 2011), however, there are specific reasons elucidated in domain specific epistemological point of view. First, learning into genetic phenomena entail the students to conceive chemical and physical interactions that prevail at minute details who do not yet have the firm grasp of fundamentals concepts surrounding the interactions between atoms and molecules (Duncan et al., 2009; Lewis & Kattmann, 2004; Marbach-Ad & Stavy, 2000; Rotbain et al., 2006; Tibell & Rungden, 2010). Second, genetic phenomena that span across multiple levels of biological organisations are overly abstract that cannot be perceived via direct hands-on experiences (Alozie et al., 2010; Duncan, 2007; Duncan et al., 2011; Duncan et al., 2009; Duncan & Reiser, 2007; Duncan & Tseng, 2011; Knippels, Waarlo, & Boersma, 2005; Marbach-Ad & Stavy, 2000; Tibell & Rungden, 2010; Williams et al., 2012). Third, genetic phenomena by nature is a complex hybrid hierarchical system built out of ontologically distinct levels that are organised hierarchically where elements at one level give rise to elements of next higher progressive levels (Duncan & Reiser, 2007; Knippels et al., 2005; Tibell & Rungden, 2010; Tsui & Treagust, 2007). As a result, there are reports about students' wide spread confusions and uncertainties that make learning into genetic phenomena heuristically challenging.

Recent research has shown that students' failure to reason genetic phenomena stems either from the view that genes are not informational or misattribution of what genes code for. The study of Venville and Treagust (1998) has discerned that students with truncated understanding view genes as either passive or active particles. In the report of Duncan and Reiser (2007), high school students view genes as the informational sequence that determines structure and function of all the levels of biological organisations. According to Duncan et al. (2011), such views are problematic because assuming genes as deterministic or particulate by nature or the entity that can code all the levels of biological organisation circumvent the understanding of the mechanisms prevailing at protein, cell, and tissue level that give rise to observable entities. Recent research by Duncan (2007) and Duncan and Reiser (2007) have shown that high school students have little or no understanding around the mechanisms that link genes with traits. Comparably, study by Marback-Ad (2001) and Marbach-Ad and Stavy (2000) have revealed that high school students often have no idea about the molecular and cellular interactions that give rise to observable characters. These findings have been confirmed by the growing body of empirical research carried out in genetic education (Banet & Ayuso, 2003; Gericke & Wahlberg, 2013; Kılıç et al., 2016; Knippels et al., 2005; Lewis, Leach, & Wood-Robinson, 2000; Lewis & Wood-Robinson, 2000; Lewis & Kattmann, 2004; Mills Shaw et al., 2008; Rotbain et al., 2006; Saka et al., 2006; Tsui & Treagust, 2003; van Mil et al., 2013;Venville & Donovan, 2005; Venville et al., 2005; Williams et al., 2012; Wood-Robinson et al., 2000). Therefore, given these evidences, it can thus be argued that mechanisms that link genes with traits, which is at the core of understanding molecular genetics, seems to remain opaque, black boxed, and mystifying akin to fiction than the scientific reality (Duncan et al., 2011; Duncan et al., 2009; Lewis & Kattmann, 2004). So, in light of such argument, it appears more than convincing to assume that there can be similar types of conceptual uncertainties existing in Bhutanese educational milieu as well.

In Bhutanese context, basic ideas of genetic phenomena are offered to higher secondary students with few contextual examples such as sickle cell anemia, phenyl ketonuria, and thalassemia (Ministry of Education, 2012; Rastogi, 2014, 2016). Thus, students at the end of instructional hours are anticipated to leave with the knowledge around how protein mediated mechanisms manifest the genetic effects at observable level called traits. However, up to now, there is virtually no research concerning Bhutanese students' reasoning ability of genetic phenomena. Therefore, given the paucity of the past study, there was a pressing need to investigate Bhutanese students' conceptual understanding of genetic phenomena with the following research questions:

1. What are Bhutanese students' conceptual understandings of genetic phenomena?
2. To what extent Bhutanese students' reason across ontologically distinct levels of genetic phenomena?

Materials and Methods

This research was an explorative case study underpinned to gain an insight into Bhutanese students' proficiency in reasoning genetic phenomena. It was carried out in three higher secondary schools of Samtse Dzongkhag towards the fall of the second term of the academic year 2016 involving seventy three (n=73) class XII students majoring in biology or bio-math who have been intervened about genetic phenomena via traditional didactic approaches. Data were collected by means of questionnaire that was administered at the end of the school hour for a period of twenty minutes. The questionnaire had a total of four subjective questions adapted from the papers of Duncan and Reiser (2007), Duncan et al., (2011), Duncan and Tseng (2011), and Lewis et al., (2000) that entailed students to give written responses concerning genes, proteins, and the mechanisms that mediate genetic effects.

Data were analyzed based on the approaches of multiple code based analysis. The coding scheme for each question was developed after several rounds of refinement and application of codes to students' data in combination with pre-existing schemes. Students' response to question: What are genes? were coded into one of the five categories of the coding schemes adapted from Duncan and Tseng (2011) and Venville and Treagust (1998) as i) hereditary material, ii) passive particle, iii) active particle, iv) informational sequence/DNA segment, and v) sets of chromosomes. Students' conception of proteins' functions (What are the various functions of proteins in our body?) were coded into one of the two broad categories of the coding scheme developed by Duncan et al., (2011) and Duncan and Reiser (2007) as i) vitalistic notions about proteins' functions–health point of view and (ii) proteins as structural or functional components of cells or tissues. However, students' response that came under the first category were further coded into three sub-categories: nutritional roles, defense against microbes, and body growth and repair. Similar to first question, students' answer to question: How do genes cause our trait? were also categorized into i) hereditary materials with sub-codes genes and chromosomes, ii) Active particles with sub-codes dominant/recessive and mutant, and iii) traits as the carrier of characters. Regarding the question: What, any if, is the connection between proteins and genetic diseases?, students' response were coded into one of the four categories of the coding scheme adapted from Duncan and Tseng (2011) as i) proteins involved-protein deficiency cause genetic diseases, ii) genes determine protein deficiency diseases, iii) Inheritance of protein deficiency diseases, and iv) genes are made of proteins. In the process of coding, this study came across students' multiple answers against each question. For this, every answer listed against the question were grouped into respective categories with which each student received multiple codes depending upon the number of answers. Therefore, sum of the frequencies in each question is different to the number of samples who took part in the study. Besides, the conceptual aspects of genetic phenomena illustrated in the biology textbooks (Rastogi, 2014, 2016) referred by students were also analyzed to gain larger picture behind students' reasoning power.

Results

This study ascertained that students' knowledge of genetic phenomena shrouded with uncertainties and misconceptions as illustrated in the following sections:

Students' conceptual knowledge of genes varied across five mutually exclusive categories as illustrated in Table 1. That is majority (n=56) in the study maintained genes as the hereditary materials (inherited materials) passed across the generations, while, two out of every four students (n=32) articulated centralised or the deterministic view (active particles) when they stated genes as the determinant of phenotypes. Meanwhile, seven students explicated the associative nature of genes (passive particles) when their argument was based around the linkage of genes with physical characteristics. Conversely, there were dozen students who conceived genes as the DNA segments or the sets of chromosomes that transfer hereditary materials across the generations. As a result, there was no understanding of genes as the informational sequence that code functional products such as proteins or RNAs. Similar findings have been reported by Duncan (2007), Duncan and Reiser (2007), Lewis et al., (2000), Mills Shaw et al., (2008), and Venville et al. (2005) .

Table 1

Students' Conception of Genes

View of genes	Number of students
Genes as hereditary materials	56
Genes as passive particles	07
Genes as active particles	32
Genes as DNA segments	07
Genes as sets of chromosomes	06

Students' conceptual knowledge surrounding the body functions of proteins seemed limited and naïve congruent with the findings Duncan (2007), Duncan and Reiser (2007), and Duncan and Tseng (2011). As a result, their little awareness was basically centered around two domains shown in Table 2. In their response, majority (n=62) stated just the constrained roles of proteins in keeping our body disease free. In light of this, as many as forty-four students claimed that the nutritional importance of proteins in preventing a disease like Kawashikhor, while remaining students expressed the protective nature against the invasion by virus and bacteria like microbes. In the meantime, at least thirteen pupils outlined the significance of proteins for the body growth and repair, whereas seven pupils in the process implied the necessity of proteins for the formation of structural and functional aspects of tissues or cells.

Table 2

Students' Understanding around the Roles of Proteins in Our Body

Roles of Proteins	Number of students
Health point of view	62
-Nutritional roles	44
-Defense against microbes	16
-Body growth and repair	13
Structural and functional component of cells and tissues	07

As students did not have the concept of genes and the functions of proteins in our body, their ability to reason about the genetic phenomena that bring genetic effects at the macroscopic level appeared remote and truncated consistent with the findings of Duncan (2007), Duncan et al. (2011), Duncan et al. (2009), Duncan and Reiser (2007), and Duncan and Tseng (2011). As a result, their limited knowledge around genetic phenomena looked more conspicuous when study did not come across any response that indicated how protein mediated mechanisms bring the mechanistic effects of genes at the macroscopic level called traits. As shown in Table 3, majority (n=58) highlighted hereditary materials as the determinant of traits, out of which thirty-three stressed upon genes while remaining maintained chromosomes as the carrier of traits across the generations. On the other hand, one-fourth samples (n=18) delineated about the determination of traits by either dominant or recessive genes in homozygous or recessive condition. At the same time, there were one in every four students (n=10) who mentioned mutant genes as the entities that ensue traits, while there were also some (n=8) who did assume traits as the phenomena that carry characters, the trend reported by Lewis and Kattamann (2004) as well.

Table 3
Students' Conception of Mechanisms that Mediate Genetic Effects

View upon Mediating Mechanism	Number of students
Hereditary materials	58
-Genes	33
-Chromosomes	25
Active particles	24
-Dominant/ Recessive	18
-Mutant	16
Traits as the carrier of characters	08

Students' extreme lack of ideas surrounding the linkage of proteins and genetic diseases further exposed their poor reasoning ability of genetic phenomena. In the study, not even a single pupil established how mutations in genes would alter the structural and functional aspects of proteins and discern changes at tissue or organ level called genetic diseases. Instead, majority of the participants just outlined mere causal relationship existing between protein deficiency and the genetic aspects with Kawashikhor as an example. In their response, more than one-half (n=39) pupils noted protein deficiency as the direct cause of genetic diseases, while, one in every two samples (n=36) claimed genes as the determinant of protein deficiency diseases. On the other hand, roughly one-seventh of the sample merely implied the hereditary nature of the protein deficiency diseases, whereas, as documented by Duncan and Reiser (2007), less than a dozen samples pointed out genes as the material entities are made of proteins. The detail of students' response regarding the connectivity between proteins and genetic diseases is illustrated in Table 4.

Table 4

Students' Ideas of Connectivity between Proteins and Genetic Diseases

View upon Connectivity between Proteins and Genetic Diseases	Number of Students
Protein deficiency cause genetic diseases	39
Genes determine protein deficiency diseases	36
Inheritance of protein deficiency diseases	10
Genes composed of proteins	11

Discussion

The study ascertained students' capacity to reason across genetic phenomena. The findings on the whole implied students' extreme lack of ideas surrounding genetic phenomena which are discussed below:

Students' conceptual knowledge surrounding genes were based around the assertion that genes are either the hypothetical materials (hereditary particles) that underlie patterns of inheritance across the generations or the particles (active or passive particles) that determine the physical attributes as inferred by Duncan (2007), Duncan et al. (2011), Duncan and Reiser (2007), Duncan and Tseng (2011), Lewis and Kattmann (2004), Lewis et al. (2000), Lewis and Wood-Robinson (2000), Mills Shaw et al. (2008), Venville et al. (2005), Venville and Treagust (1998), and Wood-Robinson et al. (2000). Technically, students' insight into genes in the aspects of hereditary or the particulate nature indicated their naïve conception limited either to Mendelian or the classical concept that do not underlie the patterns that give rise to observable effects via molecular and cellular interactions. Although, there was little awareness of genes in terms of DNA segments, yet their functional explanations of genes were exclusively the centralised or the deterministic nature with inappropriate mapping of informational content of genes directly with macro-level called traits. As a result, their understanding of genes did not illustrate the mechanisms that bring observable effects of genes. Findings from research by Duncan and Reiser (2007) and Lewis and Kattamann (2004) have also suggested students' direct linkage of genes with physical traits. These researchers have noted that students with such trivial and dubious ideas do not consider microscopic and molecular casual mechanisms that bring genetic effects at the macroscopic level. Their findings resonate with what was found out in the study, and support the assertion that students' understanding of genes was simply in the context of Mendelian or classical gene concept. Hence, the finding by nature spoke about students' extreme lack of ideas surrounding modern concept of genes. In the students' biology textbooks (Rastogi, 2014, 2016) referred by students, the details of genes were mentioned across many chapters such as Mendelian genetics, post-Mendelian genetics, and genetic disorders exclusively in Mendelian or classical context with little or no focus around modern concept. Finding from the research carried out by Flodin (2009) and Santos, Joaquim, and El-Hani (2012) have reported that most of high school biology textbooks contain gene concept in hybrid deterministic views in a historical manner inconsistent to the scientific models and the biological concept which may contribute to students' learning difficulties. In light of this, it was thus speculated that students' limited knowledge around genes could be due to the limitations of the concepts illustrated in their textbooks.

In modern genomic perspective, genes are referred as the union of DNA segments or the informational sequences that code multiple proteins or RNAs (Gerick & Hagberg, 2007; Meyer et al., 2013; Smith & Adkison, 2010) or the processes that become only when they act (Gerick & Hagberg, 2007; Meyer et al., 2013). In the popular domain specific knowledge, Duncan (2007) and Duncan and Tseng (2011) state that 'Genes-Code-for-Proteins' and 'Proteins-are-Central or Biological Elements that Mediate Genetic Effects'. In light of such heuristic idea, genes are conceived as the DNA segments that code proteins or RNAs whose interactions at one level manifest the next progressive higher levels, although, even such canonical ideas are currently into crisis with multiple anomalies around (Albuquerque, 2008; Burian, 2004; Falk, 2010; Meyer et al., 2013; Smith & Adkison, 2010). In the literature of genes and genetic education, there are theoretical frameworks that highlight the problems of conceiving genes in terms of hereditary materials or deterministic entities. For instance, Duncan et al. (2011) and Duncan and Reiser (2007) have outlined that view of genes as the informational sequence that determine any and all the levels of physical-functional up to the whole organism is a detrimental tenet that circumvent the need to explain the mediating mechanisms at protein, cells, and the tissue levels that bring the observable features called traits. According to Duncan and Resizer (2007), without understanding that genes as the instructions for coding protein structure students would less likely think proteins as the central molecules of genetic phenomena because they do not realize that genetic phenomena are inevitably mediated by proteins. Likewise, Thorne and Gericke (2014) have reported that particle gene concept appears to be an obstacle for learning functional gene concept that deals with functional products-proteins. Thus, given these claims, it was therefore easy to explain why many students failed to explain the various functions of proteins in our body.

Students' capacity to reason across the biological functions of proteins were limited and scarce, similar to the reports of Duncan (2007) and Duncan and Reiser (2007). In the study, majority had the view that proteins are involved merely for the nutritional point of view, body growth and repair, defense against pathogens, and the component of the cells and tissues. Research carried out by Duncan (2007), Duncan et al. (2011), Duncan and Reiser (2007), and Duncan and Tseng (2011) have also noticed the same trend. Biologically, proteins are chiefly involved in forming enzymes, integumentary systems, connective tissues, signal molecules, receptor molecules, regulatory molecules, transportation system, body defenses, blood clotting components, photo-receptors and any more (Duncan & Reiser, 2007; Rastogi, 2014; Rastogi, 2016). In students' biology textbooks (Rastogi, 2014, 2016), the conceptual aspects of proteins were emphasized broadly starting from chemical composition to biological functions and the disorders related to their dietary imbalance. Given this, it was thus assumed that the way the concepts are taught across the classes or the time devoted by the teachers to teach the details around proteins could be two possible reasons behind students' lack of awareness surrounding various functions of proteins. In the meanwhile, students' knowledge around the functions of proteins were simply vague as their premise did not suggest any plausible or intelligible reason behind how proteins are biologically involved in manifesting the specific roles. In the report of Duncan and Reiser (2007), when students do mention the specific function of proteins, they are vague often without knowing how proteins mediate the effects of genes in conferring the traits. Therefore, it was not surprising to note the pattern that students were exceedingly poor in giving the accounts around how protein mediated mechanisms bring their effects at macro-level called traits.

In reasoning across the hybrid genetic phenomena, understanding of genes as hereditary or deterministic particles are the mere shallow concepts that misattribute genes with traits, while at the same time, view of genes as the informational sequence is not an enough explanation to how the genetic information brings about its effect. So, it is more than important to understand what do the genetic information code for and how (Duncan & Reiser, 2007; Venville & Donovan, 2005; Venville & Treagust, 1998). Similarly, according to Duncan et al. (2011), the failure to reason across the genetic phenomena stem from the view of genes as not informational or misattribution of what genes code for. For this, Duncan and Reiser (2007) have claimed that accounting genes as the informational sequence that code trait directly is a problematic premise that constrains the understanding of mechanisms that prevail at protein, cell, and tissue that bring visible effects. In parallel to these theoretical claims, this study discerned students with trivial ideas of genes where to them, each gene is a mere particle or the hypothetical construct that determine the corresponding trait (genetic determinism) or transfer traits across the generations. In lieu to, some even noted the way the dominant or recessive gene express their effects, yet, herein as well, students did not provide any account that relate the mechanistic expression of alleles via protein mediated mechanisms. As a result, their conceptions were nothing more than the truncated and simple casual explanation that left out important causal events that take place at molecular and cellular level. Therefore, there was no clue that indicated students' mechanistic understanding of genetic phenomena manifested by molecular and cellular interactions that give rise to next higher biophysical levels. Similar trend has been reported by Lewis and Kattmann (2004), Lewis et al. (2000), Lewis and Wood-Robinson (2000), Mills Shaw et al.(2008), Venville and Donovan (2005), Venville et al. (2005) Venville and Treagust (1998), and Wood-Robinson et al. (2000).

According to Duncan (2007), Duncan et al. (2011), and Duncan and Reiser (2007), genes express their effects called traits through various mechanisms embodied within informational level (genes) and hierarchically organized biophysical levels. The information specified within the informational level determine structural and functional aspects of proteins which in turn characterize cell, tissue, and organ at large. In the essence, proteins form the central part of the mechanisms that link genes with traits (Duncan & Tseng, 2011). However, none of the students in the study indicated genes as the productive instructional sequences that code proteins-the mediating molecules of genetic effects. For this, Duncan and Reiser (2007) have claimed that lack of ideas surrounding proteins as the mediating molecules impact the ability to reason out the biological events at subsequent levels and to provide coherent mechanistic explanation of how genes determine traits. Therefore, students' failure to give mechanistic explanation of gene-trait relationship could be due to their lack of awareness surrounding proteins that mediate genes and traits. In the students' biology textbooks (Rastogi, 2014, 2016), the conceptual aspects of gene-trait relations were illustrated exclusively in the context of Mendelian or classical genetics without much focus around proteins and cell mediating mechanisms. So, there was no adequate concepts that illustrated how genes confer traits other than the sickle cell anemia. Similar trend has been unveiled across the student textbooks by Flodin (2009), Gericke and Hagberg (2010a, b), Gericke, Hagberg, Santos, Joaquim, and El-Hani (2012), and Santos, Joaquim, and El-Hani (2012). This could be another reason why students did not have any idea regarding the biological roles of proteins in mediating the genetic effects. The other reason could be the way the conceptual aspects are introduced or the limited instructional time devoted by the subject teachers to the topic of the issue. In this context, Thörne and Gericke (2014) have examined Swedish students' conceptual understanding of genetic phenomena as a result of teachers' talk around proteins when teaching genetics. In their finding, they have revealed that students' proficiency to reason across the gene phenomena is influenced largely by teachers' linguistic focus around proteins.

As students were poor in reasoning across protein mediated mechanistic expression of trait, their knowledge around the connectivity between proteins and genetic diseases seemed far from the scientific reality. This ambience in particular further, consolidated the fact that students were extremely poor in reasoning across the domain specific mechanisms of genetic phenomena. In the study, students had non-normative views predominantly based around protein deficiency diseases with extensive focus around Kawashikhor as the example. In their explanation, many had the view that genetic diseases are caused by protein deficiency diseases, protein deficiency diseases are determined by genes, protein deficiency diseases are inherited, and genes are made of proteins. These findings have been reported by Duncan (2007), Duncan et al. (2011), Duncan and Reiser (2007), and Duncan and Tseng (2011) as well. These results in particular indicated students' misconceptions around what and how protein deficiency and genetic diseases are caused, what are genes made of, and what forms of diseases are inherited. One of the reasons behind students' excessive focus around protein deficiency diseases could be due to a unit in the students' biology textbook that has emphasized the details of Kawshikhor extensively (Rastogi, 2016).

In the actual concept, protein deficiency diseases are caused by the imbalance of protein diet and by this token, it has nothing to do with genes and inheritance. Similarly, the genetic diseases that confer visible effects are ensued, as a result of changes or disorders that prevail within the gene or chromosomes (Rastogi, 2014; Rastogi, 2016) and have nothing to do with protein deficiency diseases. However, the fact is that the results of genetic change that engender visible effects arise only via protein mediated mechanisms. According to Duncan and Reiser (2007) and Duncan et al. (2009), changes that occur at the level of genes (mutation-harmful, advantageous or neutral) alter the structural and functional attributes of proteins which beget visible effects at macro-level via molecular and cellular interactions. For example, in sickle cell anemia, the gene for hemoglobin-the protein involved in transportation of oxygen in red blood cells has mutation that alter the structure of protein which as a result make the protein molecules to stick around each other and confer red blood cells to assume sickle like structure with many symptoms and disorders. Therefore, while reasoning across the domain specific genetic phenomena, one must understand that changes in genes can alter the structure and functions of proteins inside the cells which as a result can ensue changes in the structure and function of the cells with new effects at the observable traits (Duncan et al., 2011). However, there was no response that suggested even a little awareness around the simple causal relationship between proteins and genetic diseases let alone the intricate mechanisms prevailing at molecular and the cellular level. Thus, the results demonstrated students' extreme lack of awareness surrounding how changes in proteins inside the cells mediate the genetic effects called genetic diseases. One of the possible reasons for students' failure to recognize the connectivity between proteins and genetic diseases could be due to their lack of knowledge around what genes code for, how are proteins involved in mediating the genetic effects through various functions inside the body, and how interactions at the physical levels bring the effects of information at the macro-level called traits. In the report of Duncan and Reiser (2007), when students do not conceive genes as the productive sequence for proteins, they fail to presume that proteins are actively involved in any phenomenon that has the genetic origin. As a result, the connection between genes and traits by nature remains a black box which can negate students' capacity to reason the genetic phenomena with mechanistic explanations around microscopic and cellular interactions.

In the meanwhile, study also ascertained that students have little or no understanding about the size sequence of biological structures. For instance, in the study, a couple of students explicated that genes are built out of chromosomes. This indicated the fact that students had the idea around genes as the physical entities bigger than chromosomes. This finding has been confirmed in the recent research carried out by Kibuka-Sebitosi (2007), Kılıç et al. (2016), Knippels, Waarlo, and Boersma (2005), Lewis et al. (2000), Lewis and Wood-Robinson (2000), Saka et al. (2006), Topcu and Sahin-Pekmez (2009), Venville et al. (2005), and Wood-Robinson et al. (2000). However, in the scientific model, genes are recognized as the union of DNA segments that have specific location within the chromosomes (Duncan et al., 2009). At the same time, study also ascertained students' treatment of traits and characters as different levels of biological organization. According to Vishnoi (2012), characters are the features of an organism inherited across the generations, while traits are the alternative forms of character that may appear contrasting to each other. For instance, if height is taken as a character, traits of it can be either short or tall. This alternative framework therefore suggested that students had no ideas around even the basic concepts of Mendelian genetics.

Conclusions

Student's conceptual understanding around genetic phenomena was from the view of scientist and the scientific community. Therefore, their capacity to reason domain specific knowledge embodied across ontologically distinct levels of biological organizations appeared exceedingly poor. Although, there was little awareness of genes as the DNA segments, however, this idea did not extend students' conceptual understanding around how genes manifest their effects at macro-level via protein mediated mechanisms. Instead, students had centralized or deterministic view of genes that are either the hereditary materials or the active particles that control or determine the characters directly. As a result, their capacity to explain casual mechanistic expression of traits via molecular and cellular interaction looked opaque and black box. So, there was no clue that indicated students' understanding of what are genes and what do they do in our body consistent with modern concepts. Concurrently, there was also no clue that implied students' recognition of proteins as the biological molecules that mediate genetic effects with various body functions. As consequence, their knowledge around what are proteins and what do they do in our body appeared naïve and limited. In light of such contexts, students seemed completely unaware of how the structural and functional aspects of proteins bring out the effects of genetic changes called mutations. In the meantime, students' knowledge around genetic phenomena looked similar to the limited conceptual aspects outlined in the curricular materials. In the students' biology textbooks, the conceptual details of genes were outlined exclusively in the context of Mendelian or classical genetics with little or no focus around how genetic effects are produced at macro-level via protein mediated mechanisms-molecular and cellular interactions. Therefore, the findings of the study implied serious implications that demand the need to remedy the conceptual deficiencies with accurate knowledge and relevant curricular materials.

Educational Implications

Students' conceptual ideas around the domain specific knowledge of genetic phenomena appeared naïve and uncertain. As a result, students did not have any reasoning ability to map how protein mediated mechanisms produce the genetic effects at the macro-level via molecular and cellular interactions. Their weaknesses in reasoning were speculated much around the defects of curriculum or the way the details are taught across the classes or the proficiency of the subject teachers in dealing with the specific topic. Therefore, to make the domain specific knowledge of genetic phenomena within the reach of students' intelligible realm of understanding, the educational setting in Bhutanese context should consider the following three aspects:

A. First, the stakeholders at the national level and the relevant agencies (Ministry of Education and Royal Education Council) must get familiarized with the evolving curriculums and design the curricular materials (curriculum frameworks and textbooks) that discuss the domain specific knowledge of genetic phenomena consistent with the international standard and the implications outlined in the empirical research.

B. Second, teachers teaching genetics must recognize the core ideas of genetic phenomena and teach them accordingly. This might help students to build mechanistic explanation of the whole phenomena underpinned by the core ideas that are congruent to the view of scientists and the scientific community. Some of the core ideas that can be recognized are:

i. Recognition that genes are the DNA segments that code proteins
ii. Recognition that proteins are the biological molecules that carry out various body functions (expose to the specific roles of proteins)
iii. Recognition that proteins act as the mediator molecules of genes and traits via various body functions
iv. Recognition that genetic phenomena is comprized of two ontologically distinct levels- information level (genes) and biophysical levels (proteins, cells, tissues, and organs)
v. Recognition that effects of genes are manifested at macro-level via molecular and cellular interactions (protein mediated mechanisms)
vi. Recognition that changes in genes will alter the structural and functional correlations of proteins that in turn will affect the corresponding biophysical levels.

C. Third, teaching and learning of genetic phenomena is challenging ontologically as well as epistemologically. Therefore, teachers teaching genetics can introduce genetic phenomena better via empirically proven effective domain specific inquiry modes such as cognitive models (domain specific heuristics and domain specific explanatory schemas) of Duncan (2007), Gene-Protein-Cell-Tissue model of Duncan et al. (2011), and design-based project model of Duncan and Tseng (2011).

References

Albuquerque, P. M. (2008). Gene concepts in higher education cell and molecular biology textbooks. *Science Education International, 19*(2), 219–234.

Alozie, N., Eklund, J., Rogat, A., & Krajcik, J. (2010). Genetics in the 21st century: The benefits and amp; challenges of incorporating a project-based genetics unit in Biology classrooms. *The American Biology Teacher, 72*(4), 225–230.

Bahar, M., Johnstone, A., & Hansel, M. (2000). Revisiting learning difficulties in biology. *Journal of Biological Education, 33*(2), 84–86.

Banet, E., & Ayuso, E. (2003). Teaching genetics at secondary school: A strategy for teaching about the location of inheritance information. *International Journal of Science Education, 25*(3), 373–407.

Burian, R. M. (2004). Molecular epigenesis, molecular pleiotropy, and molecular gene definitions. *History and Philosophy of the Life Sciences,* 59–80.

Chattopadhyay, A. (2005). Understanding of genetic information in higher secondary students in Northeast India and the implications for genetics education. *Cell Biology Education, 4*(1), 97–104.

Chattopadhyay, A. (2012). Understanding of mitosis and meiosis in higher secondary students of Northeast India and the implications for genetics education. *Education, 2*(3), 41–47.

dos Santos, V. C., Joaquim, L. M., & El-Hani, C. N. (2012). Hybrid deterministic views about genes in biology textbooks: A key problem in genetics teaching. *Science Education, 21*(4), 543–578.

Duncan, R. G. (2007). The Role of domain-specific knowledge in generative reasoning about complicated multi leveled phenomena. *Cognition and Instruction, 25*(4), 271–336.

Duncan, R. G., Freidenreich, H. B., Chinn, C. A., & Bausch, A. (2011). Promoting middle school students' understandings of molecular genetics. *Research in Science Education, 41*(2), 147–167.

Duncan, R. G., & Reiser, B. J. (2007). Reasoning across ontologically distinct levels: Students' understandings of molecular genetics. *Journal of Research in Science Teaching, 44*(7), 938–959.

Duncan, R. G., Rogat, A. D., & Yarden, A. (2009). A learning progression for deepening students' understandings of modern genetics across the 5th-10th grades. *Journal of Research in Science Teaching, 46*(6), 655–674.

Duncan, R. G., & Tseng, K. A. (2011). Designing project-based instruction to foster generative and mechanistic understandings in genetics. *Science Education, 95*(1), 21–56.

Falk, R. (2010). What is a gene?—Revisited. Studies in History and Philosophy of Science Part C: *Studies in History and Philosophy of Biological and Biomedical Sciences, 41*(4), 396–406.

Flodin, V. (2009). The necessity of making visible concepts with multiple meanings in science education: The use of gene concept in a biology textbook. *Science Education, 18*(1), 73–94

Gericke, N. M., & Hagberg, M. (2007). Definition of historical models of gene functions and their relation to students' understanding of genetics. *Science and Education, 16*(1), 849–881.

Gericke, N. M., & Hagberg, M. (2010a). Conceptual incoherence as a result of the use of multiple historical models in school textbooks. *Research in Science Education, 40*(4), 605–623.

Gericke, N. M., & Hagberg, M. (2010b). Conceptual variation in the depiction of gene function in upper secondary school textbooks. *Science and Education, 19*(10), 963–994.

Gericke, N. M., Hagberg, M., Santos, V. C., Joaquim, L. M., & El-Hani, C.N. (2012). Conceptual variation or incoherence? Textbook discourse on genes in six countries. *Science and Education.*

Gericke, N. M., & Wahlberg, S. (2013). Clusters of concepts in molecular genetics: A study of Swedish upper secondary science students' understanding. *Journal of Biological Education, 47*(2), 73–83.

Hott, A. M., Huether, C. A., McInerney, J. D., Christianson, C., Fowler, R., Bender, H., & Karp, R. (2002). Genetics content in introductory biology courses for non-science majors: *Theory and practice. BioScience, 52*(11), 1024–1035.

Kibuka-Sebitosi, E. (2007). Understanding genetics and inheritance in rural schools. *Journal of Biological Education, 41*(2), 56–61.

Kılıç, D., Taber, K. S., & Winterbottom, M. (2016). A cross-national study of students' understanding of genetics concepts: Implications from similarities and differences in England and Turkey. *Education Research International,* 1–14.

Knippels, M.-C. P., Waarlo, A. J., & Boersma, K. T. (2005). Design criteria for learning and teaching genetics. *Journal of Biological Education, 39*(3), 108–112.

Lewis, J., & Kattmann, U. (2004). Traits, genes, particles and information: Revisiting students' understandings of genetics. *International Journal of Science Education, 26*(2), 195–206.

Lewis, J., Leach, J., & Wood-Robinson, C. (2000). All in the genes? Young people's understanding of the nature of genes. *Journal of Biological Education, 34*(2), 74–79.

Lewis, J., & Wood-Robinson, C. (2000). Genes, chromosomes, cell division and inheritance-do students see any relationship? *International Journal of Science Education, 22*(2), 177–195.

Marbach-Ad, G. (2001). Attempting to break the code in student comprehension of genetic concepts. *Journal of Biological Education, 35*(4), 183–189.

Marbach-Ad, G., & Stavy, R. (2000). Students' cellular and molecular explanations of genetic phenome phenomena. *Journal of Biological Education, 34,* 200–205.

Meyer, L. M. N., Bomfim, G. C., & El-Hani, C. N. (2013). How to understand the gene in the twenty-first century? *Science and Education, 22*(2), 345–374.

Mills Shaw, K. R., Van Horne, K., Zhang, H., & Boughman, J. (2008). Essay contest reveals misconceptions of high school students in genetics content. *Genetics,* *178*(3), 1157–1168.

Ministry of Education. (2012). *Science curriculum framework*. Thimphu: DCRD Publications.

Rastogi, V.B. (2014). *Srijan biology: Bhutan edition*. Delhi: Srijan Publisher Pvt. Ltd.

Rastogi, V.B. (2016). *Srijan biology: Bhutan edition*. Delhi: Srijan Publisher Pvt. Ltd.

Rotbain, Y., Marbach-Ad, G., & Stavy, R. (2006). Effect of bead and illustrations models on high school students' achievement in molecular genetics. *Journal of Research in Science Teaching, 43*(5), 500–529.

Saka, A., Cerrah, L., Akdeniz, A. R., & Ayas, A. (2006). A cross-age study of the understanding of three genetic concepts: How do they image the gene, DNA and chromosome? *Journal of Science Education and Technology, 15*(2), 192-202.

Smith, M. U., & Adkison, L. R. (2010). Updating the model definition of the gene in the modern genomic era with implications for instruction. *Science and Education, 19*(1), 1–20.

Thörne, K., & Gericke, N. (2014). Teaching genetics in secondary classrooms: A linguistic analysis of teachers' talk about proteins. *Research in Science Education, 44*(1), 81–108.

Tibell, L. A., & Rundgren, C.-J. (2010). Educational challenges of molecular life science: Characteristics and implications for education and research. *CBE-Life Sciences Education, 9*(1), 25–33.

Topçu, M. S., & Þahyn-Pekmez, E. (2009). Turkish middle school students' difficulties in learning genetic concepts. *Journal of Turkish Science Education, 6*(2), 55.

Tsui, C.Y., & Treagust, D.F. (2003). Genetics reasoning with multiple representations. *Research in Science Education, 33,* 111–135.

Tsui, C.-Y., & Treagust, D. F. (2007). Understanding genetics: Analysis of secondary students' conceptual status. *Journal of Research in Science Teaching, 44*(2), 205–235.

van Mil, M., Boerwinkel, D., & Waarlo, A. (2013). Modelling molecular mechanisms: a framework of scientific reasoning to construct molecular-level explanations for cellular behaviour. *Science and Education, 22*(1), 93–118

Venville, G. J., & Donovan, J. (2005). Searching for clarity to teach the complexity of the gene concept. Teaching Science,51(3), 20–24.

Venville, G., & Donovan, J. (2007). Developing year 2 students' theory of biology with the concepts of the gene and DNA. *International Journal of Science Education, 29*(9), 1111–1131.

Venville, G., Gribble, S. J., & Donovan, J. (2005). An exploration of young children's understandings of genetics concepts from ontological and epistemological perspectives. *Science Education, 89*(4), 614–633.

Venville, G., & Treagust, D.F. (1998). Exploring conceptual change in genetics using a multidimensional interpretive framework. *Journal of Research in Science Teaching, 35*(9), 1031–1055.

Vishnoi, H.S. (2012). *Concise biology: ICSE for class-X*. New Delhi: Selina Publishers.

Williams, M., Montgomery, B. L., & Manokore, V. (2012). From phenotype to genotype: Exploring middle school students' understanding of genetic inheritance in a web-based environment. *The American Biology Teacher, 74*(1), 35–40.

Wood-Robinson, C., Lewis, J., & Leach, J. (2000a). Young people's understanding of the nature of genetic information in the cells of an organism. *Journal of Biological Education, 35*(1), 29–36.

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The Role of Critical Pedagogy in Place-Based Education: A Literature Review

EMMA GRIFFIN

Abstract

Place-based Education is a teaching pedagogy that includes the local environment and community in schooling, with the aim to instill a sense of place and increase content knowledge. Place-based Education has the power to enhance community partnerships and build global citizens, but for whom is this education intended for? This literature review has uncovered areas of the pedagogy that disregard certain economic, social, cultural and political aspects of place, which prevents it from being an inclusive teaching pedagogy. The literature shows that Critical Pedagogy examines and questions those components of place within society and education, but disregards the environment. A bridge between Place-Based Education and Critical Pedagogy would provide a holistic approach to place in education and an inclusive educational philosophy that addresses all facets of place.

Key words: Place-based Education, Critical pedagogy, Pedagogies of place, sense of place, Inclusive pedagogy

Introduction

At the core of our education system, all learning was generally place-based; Students would learn about the land from the land. As the economy became more industrialized and technology advanced, the education system moved away from hands-on learning and its roots in place, eliminating the context where authentic learning occurs. Orr (2004) states that the current educational system has become too absorbed in technology and economic growth. As such, education has lost its connection to place and the natural world. The educational pedagogy of Place-based Education (PBE) claims to restore the connection between place, community, and education by bringing the system back to its roots in place. Expanding the context of learning to move beyond the four walls of the class allows for such reform.

Students walk into classrooms intertwined with the narratives that tell the world of their challenges, growth, and experiences discovering self and place. Occurring outside of the four walls that traditionally define the classroom, such narratives are disregarded in teaching. Haas and Nachtigal (1998), in their short book of essays on Place Value, argue that when this traditional thinking of classrooms occurs, "schools are disconnected from specific places and life in communities, they cease to be public institutions, serving the public good" (p.5). Education is broader than a school building or classroom; it extends into every aspect of life and doesn't happen independently of the world outside. It is a public act and involves self, people, and places, as well as the facets that define them.

Giroux (2011) writes that "pedagogy must always be contextually defined, allowing it to respond specifically to the conditions, formations, and problems that arise in various sites in which education takes place" (p. 75). Education needs to respond and adapt to current cultural, historical, social and political influences. This literature review is grounded in the idea that education needs a pedagogy that includes the connection between self and place. In this paper, I briefly explore the different Place Pedagogies (Outdoor Education, Environmental Education, and Place-based Education), focusing on PBE, which is seen as the most progressive in including place in education. Sobel (2004) defines it as the "process of using the local community and environment as a starting point to teach interdisciplinary concepts" (p. 6). PBE attempts to use the many facets of place as context for community learning but disregards the complexity of place.

The idea of critically addressing the complex nature of places is rooted in Critical Pedagogy, which "draws attention to the ways in which knowledge, power, desire, and experience are produced under specific basic conditions of learning" (Giroux, 2011, p. 4). Critical Pedagogy needs to be used when addressing the many facets of place and their connection to self. Investigating the self through a Critical lens allows students and teachers to evaluate the knowledge, power, and experiences that exist between themselves, place, and community. Arguing for a pedagogy that addresses all facets of place, including social, political, cultural, and natural, this paper presents a bridge between Place-Based Education and Critical Pedagogy.

Gruenewald (2003b) discusses a similar pedagogy that bridges PBE and Critical Pedagogy: Critical Pedagogy of Place. Expanding Gruenewald's idea creates a more intentional bridge between the two pedagogies. Critical Pedagogy is discussed in the Place Pedagogies, but it is regarded as an "add-on" with the focus on the natural aspects of place. Moving away from the idea of Critical Pedagogy as a side conversation, a holistic approach to place in education could be achieved. These ideas have led me to my research question:

What does the literature tell us about the role of Critical Pedagogy in Place-based Education?

Addressing the above research question, I present a literature review on Place-based Education, identify the areas that need to be critically reexamined and re-evaluated for the benefit of being an inclusive teaching and learning pedagogy.

To fully understand the use of place as a context for learning, there needs to be an understanding of how place is defined within educational philosophies.

The Definition of 'place' in Place Pedagogies

Including place in education requires intentional connections and deliberate teaching. Educators must understand sense of place, and the use of connections between people and place to foster the skills and knowledge needed for learning and discovery. The definition of PBE may vary depending on the source and the author's interpretation of what it means to include place in education. All definitions have the same general idea: the context of place is an essential component of meaningful learning but is often disregarded in classrooms today. A deeper exploration of the definitions will reveal that each definition, even though it has the same main purpose, varies in terminology and meaning, raising the following questions: "How do we define place?" and "What aspects of place are included"?

The definition of place relies on an understanding of the connection between people, places, and experiences. Places are defined spaces, with the meaning and purpose resulting from human constructs. Places present certain meanings to individuals, which create connections that change according to personal experiences and perceptions of that place. This makes place a complex social construct, difficult to define and to incorporate in education. There are many facets of place that stem from these different interactions, definitions, and purpose of certain spaces. There are physical facets of place like the environment but also social, political, economic, historical, and cultural facets that need to be considered. The challenge of using place as a pedagogy lies in this intricacy.

Gruenewald (2004) refers to place pedagogies, defining them broadly. For the purpose of this paper, place pedagogies are defined as Outdoor Education, Environmental Education, and Place-Based Education. These place pedagogies each have a unique way of incorporating place, highlighting a different aspect, and approaching the role of place in education differently. Outdoor Education has roots in outdoor leadership, while Environmental Education is focused more on ecology and science, and Place-based Education attempts to teach to community. There is a connection between each of them, an evolution of ideas, thoughts, and applications of place in education that build upon each other.

Woodhouse and Knapp (2000) write about the place-based approaches that can be identified in Outdoor Education defining it as a way "to provide meaningful contextual experiences- in both natural and constructed environments- that complement and expand classroom instruction" (p. 2). Outdoor Education takes the learning outside of the classroom walls and into the natural environment, usually the wilderness, to provide the students with meaningful experiences that supply context for their learning, moving beyond textbooks. Wattchow and Brown's book, A Pedagogy of Place (2011), discusses the purpose of Outdoor Education at its most basic level stating that it aims "to heighten awareness of and foster respect for self, others, and nature" (p. 17). This is a start to including the natural world in education, but when examined more critically, it fails to address crucial aspects of place.

Woodhouse and Knapp's definition of Outdoor Education state that it takes education outside of the classroom and into "natural and constructed environments" (2000). Wattchow and Brown (2011) argue that it is in these constructed environments that Outdoor Education diverges from the connection to place. In the construction of environments, Outdoor Education gives its students the false reality that nature is "accessible, predictable and affordable" (p. 27). When nature is fabricated it disregards the potential for dangerous, unpredictable, and unfamiliar physical and social terrain. Instead of providing context for the learning, these environments provide an inaccurate idea about place. All places are constructed, they are social constructs, defined by humans, but Outdoor Education constructs place to be something it isn't. For the most part, Outdoor Education focuses on wilderness as context for its connection between self, others, and nature, but pristine and protected wilderness doesn't give an authentic representation of nature. "When nature is seen as a place it is messy, contested and constantly changing", only then can it be used as an authentic environment for including place in education (Wattchow & Brown, 2011, p. 33).

Orr (2004) examines the purpose of education stating that its roots are in Environmental Education. He argues that all education should be teaching students how to create relationships with the natural world. Environmental Education explores how humans are a part of the natural world and in turn how our actions or inactions affect natural systems, just as natural systems affect us. Environmental Education, as the terminology of the pedagogy suggests, focuses on the environment (i.e., the environmental facet of place). Gruenewald (2004), defines the purpose of Environmental Education "to provide people with the experience and knowledge needed to care for our environment" (p. 73). For Environmental Education, the knowledge needed to care for the natural world is primarily science-based. Students learn about natural systems (i.e., ecology) with the goal of understanding one's role in those systems.

To learn how to make positive change and understand their role in the natural system, students must understand themselves and their connection to the environment. Students might explore their surroundings using their five senses or enhance their physical connection to the natural world with sound maps or sensory activities. The scientific process is introduced as a tool to enhance their connection to place, developing an understanding of the role that science plays in nature and the role that humans play. These lessons and activities aim to foster a sense of place and connection to nature, providing the necessary scientific knowledge that can nurture the development of love, care and protection for the environment. The North American Association for Environmental Education, states that "environmental education is a process that helps individuals, communities, and organizations learn more about the environment, develop skills to investigate their environment and to make intelligent, informed decisions about how they can help take care of it" (2017). Environmental Education strives to produce environmentally involved citizens through science learning, introducing issues that exist, and developing informed decisions making skills. Environmental Education deepens the idea of the connection between self, others and nature found in Outdoor Education, through the introduction of science education, environmental stewardship and a touch of environmental activism.

Gruenewald (2004) claims that "environmental education is disciplined by science and conventional environmentalism, it tends to neglect the social, economic, political and deeper cultural aspects of the ecological problem" (p. 94). He argues that Environmental Education focuses on science and the natural world, disregarding the many other aspects that influence the environment. Environmental Education leaves out the aspects of place that make it messy, contested and complicated: the social, political, cultural, economic and historical facets (Cole, 2007). Leaving these aspects of place out of the discussion disregards the relationships that exist within these facets of place and the environmental issues and concerns that Environmental Education strives to address.

To ignore the influence that the social, political, cultural and historical aspects of place have on the environment is ignoring the root issue (Gruenewald, 2004). The environment is manipulated and controlled by human constructs (i.e., social, political, cultural, economic, historical influences), which means that the issues and concerns that are addressed in science and environmental education are results of human's actions or inactions. This connection between humans and environment is often forgotten in Environmental and Outdoor Education, which leads to the ideas of Place-based Education.

Smith, a leading educational writer on Place-based Education (PBE) discusses its origins, stating that it has roots in Environmental Education, but it differs in the "attention its practitioners direct towards both social and natural environments" (2007, p. 190). The pedagogy of PBE focuses on using the natural environment as a context for learning that occurs outside of the classroom, while also directing focus on the social interactions. In short, PBE aims to connect schools with their local communities (Gruenewald, 2003a; Smith, 2007; Sobel, 2004;). Aiming to extend the classroom walls to include the outdoors and the community, it hopes that students can take the multidisciplinary knowledge learned in school and apply it in real-world situations that deepen and strengthens their understandings. Sobel (2004), defines PBE in more depth stating that,

> Place-based Education is the process of using the local community and environment as a starting point to teach concepts in language arts, mathematics, social studies, science and other subjects across the curriculum. Emphasizing hands-on, real-world learning experiences, this approach to education increases academic achievement, helps students develop stronger ties to their community, enhances students' appreciation for the natural world, and creates a heightened commitment to serving as active, contributing citizens. (p.7)

PBE builds upon the principles and theories of Outdoor Education and Environmental Education that provide students with the tools for self- discovery and developing a sense of place through their lived experiences. PBE facilities interdisciplinary learning with the purpose of guiding students to be productive citizens who understand, love, care for and protect the environment and the living and non-living that inhabit it. This education should not be diminished, but examined with a question in mind: Is PBE a pedagogy that addresses all aspects of place for the benefit of serving all students?

The Claims of Place-Based Education

PBE makes certain claims regarding its methods of including place in education. It makes statements about connecting schools with communities, and including all aspects of place in the exploration of the environment, but in the practical application of these ideas, it rarely makes the connections that it intends. Smith and Sobel (2010), in their collaborative writing about PBE, consider its roots in community, highlighting this focus in their definition, and addressing PBE as "place- and- community-based education". Including community in Place-based Education is logical, and strives to include an aspect of place that is disregarded in other pedagogies of place.

The Rural School and Community Trust, an organization that was at the forefront of PBE in the United States, states that

> Place-based education is learning that is rooted in what is local: the unique history, environment, culture, economy, literature, and art of a particular place. The community provides the context for learning, the students' work focuses on community needs, and interests and community members serve as resources and partners in every aspect of teaching and learning. (as cited in Smith & Sobel, 2010, p.23)

PBE's claim of community- based education is weakened when it disregards the complicated factors that makeup community, which is frequently what happens when PBE is enacted in schools.

A community involves the commons, which in its most simple definition includes systems, spaces and relationships that revolve around shared resources. Hardin (2009) wrote about The Tragedy of the Commons, which discusses the economic downfall that can occur when people living within the commons choose self-interest over community wellbeing, thus resulting in inappropriate use of the shared resources. The commons, for the purpose of this argument, are all the environmental and human resources that are shared between the community, influencing life styles, livelihood, and interactions with others and place (Bowers, 2001; Haas & Nachtigal, 1998). With the inclusion of resources that make a living, the commons become an economic and political subject. When the shared use of the commons is managed effectively, the well-being of the community increases (Bowers, 2001). For the commons to be managed effectively there needs to be a strong connection between people and place. There needs to be an understanding about how people and places influence each other and shape economic and political constructs.

The many facets of the commons, like the facets of place are also messy and often contested. Low and Lawrence-Zuniga (2003) define contested places as "geographic locations where conflicts in the form of opposition, confrontations, subversion, and/or resistance engage actors whose social positions are defined by differential control of resources and access to power" (as cited in Tzou, Scalone, & Bell, 2010, p.110). The commons design communities, which are shaped by places, and made up of resources, and it is when the resources are dominated by one group that others feel oppressed. One can't discuss the construction of place or the involvement of place and community in education without addressing these stories of contested places, and the relationships that develop from the sharing of the commons.

In their argument for including place in Outdoor Education, Woodhouse and Knapp (2000), claim that PBE "emerges from the particular attributes of a place. The content is specific to the geography, ecology, sociology, politics and other dynamics of that place. This fundamental characteristic established the foundation of the concept" (p. 4). They claim that PBE's curriculum has a foundation in the social and political dynamics of place, but PBE's attempts to include the social and political dynamics occur solely through community-based education, which as stated before, doesn't fully address the complexity of social interactions. For example, a school and the local community might combine efforts to promote stream restoration and health in their community, but disregard the historical aspects of place, and the events that led to the degradation of the stream, sometimes overlooking where the stream is located and who is affected most (Null, 2002). It disregards the contested story of that community and use of resources. Gruenewald (2003a), in his examination of PBE, states "place-based education continues to foreground local environmental study while neglecting the more politically charged cultural environment" (p. 149). PBE focuses on the local environment (i.e., local stream health), but without consideration of the social and political influences that made the stream unhealthy in the first place.

McInerney, Smyth and Down's 'Coming to a Place near You?' (2010), evaluates the politics and possibilities of Place-based Education stating that one can't expect a student to engage in learning that increases their sense of place, and fosters a love of their local environment if they feel excluded or oppressed. We can't let the contested nature of places exclude our students, and continue the cycle of oppression that occurs when we fail to address all facets of place. Without critical inquiry, and providing our students the opportunity to question their place, how do we expect them to make a positive change? The learning that occurs from PBE should not be disregarded, but it should be questioned. Educators must start to question and examine the social, racial, political, cultural, economic, environmental, and historical facets that shape a place in order to claim its appropriate and effective use of it as context to teach all students.

The Role of Critical Pedagogy

The limitations of Place Pedagogies allow for a pedagogy that is more inclusive, one that invites collaboration and open inquiry (Gruenewald, 2003b). Freire (1971) states that to be fully human, we must question. Questioning one's role in the social, political and cultural aspect of place accentuates the existing relationships between power and language. Critiquing Place-based Education through the lens of a Foucault analysis, Gruenewald (2004) examines how power relationships are formed through the expression of words. An important form of language is inquiry, which he argues is lacking in PBE, specifically the question of "Who benefits and why"? Inquiry provides a tool to critique the relationship between power and language as well as the relationship between people, place, and experiences.

A critique of these relationships offers room for improvement, rather than identifying a failure. Michel Foucault, the founder of the analysis, defines the role of critiques, stating that,

> Critique is not a matter of saying that things are not right as they are. It is a matter of pointing out what kind of assumptions, what kind of familiar, unchallenged, unconsidered modes of thought the practices that we accept rest. (as cited in Gruenewald, 2004, p. 93)

The critique of Outdoor Education, Environmental Education and Place-based Education in the preceding section strives for this analysis. Place Pedagogies have their purpose and time in education, proven to be powerful pedagogies for some students in specific situations. These educational frameworks hold privilege in their thinking, disregarding the contested facets of place. My critique attempts to address the aspect of Place Pedagogies, more specifically Place-based Education, that have become familiar and unchallenged, highlighting those claims in a new light that refocuses the Pedagogy to be more inclusive.

The claims of PBE that have not been questioned, need to be addressed, examined, and re-evaluated, which positions Critical Pedagogy in a vital role within Place-based Education. Critical Pedagogy is rooted in Neo-Marxist Critical Theory, applying Marx's theory of socioeconomic analysis to present day. The theory analyses the way that issues of class relations, and societal conflicts arise, are confronted, and maintained by present-day society (Bowers, 2001; Burbules & Berk, 1999; Giroux, 2011). Smyth (2011), writes about Critical Pedagogy and Social Justice, defining the Pedagogy as a place where "schooling becomes a project of helping students to see injustices and assisting them to locate themselves in relation to such issues and to see how society is structured in ways that both sustain and maintain those inequities" (p. 51). Critical Pedagogy highlights the social inequalities that are present in schooling and society, assists students in identifying their role in power relationships, and then translates their awareness into actions.

Critical Pedagogy is learning about social injustices and creating awareness, but then asking the questions, "Who benefits? And how can we change it?" (Burbules

& Berk, 1999). It moves beyond simply learning about injustices, to analyzing in-depth, the role that one plays in the relationship of power that creates, maintains and fuels social injustices both locally and globally. Inquiry illuminates the patterns of social injustice throughout history, assists one in finding their position within the system, and asks the question of how do we make a change?

In its efforts to address the social, political and economic inequalities of the world, Critical Pedagogy fails to address the role that the environment plays. Gruenewald (2004) makes a similar claim against Critical Pedagogy, also quoting Bowers (2001). "Indeed, it seems incomprehensible to write about social justice for women, minorities, and the economic underclass without considering the ways in which the Earth's ecosystems are being rapidly degraded" (p. 3). One can't fully address social justice without considering the effect on the environment; similarly, one can't completely discuss environmental problems without addressing the underlying social, political and cultural issues that cause the degradation. Environmental issues and social inequalities run parallel to each other; disregarding one or the other exacerbates the issue.

The Bridge: Critical Pedagogy of Place

Throughout his career, Gruenewald makes an argument that there is a natural connection between Place-based Education and Critical Pedagogy. Places are contested through the manipulation of human's thoughts, experiences, and opinions, which makes both people and place politically, culturally, socially, and environmentally charged subjects. The unchallenged and unexamined claims of PBE that disregard the contested aspects of place are questioned with Critical Pedagogy, while the relationship between the local environment and communities is disregarded by the Critical is illuminated in PBE. The two Pedagogies complement each other, fitting together like a puzzle, strengthening the relationships between individuals, communities, and the places they inhabit.

The most influential work of Gruenewald, "Critical Pedagogy of Place" (2003b), is an educational philosophy that takes into account five dimensions of place: 1) perceptual, 2) sociological, 3) ideological, 4) political, and 5) ecological. It attempts to address the many facets of place through a Critical lens. Gruenewald's pedagogy bridges Place-based Education's ability to use the local community and environment as a foundation of learning, with Critical Pedagogy's exploration of power relationships, to create one concise pedagogy. Later in his career, Greenwood (2009) [Gruenewald changes his name to Greenwood later in his career], broadly defines his Pedagogy as a way of "remembering a deeper and wider narrative of living and learning in connection with others and with the land" (p. 5). His work takes into account the power of the local environment as an education tool, the inclusion of all facets of place, and the use of 'place-based inquiry' to answer the question: "What in this place needs to be remembered, restored, conserved, transformed, or created?" (p. 5).

Critical Pedagogy of Place could be the solution to the lack of critical examination in PBE, and the exclusion of the natural world in Critical Pedagogy, but it is presented as an add-on, an additional component to the Pedagogies of Place (Outdoor Education, Environmental Education, and Place-Based Education). Gruenewald (2004) states that education needs to move past the idea of EE since it is an add-on to an already "crowded discipline" (i.e., science and ecology units). In Gruenewald and Smith's book, Place-Based Education in a Global Age (2007), there is a single chapter on Critical Pedagogy, and while its ideas are addressed sporadically throughout the book, it is not the central focus of PBE, but rather framed as an additional thought to consider with Place-based Learning. For our educational system to undertake the task of including all aspects of place there needs to be intentional space for it. That is, it should be a pedagogy that stands alone as a foundational platform rather than an additional piece.

The foundational idea of Place Pedagogies that attempts to inspire love and care for the environment can't be implemented without the consideration for the power relationships that fuel environmental degradation. One can't effectively teach about local stream's health without addressing who is being affected and why. Teaching students in a uniform manner that is disconnected from the social, racial, political, cultural, historical, and environmental experiences that affect each student uniquely, removes the possibility of exploring differences and asking why. "If we are at all interested in place, pursuing the questions [of why] needs to become a prominent feature of educational inquiry" (Greenwood, 2009, p. 5).

Critical Pedagogy and Place-based Education have a natural connection between them, with the Critical as a foundation of PBE. Inviting open-minded thinking and collaboration into the discipline of Critical Pedagogy joins with the invitation of ecologically minded individuals to think more socially and critical, thus forming a bridge (Greenwood, 2008). Educators need to recognize and utilize this bridge to its full potential to help students understand themselves and others in the context of place.

Conclusion

The pedagogies presented in the literature review have overlooked an aspect of self or place in the attempt to incorporate place in education. Outdoor Education aims to teach in the name of self, others, and nature, exploring beautiful landscapes and constructed places but misses the opportunity to engage in deeper academic discussions. Environmental Education takes advantage of the missed opportunities that Outdoor Education chooses to not explore, using science and critical thinking to achieve the development of environmentally conscious citizens. The literature suggests that EE neglects to dissect the environmental issues it teaches about leaving the social, political, or economic influences unexamined. This dissection is vital to education and its ability to produce citizens who love, care, understand, and protect all components of a place.

Environments encompass many facets of a place, including, but not limited to, the social, political, cultural, natural, racial, and historical. Place-Based Education, which attempts to incorporate the locality of place into education, claims to build from EE's connection to the natural world by adding the social component. It uses interdisciplinary learning to foster a sense of place and stewardship primarily through science education, with the hope of producing stewards of the land and community. PBE literature recognizes the need to include the many facets of place, using Critical Pedagogy to incorporate the social, political and economic issues that EE and Outdoor Education disregard in their philosophies. The critical is considered an add-on to the discipline of PBE, taking away from its potential to include all facets of place. Building from Gruenewald's argument, I assert that there is a natural bridge between the pedagogies of PBE and the Critical that when facilitated with intention can enhance the philosophy of including place in education.

A holistic approach to incorporating place in education is warranted in today's education system. Bridging PBE and Critical Pedagogy should be the foundation of education, providing a learning pathway that emphasizes all the facets that place offers. The literature demonstrates that Critical Pedagogy has a role within PBE as a tool to question and critique the use of place, but it requires deliberate practices and intention. Fitting together like a puzzle, the pedagogies supplement each other's idea with elements that were unchallenged by the former. The role of the critical is to uncover and challenge the aspects of Place-based Education that have gone unnoticed and forgotten. The role of the Critical needs to move from an additional component to the main component of PBE. A foundation of the critical in the teachings of PBE provides a space for the self to be highlighted and challenges the idea that education is contained within four walls. My intent is not to overgeneralize the ideas of Place-Based Education or Critical Pedagogy, but to examine the role that Critical Pedagogy plays in all facets of place in the discussion of education, and how it can be utilized to enhance PBE.

If the purpose of Place-Based Education is to use place as a context for interdisciplinary, hands-on, community learning; and the purpose of Critical Pedagogy is to question and examine the social, political and economic aspects of society present in schooling; then the purpose of a bridge between the two is to use all facets of place as the context to engage in relevant learning that involves place-and-socially-based inquiry. The logical bridge of PBE and Critical Pedagogy strives to move away from the traditional monoculture education system to an inclusive pedagogy that addresses all facets of place for the benefit of all students who wish to engage with place-making and transforming.

References

Bowers, C. A. (2001). *Educating for eco-justice and community.* University of Georgia Press.

Burbules, N. C., & Berk, R. (1999). *Critical thinking and critical pedagogy: Relations, differences, and limits. Critical Theories in Education: Changing Terrains of Knowledge and Politics, 45-65.*

Cole, A. G. (2007). Expanding the field: Revisiting environmental education principles through multidisciplinary frameworks. *The Journal of Environmental Education, 38*(2), 35-45.

Dewey, J. (1986). Experience and education. *The Educational Forum, 50*(3), 241-252.

Freire, P. (1971). *Pedagogy of the oppressed.* New York: Herder and Herder.

Giroux, H. A. (2011). *On critical pedagogy.* USA: Bloomsbury Publishing.

Green, T. L., & Gooden, M. A. (2014). Transforming out-of-school challenges into opportunities: Community schools reform in the urban midwest. *Urban Education, 49*(8), 930-954.

Greenwood, D. A. (2008). A critical pedagogy of place: From gridlock to parallax. *Environmental Education Research, 14*(3), 336-348.

Greenwood, D. A. (2009). Place, survivance, and white remembrance: A decolonizing challenge to rural education in mobile modernity. *Journal of*

Research in Rural Education, 24(10).
Griffin, E. (2014). *Gunnison county almanac: Developing a land ethic in environmental education*. Western State Colorado University.
Griffiths, M. (1993). Self-identity and self-esteem: Achieving equality in education. *Oxford Review of Education, 19*(3), 301-317.
Gruenewald, D. A. (2003a). Foundations of place: A multidisciplinary framework for place-conscious education. *American Educational Research Journal, 40*(3), 619-654.
Gruenewald, D. A. (2003b). The best of both worlds: A critical pedagogy of place. *Educational Researcher, 32*(4), 3-12.
Gruenewald, D. A. (2004). A foucauldian analysis of environmental education: Toward the socio ecological challenge of the earth charter. *Curriculum Inquiry, 34*(1), 71-107.
Gruenewald, D. A., & Smith, G. A. (2014). *Place-Based Education in the global age: Local diversity*. USA: Routledge.
Haas, T., & Nachtigal, P. (1998). *Place value: An educator's guide to good literature on rural lifeways, environments, and purposes of education*. ERIC.
Hardin, G. (2009). The tragedy of the commons. *Journal of Natural Resources Policy Research, 1*(3), 243-253.
Kellner, D. (1998). Multiple literacies and critical pedagogy in a multicultural society. *Educational Theory, 48*(1), 103-122.
Low, S. M., & Lawrence-Zúñiga, D. (2003). Locating culture. The anthropology of space and place: *Locating Culture,* 1-47.
McInerney, P., Smyth, J., & Down, B. (2011). 'Coming to a place near you?' The politics and possibilities of a critical pedagogy of Place-Based Education. *Asia-Pacific Journal of Teacher Education, 39*(1), 3.
North American Association for Environmental Education. (2017) Retrieved from, https://naaee.org/.
Null, E. H. (2002). *East feliciana parish schools embrace Place-Based Education as a way to lift scores on Louisiana's high-stakes tests*. Rural Trust Featured Project.
Oldster, K. J. (2015). *Dead toad scrolls*. Booklocker.com, Incorporated.
Orr, D. W. (2004). E*arth in mind: On Education, environment, and the human prospect*. Island Press.
Ruiz-Gallardo, J. R., Verde, A., & Valdés, A. (2013). Garden-based Learning: An experience with "at risk" secondary education students. *The Journal of Environmental Education, 44*(4), 252-270.
Smith, G. A. (2007). Place-Based Education: Breaking through the constraining regularities of public school. *Environmental Education Research, 13*(2), 189-207.

Smith, G. A., & Sobel, D. (2014). *Place-and community-based education in schools.* USA: Routledge.
Smyth, J. (2011). *Critical pedagogy for social justice* (2). A and C Black.
Sobel, D. (2004). Place-Based Education: Connecting classrooms and communities. *Interdisciplinary Studies in Literature and Environment, 13*(1), 238-240.
Stapp, W. B. (1969). The concept of environmental education. *Environmental Education, 1*(1), 30-31.
Theobald, P., & Siskar, J. (2014). *Where diversity and community can converge.* Place-based Education in the Global Age: Local diversity, 197.
Tzou, C., Scalone, G., & Bell, P. (2010). The role of environmental narratives and social positioning in how place gets constructed for and by youth. *Equity and Excellence in Education, 43*(1), 105-119.
Wattchow, B., & Brown, M. (2011). *A pedagogy of place.* Victoria: Monash University Publishing, 1-105.
Woodhouse, J. L., & Knapp, C. E. (2000). *Place-based curriculum and instruction: Outdoor and environmental education approaches.* ERIC digest.

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Effectiveness of Mutation, Amino-acid, Protein, Characteristics, and Evolution (MAPCE) Model for Teaching Genetic Basis of Evolution: Students' Perspectives.

KARMA DORJI AND NAMKANG SRIWATTANAROTHAI

Abstract

Evolution is a unifying theory of biological science critical for understanding the mechanisms that underlie biological biodiversity. Growing body of research have shown, that high school students leave the school often with little or no understanding of the phenomena that drive the evolutionary change. One of the reasons reported iteratively is students' pre-existing teleological concepts that impede the understanding around the role of randomness in evolution. As a result, recent policies have highlighted the essential of grounding genetic basis of evolution via inquiry-based learning models. Therefore, a MAPCE model-based learning unit was contrived to enhance students' conceptual understanding around genetic basis of evolution. It was implemented involving fifty six (n=56) class XI students majoring in biology or biology-mathematics. Data collected by means of learning unit perception questionnaire and semi-structured interview protocol were analyzed computing grand mean scores and deriving themes based on Braun and Clarke's thematic coding technique. The findings from the students' perspectives indicate the effectiveness of MAPCE model learning unit in enhancing students' conceptual understanding of the genetic basis of evolution. The result, therefore implies the robustness of inquiry-based MAPCE model learning unit in enhancing students' academic rigor and biological literacy in the domain of molecular evolution.

Key words: Gene mutation, 3-D protein structure, BSCS 5E learning model, Evolution, Perspectives

Introduction

Evolution is a unifying theory of biology. In the most often-cited essay, "Nothing in biology make sense except in light of evolution" Dobzhansky (1973, p.125) plausibly outlines the centrality of evolution for all the domains of biological concepts (Dobzhansky, 1973; Frey, Lively, & Brodie, 2010). In the contemporary biology education, evolutionary theory is reckoned as the indispensable and intelligible scientific knowledge that demystifies the reasons behind the existence of biological diversity and the constant appearances of new varieties in the living population (Pazza, Penteado, & Kavalco, 2010; Rice, Oslon, & Colbert, 2014; Sickel & Firedrichsen, 2013; Wagler, 2012). So, in light of its valid principles and ideas, it is increasingly applied as the basic framework to solve the multitude real-world uncertainties across the cross-cutting disciplines such as medicine, agriculture, conservation biology, green technology, and the natural phenomena (Sickel & Firedrichsen, 2013). Therefore, it appears to be the scientific domain that everyone needs to understand as one of the core components of biology education across schools and colleges (Passmore & Stewart, 2002; Passmore, Stewart, & Zoellner, 2005; Rice et al., 2014; Sickel & Firedrichsen, 2013; Wagler, 2012). However, the growing body of literature emphatically corroborates that evolutionary concepts are most particularly misunderstood, remain deep-seated far beyond the intelligible realm of young novices possibly fueled by the climate of multiple reasons (Alter & Nelson, 2002; Christensen-Dalsgaard & Kanneworff, 2009; Foster, 2012; Frey et al., 2010; Kalinowski, Leonard, & Andrews, 2010; Passmore et al., 2005; Pazza et al., 2010; Robson & Burns, 2011; Schauer, Cotner, & Moore, 2014; Sickel & Firedrichsen, 2013; Speth, Shaw, Momsen, Reinagel, Lee, Taqiedden, & Long, 2014; White, Heidemann, & Smith, 2013;Yamanoi, Suzuki, Takemura, & Sakura, 2012).

Several recent studies (e.g., Alters & Nelson, 2002; Brumby, 1984; Mills Shaw, Van Horne., Zhang., & Boughman, 2008; Nehm & Reilly, 2007; Passmore et al., 2005; Robson & Burns, 2011; Speth et al., 2014; Sundberg & Dini, 1993; Yamanoi et al., 2012) have shown that the students do not hold a valid scientific concept regarding the cause of biological evolution even after completing relevant courses. In their study of a new integrative approach for evolution, White, Heidemann, and Smith (2013) posit that reasons for conceptual deficiencies in evolution are complex rather, however, at the core, the complexities of the principles underlying in evolution make complicated to fully understand. As is the case usually, students' pre-conceptions are found to be partly generated from their prior experiences, societal belief, cultural, religious and unfounded assumptions (Moore, Brooks, & Cotner, 2011; Kalinowski et al., 2010; Robson & Burns, 2011) or many, if not mostly, are the direct results of "crime omission" or "didaskalogenic"- the omission of evolutionary concepts and exposure of students via passive teaching styles (Henson, Cooper, & Klymkowsky, 2012; Pazza et al., 2010). According to Rice et al. (2014), the extent to which the teacher's pedagogical content knowledge will have deepening effect upon students' reasoning power or ability to draw in the concepts. In their study on misconceptions of genetic drift, Andrews, Price, Mead, McElhinny, Thanukos, Perez, Herreid, Terry, and Lemos (2012) note that deep-seated, and often unaddressed, misconceptions, and shallow understanding around random process emerge as the leading factor that saddle students from understanding. Yet, many, argue that, perhaps, Lamarckism, Darwinism, saltationism, orthogenesis, and teleological concepts are some of the most notable and pervasive inaccurate knowledge that students hold into (Christensen et al., 2009; Gregory, 2009; Robson & Burns, 2011; Sickel & Firedrichsen, 2013; Staub, 2002; Yamanoi et al., 2012).

It is true, most often, students' alternative tenets appears difficult to be replaced (Frey et al., 2010; Robson & Burns, 2011) or intuitively get reconciled with new ideas that further deepen the confusion (Robson & Burns, 2011). Going by the reports of recent studies, student largely assume that change of the organisms is fuelled by the individual's desire (Kalinowski et al., 2010; Robson & Burns, 2011; Sickel & Firedrichsen, 2013; Yamanoi et al., 2012), purposeful or goal-driven process rather than the accumulation of random events (Moore, Mitchel, Balley, Inglis, Day, & Jacob, 2002; Yamanoi et al., 2012), and occur at the individual level (Robson & Burns, 2011; Speth et al., 2014). Therefore, in the most common understanding forum, it is these inconsistent ideas and lack of focus around DNA from evolution that are supposed as the incontrovertible reasons that perpetuate students' shallow knowledge around the genetic basis of evolution (Garvin-Doxas & Klymkowsky 2008; Kalinowski et al., 2010; Speth et al., 2014). To refute teleological ideas and to transcend the actual driving force of evolution, researchers recommend the educators to incorporate biological evolution in relation to the changes taking place at the molecular level particularly the DNA sequence (Bizzo & El-Hani, 2009; Eterovic & Santos, 2013; Kalinowski et al., 2010; White et al., 2013; Yamanoi et al., 2012). At the core of the biological evolution, mutation-the changes of the DNA sequence - is certainly the driving force that generate raw materials for evolution (Bizzo & El-Hani, 2009; Eterovic & Santos, 2013; Gregory, 2009; Hott, Heuther, McInerney, Chirstianson, Fowler, Bender, Jenkin, Wysocki, Markle, & Karp, 2002; Kalinowski et al., 2010; Sickel & Firedrichsen, 2013; Yamanoi & Iwasaki, 2015; Yamanoi et al., 2012). Nei (2005) claims that there could be evolution without natural selection but there would be no evolution without mutation. Comparatively, Kalinowski et al., (2010, p.87) reports "nothing in evolution makes sense except in light of DNA". In light of such exquisite, yet strikingly powerful statements, it is not surprising to presume that mutation, as proven by many empirical studies is one of the random effects that create raw material for evolution. In the study of introductory biology students' conceptual models, Speth et al. (2014) maintains that evolution as a process can be deconstructed in two fundamental principles, i. e., random genetic effects that give rise to variation within phenotypes of the population and environment select the phenotypes that best suits to fit in the surrounding environment, the idea that is famously revered as the Darwinian natural selection or Wallace's survival of the fittest. According to Henson et al. (2012) "mutation as a creative force, effects on the time, place, and level of gene expression or the activities of the gene product, whether polypeptide, regulatory, or structural RNA, provide the raw material from which new phenotypes arise" (p. 406). In the global scenario, mutation and its effect upon corresponding traits are basically offered since class 4, but, the detail accounts of mutation and its impact upon development of new variants is widely articulated in the high school and college biology curricula (Dougherty, 2009; Dougherty, Pleasants, Solow, Wong, & Zhang, 2011; Duncan, Rogat & Yarden, 2009; Duncan & Tseng, 2011; Knippels et al., 2005; Wagler, 2012) while in Bhutanese educational context, it is discussed well across the spectrums of higher secondary biology curricula (Dorji & Sriwattanarothai, 2015; Ministry of Education, 2012; Rastogi, 2014; Rastogi, 2016).

In the widely discussed scenario, to eject students' inaccurate knowledge, researchers who are inclined towards constructivist approaches in evolution education recommend active learning strategies for the conceptual change. Therefore, in this research- an innovative study with a developed learning unit-an inquiry-based approach to enhance students' conceptual understanding of the role of mutation in evolution is largely driven by the theoretical underpinnings stated in the following sections.

Theoretical Framework

As the study was designed to inform the linkage between the randomness with changes at the population level, the core theoretical idea behind the development of the learning unit is informed by the profundity of the literature that outlines the following key educational implications.

The first case of our theoretical focus is the principle learning theory of modern education- the paradigm shift from instructivism to constructivism that explains how children make best learning from their immediate environment. In general school of thought, constructivist approaches are, perhaps, best equated as learning by doing that discernibly facilitate conceptual change via active and engaged fashion (Cakir, 2008; Coperstein & Weidingner, 2004; Kalpana, 2014; Nehm & Reilly, 2007; Susan, 2004; Sutinen, 2007; Tanner, 2013). Presumably, the researchers who take on constructive approaches explicate the promising development in terms of conceptual literacy and positive attitude if students are intervened through the dimensions of active learning approaches (Dauer, Momsen, Speth, Makohon-Moore, & Long, 2013; Kalinowski et al., 2010; Passmore & Stewart, 2002; Rotbain, Marbach-Ad, & Stavy, 2006; Staub, 2002;Taskin, 2011;Yamanoi & Iwasaki, 2015; Yamanoi et al., 2012). Additionally, Robson and Burns (2011) note that "conceptual change that displaces deep misconceptions requires cognitive conflict which can be presented through active engagement with new information powerful enough to prove the pre-concepts wrong. According to the Frey et al. (2010) to facilitate conceptual change in evolutionary literacy, classroom instruction should be based on the constructivist approaches that can offer students a platform to actively raise the question, design and collect data, analyze and rethink, and construct new information with valid evidences. In the study of explanation of origin of variation, Speth et al.

(2014) eloquently reminds engagement of students to actively construct their own knowledge that is deemed critical and something beyond the negotiation both inside and outside the class.

There are many current literatures that emphasize the illustration of evolutionary concepts through effective strategies. As research in molecular evolution is gaining momentum, especially in the aspects of approach towards informing evolutionary concepts, many suggest to re-think over the instructional style and craft into the framework that foster learning via active research engagement guided by critical questions (Frey, 2010; Kalinowski et al., 2010; Passmore & Stewart, 2002; Rotbain et al., 2006; Tanner, 2013). The strategy that is deeply rooted in the core of the research in teaching and learning, one of the essential strategies of teaching science, is indeed the inquiry-based approach that facilitate learning through authentic questions (Alter & Nelson, 2002; Cartier, Stewart, & Zollener, 2006; Passmore & Stewart, 2002; Kalinowski, Taper, & Metz, 2006; Passmore, Stewart, & Zoellner, 2006; Robson & Burns, 2011; Thapa, 2014). For instance, Altesr and Nelson (2002) and Frey et al. (2010) maintains that to generate conceptual change and to increase evolutionary literacy, students must be given realistic inquiry to pose questions, formulate hypothesis, collect data, analyze and share with the peer. At the least, but most eloquently Kalinowski et al., (2006) and Robson and Burns (2011) go on to claim that most of scientific inquiry method or hypothetic-deductive reasoning is good, if not best to reject deeply rooted misinformation with critical questions. On the other hand, there are those that necessitate the essence of having curricular materials with core conceptual aspects.

Yamanoi and Sakura (2010) say that without random events at the molecular entities in the instructional package, students view evolution as the direct consequence of mere goal-driven teleological phenomena. In light of such aspect, researchers in evolution education increasingly advocates the necessity of incorporating DNA sequence as the basis of the evolutionary mechanism (Eterovic & Santos, 2013; Kalinowski et al., 2010; Kalinowski et al., 2006; Offner, 2013; Speth et al., 2014; White et al., 2013; Yamanoi & Iwasaki, 2015; Yamanoi et al., 2012). White et al. (2013) maintains that to make students fully understand the mechanisms of evolution, it is crucial to inform about the nature of genetic mutation and the consequences at the population level over the novel phenotypes. With the statement “nothing in evolution make sense except in light of DNA” Kalinowski et al. (2010, p.87) note that DNA sequence should be woven in the evolution education to favour students to realize better conceptual framework of the evolutionary mechanisms. As evolution is a perfect example of genetic phenomena, Offner (2013) notes that concrete examples of mutation that alter protein, in turn phenotype is perhaps the best way to connect with evolution. Roberts, Hagedon, Dillenburg, Patrick and Herman (2005) and Robic (2010) articulate that a small change resulting from mutation can consequently affect their structure and the corresponding function. At the least, but most abundantly, there are increasing current literatures that necessitate about the inclusion of protein in any genetic phenomena (Duncan, 2007; Duncan, Freidenreich, Chinn, & Bausch, 2011; Duncan, Rogat, & Yarden, 2009; Duncan & Reiser, 2007; Duncan & Tseng, 2011; Thörne & Gericke, 2014). In the research of teaching genetic phenomena, several studies (e.g., Duncan & Reiser, 2007; Duncan & Tseng, 2011; Thörne & Gericke, 2014) suggest that students should know 'genes code for proteins' and 'proteins are central' in order to have deeper mental framework of genetic effects upon novel phenotype. In this connection, Duncan (2009) claims that significant progress can be made in terms of students' conception of links between genes and traits if the instructional framework address equally upon genes, proteins and traits. In light of these theoretical constructs, the implication here is the focus to promote students' understanding of gene mutations and their effects upon traits via protein mediated mechanism which undoubtedly is the universal goal of evolution education. So with the theoretical aspects and the empirical suggestion advocated by Dorji and Sriwattanarothai (2015), a learning unit-MAPCE (Mutation, Amino-acid, Protein, Characteristics, and Evolution) was contrived based on the constructive-based inquiry learning approach using Biological Science Curriculum Studies (BSCS) 5E learning model with the research question that states:

What are the students' perceptions regarding the effectiveness of MAPCE model learning unit in enhancing the genetic basis of evolution?

Materials and Methods

This study was a quasi-experimental research grounded upon the parameters of pragmatism with concurrent mixed method approaches. It was based upon one group pre-posttest design where quantitative data were corroborated with qualitative data. It was carried out in the academic year 2014 in one of the higher secondary schools in the eastern Bhutan involving 56 class 11 students majoring in biology or biology and mathematics. The samples were chosen based on their pre-requisite knowledge around DNA sequence, gene expression, and mutation. Samples were intervened with MAPCE model learning unit for a period of approximately 2 hours as detailed below:

The learning unit MAPCE was developed based on the epistemology that a gene mutation (M) would render impact upon the amino acid (A) sequence, which in turn would alter three-dimensional (3-D) structure of protein (P) and the characteristics (C) which in the long run would abet in the evolution (E) of new species.The learning unit contain three overarching goals: i) effect of mutation upon the linear sequence of protein, ii) linkage of mutation with 3-D protein moiety and phenotype, and iii) role of mutation in evolution. As there is increasing pressure upon how to link randomness with speciation, there were many studies that have experimented the effectiveness of instructional designs. For instance, Linking Mutation with Three-dimensional Protein Structure (Dorji & Sriwattanarothai, 2015), Origami Bird Protocol (Yamanoi et al., 2012), Origami Bird Simulator (Yamanoi & Iwasaki, 2015), Teaching the Role of Mutation by Means of Board Game (Eterovic & Santos, 2013), and Can Random Mutation Mimic the Design? (Kalinowski, 2006) were some of the instructional packages that have informed students regarding the role of randomness in evolution. Although similar in nature, MAPCE model in its way is different by the presence of focus around protein as the central molecule between randomness and evolution. The hands-on learning activities of the model are driven by the procedural flow of the Inquiry-based BSCS 5E learning model, i.e., engagement, exploration, explanation, elaboration, and evaluation. It was implemented within the groups of six members as explained in the following ways:

Engagement

Students were asked to manipulate the three-lettered five words “THE CAT SAW THE DOG” to see the changes in the semantic meaning when letters are replaced, removed or added into. It was offered as a unit to induce motivation, curiosity and to relate with the mechanisms and the effects of mutation.

Exploration and Explanation

This phase was focused to demonstrate the central idea of the study: The linkage of gene mutation with novel phenotypes and speciation via protein molecules. The activity was started with the introduction of objectives followed by the exposure of students to an authentic guiding question: How is mutation responsible for the creation of evolution? To assist in making connection with real-world situation, students were informed to construct their thinking in terms of the evolution of new variant of crickets (silent cricket) largely shaped by the predation. This was followed by introduction of the materials gathered for the activity (mutation source boards, flexible wires, database tables and the worksheets) and the operational procedures. The Mutation

Source Board (MSB) as shown in Figure 1 was derived from the gametic mutation box devised by Yamanoi et al. (2012) to generate random mutation over the numbered bases of 12 bp (base pair) DNA sequence (Table 1). The MSB contain two wheels namely-positon wheel (left) and outcome wheel (right). The operational procedures are such that to generate gene mutation, the arrows placed over the wheels will have to be rotated and take note of the resting position. The final resting position of the arrows placed over the two wheels is to determine the types of mutation the numbered bases in the 12 bp DNA sequence will have in each play. For instance, in Figure 1, the resting position of the arrow of position wheel lies in the 3rd quadrant and by this status, the base numbered 3 in the normal DNA sequence will mutate. Nonetheless, it will undergo deletion mutation as the resting position of the arrow of mutation wheel lies in the sector with minus sign. The 12bp DNA sequence is to serve as the wild copy, a part of the gene that regulates the call song of the crickets. The DNA sequence has four bases numbered 1 to 4 as the representation of mutation sites. To produce each mutant DNA, students have to abide by the same procedures followed for the creation of first mutant DNA sequence.

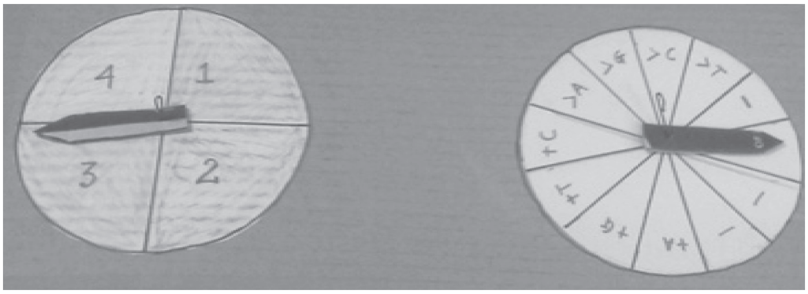

Figure 1. Mutation source board: Position wheel (left) and the outcome wheel (right).

Table 1

Normal DNA Sequence (12bp) used for the generation of mutant DNA sequences

		1			2			3			4	
	A	T	G	T	C	T	G	A	A	T	G	C

The activity was carried out within two member, where each pair in a group took part in generating mutation, modelling 3 dimensional (3-D) motifs of protiens and the recording of the findings in the worksheet in turn wise. The activity was started with students translating the normal DNA sequence into mRNA and the linear peptide followed by 3-D modelling of wild protein (3-D conformation). It was then linked with the function and the call song of the crickets (phenotypes) with reference to the information given in the database. In the next part, students created 4-5 mutant DNA sequences as well their corresponding transcripts and the peptides. Each mutant DNA sequence was then linked to the crickets' call songs through structural (3-D motif) and functional aspects of the protein. The process of modelling was proceeded in a way that, at first, students built linear peptide out of colored flexible wires by fastening their naked ends. In accordance to the data reflected in the database, students then modelled 3-D conformation of protein by simply folding the linear polypeptide chain with the help of a thin copper wire coiled around each flexible wire. Once done modelling of mutant protein, each was then linked with their respective function and the kind of crickets' call song it encode for. Students recorded their results along with the flow of the activity and explained their findings to the whole class with the discussion and deliberation upon the variant of the cricket that would most likely to be able to survive and reproduce in the predatory environment. Details of the activity are shown in Figure 2.

Figure 2. Students modelling 3-D motifs of proteins.

Elaboration

To test their knowledge, students were asked to develop a conceptual framework for how gene mutation is responsible for the appearance of malarial resistant people in Africa in the form of concept map.

Evaluation

Students were asked to arrange the jumble words starting from molecular events to the phenomena of the population to test their conceptual understanding.

The data was collected by means of learning unit perception questionnaire and focused-group interview protocol. The questionnaire contained ten close-ended Likert-type statements with five levels of agreement (Strongly Agree=5, Agree=4, Neither Agree nor Disagree=3, Disagree=2 and Strongly Disagree=1) and three open-ended questions, while the protocol had five open-ended questions. The tools were validated by two Thai experts (lecturers at Institute of Innovative Learning, Mahidol University, Thailand) and four senior Bhutanese biology teachers with teaching experience of more than 5 years in the higher secondary schools. The data gathered through Likert-type statements were computed into grand-mean scores under two broad themes: Satisfaction and Achievement and interpreted based on the scales advocated by Scales, Terry and Torres (2009), while those gathered via open-ended questions were analyzed by deriving themes based on Braun and Clarke's (2006) thematic coding approach.

Results and Discussion

The findings indicate the effectiveness of MAPCE model learning unit in enhancing the conceptual understanding of genetic basis of evolution which are discussed as follows:

Students' perceptions gathered via Likert-type statements were computed into grand mean scores under two broad themes: Satisfaction and Achievement as shown in Table 2. The result shows that students' grand mean scores in the themes, i.e. satisfaction and achievement are 4.85 ± 0.07 and 4.84 ± 0.09 respectively within the range "Strongly Agree" advocated by Scales, Terry and Torres (2009). This infers that MAPCE model learning unit is perceived as an effective instructional design towards informing the genetic basis of evolution.

Table 2

Students' Grand Mean Scores from Likert-type Statements

Statements	**Percentage**
Theme: Satisfaction	
1. I enjoyed participating in the class	4.96 ± 0.18
2. I had fun working in a group	4.72 ± 0.44
3. The learning activities on gene mutations were interesting	4.85 ± 0.35
4. I enjoyed building protein structures	4.77 ± 0.67
5. I liked the lessons about gene mutations	4.83 ± 0.37
6. I liked relating gene mutations to the real world	4.90 ± 0.29
Grand mean score	**4.85 ± 0.07**
Theme: Achievement	
7. The lessons promoted my understanding of mutation	4.91 ± 0.28
8. Learning activities helped me to see the effects of gene mutations	4.89 ± 0.31
9. The learning activities kept me active throughout the lessons	4.71 ± 0.45
10. The learning activities kept us engaged	4.87 ± 0.33
Grand mean score	**4.84 ± 0.09**

However, the detail aspects of students' perspectives were documented by open-ended questions. In questionnaire as well as protocol, students accredited that the learning unit as a whole is "very exciting", "worth attending", "fun", "practically oriented", and "satisfactory". These explicit claims indicate that students are impressed with MAPCE model learning unit. In their response, most respondents stated that the organizations of the activities that are based upon the heuristic principles of learning by doing enriched their learning with fun, excitements, intrinsic joys, insights and the experiences that broke their everyday monotonous learning styles. These assertion resonates the theoretical prospects of learning by doing advocated by Cakir (2008), Coperstein and Weidingner (2004), Kalpana (2014), Nehm and Reilly (2007), Susan (2004), Sutinen (2007), and Tanner (2013). Many maintained that the sequential flow of the activities kept them actively engaged with investigative fashion. In light of such findings, it is not surprising to presume that an epistemological effect of an inquiry-based approach as advocated by Frey (2010), Kalinowski et al. (2010), Passmore and Stewart (2002), Rotbain et al. (2006) and Tanner (2013) have entailed the students to explore the underlying concepts with authentic questions. At the center, the responses infers that the flow of the activities driven by the pedagogical framework of Inquiry-based BSCS 5E learning model, particularly, the exploration phase has anchored students into the light of an active engagement with rich experiences and investigation. This is in congruent with the promising effects of BSCS 5E learning model informed by Fazelian, Ebrahim and Soraghi (2010) in the aspects of rich experiences and investigation. Similar to the findings of this study, Hirca, Calik and Seven (2011), Lin, Cheng, Chang, Li, Chang, and Lin (2014), and Munmai, Ruenwongsa, Panijpa, Barman, Magee, and Somsook (2011) have documented students' gloating experiences with the pedagogical design of 5E learning model for making the learning experiences engaging with rich experiments and research techniques. So, these evidences imply that the pedagogical design of the learning unit based upon Inquiry-based BSCS 5E learning model is proven to be effective in illustrating the underlying concepts of genetic basis of evolution.

Of the several patterns noticed across the responses, it was observed that students' favourite activity was the phase that entailed them link gene mutation with phenotypes via 3-D modelling of proteins. In their claim, most maintained that activity in particular was intriguingly unique that helped them to understand how random events at the molecular level confer effects at the corresponding traits via protein mediated mechanisms. The result therefore strongly supports the findings confirmed by Dorji and Sriwattanarothai (2015), Duncan et al. (2011), and Duncan and Tseng (2011) in informing the linkage between gene mutation and phenotypes via protein mediated mechanism. Concurrently, the finding also appears to be in support of the reports made by the closely related research study conducted by Yamanoi et al. (2012), Yamanoi and Iwasaki (2015), and Eterovic and Santos (2013) regarding the promising effects of the instructional strategy towards enhancing students' literacy in evolution. At the same time, the result reinforces the points maintained by Alter and Nelson (2002), Frey (2010), Kalinowski et al. (2010), Kalinowski et al. (2006), Passmore and Stewart (2002), Passmore et al. (2005), Robson and Burns (2011), Rotbain et al. (2006), and Tanner (2013) with respect to the positive effect of including random events in the instructional strategy for assisting in the development of correct evolutionary literacy. At the same time, it was found that as a result of 3-D modelling, many managed to realize how proteins are actually involved in taking up their ontological form and link the effects of genes at the trait level. These responses appear consistent with the finding of Roberts et al. (2005) in their study conducted to enhance molecular three-dimensional literacy of proteins via physical modelling. Similarly, in the study carried out by Bednarski, Elgin and Pakrasi (2005), Herman, Morris, Colton, Batiza, Patrick, Franzen, and Goodsell (2006) and White (2006), participants have acclaimed that the modelling activity of protein is critical for understanding the three-dimensional literacy of the proteins. However, their intention was much more detailed at the level of residues and the interactions of different forces involved in forming native state of proteins. On the other hand, modelling in this study was based on the simple idea that change incurred at the microscopic entity gene and/or DNA would confer effects at the functional and structural aspects of protein. Therefore, hands-on modelling was nothing more than a novice type and did not have the scope to exhibit how side chain interactions, interaction with ligands, and covalent and non-covalent forces are involved in the formation of final 3-D protein moiety. So, students' effort put in to build 3-D protein structure was nothing more than a simple, representative, and the novice idea. In the meantime, results also evidenced students' satisfaction with the activity that linked gene mutations with the evolution of the crickets. Their reasons were such that the activity in particular educed them with the sense of appreciation with how much the knowledge of biology is based upon the phenomena of the nature. This implies the effectiveness of the lessons that are based upon the real life examples. Similar kind of reaction has been noted by Tanner (2011) in a study underpinned towards moving theory into practice. Students emphatically appraised the effectiveness of the learning activities. However, the real attributes of the learning unit was not seen to be plausible until when students explicated that the activities by nature assisted them to construct visuospatial mental picture of the underlying concepts via visualization and tangible experiences. The 3-D modelling of protein moiety was the center of their focus as there was general consensus among the students that the nature of the activity enabled them experience and visualize the processes involved in forming the native structure of the protein as inferred by Alozie, Eklund, Rogat, and Krajcik (2010), Beltramini, Araujo, Oliveira, Abel, Silva, and Santos (2006), DeBruyn (2012), Herman et al. (2006), Marshall (2014), Roberts et al. (2005), Robic (2010), Rotbain et al. (2006), Venville and Donovan (2008), and White (2006). At the same time, it was also noticed that students learning outcome was made enduring one supposedly out of noble activities that have lessened the complex knowledge structure represented by symbols, formulae, figures and the texts. This particular finding appears in consonant to the theoretical explanation explicated by Chakraborty and Zuckerman (2013) and Herman et al. (2006) regarding the educational implication of modellings in forming the visuospatial mental models via tactile visualization. Similar kinds of reactions have been documented by Roberts et al. (2005), Rotbain et al. (2006), and White (2006) in their study conducted to investigate the effectiveness of physical models and modelling. So, these findings consolidates the premise that MAPCE model as an instructional design has the robust attributes to enhance students' conceptual understanding of genetic basis of evolution via visualization and direct hands-on experiences apparently analogous to the real concepts.

Conclusions

Findings of the study unveiled students' positive perspectives towards MAPCE learning model.The grand mean scores of two themes: satisfaction and the achievements were 4.85 and 4.84 respectively indicating the effectiveness of the MAPCE learning model. In their response, many maintained that learning activities as whole were "very exciting", "worth attending", "fun", "enjoyment", "practically oriented" and "satisfactory to learn". Their reasons were such that flow of the activities kept them engaged with rich investigation with direct hands-on experiences analogous to the realities. Interestingly, students' favorite activity appeared to be the second learning goal in this study that was contrived to inform how random events at molecular level confer effects at organism level via protein mediated mechanism. Their assertion was such that activity in its unique design assisted them to view how proteins as the mediating molecule attain their native 3-D moiety and determine the characteristics. However, the actual strength of the learning unit was not reckoned until when students claimed that it was easy for them to understand the underling concepts at the behest of the activities that are grounded upon the principles of visualization and tactile experiences. As a result, many pointed out that concepts built out of learning unit would remain enduring in their life time. It was because the nature of the activity was simple, active experiences and real life examples. Therefore, with these perspectives, it can be surmised that MAPCE learning model as an instructional unit is effective in enhancing students' conceptual understanding of genetic basis of evolution.

Limitations of the MAPCE model learning unit

Although the MAPCE model is proven effective in this study, there are many limitations that the learning model fail to address. MSB in its design has the capacity to generate only single mutation in a single DNA base in each round. However, in reality, several mutational processes take place in the long sequence of bases. The process of modelling 3-D protein structures are nothing more than mere examples which are far from the reality. As a result, processes of modeling do not have the attributes to illustrate the forces that are actually involved in forming final native state of the proteins. Last, 12bp normal DNA sequence and the corresponding polypeptide employed are far too to be analogues to the reality. In the actual scenario, gene mutation involves long sequence of DNA bases and confer effects upon series of amino acids in the polypeptide chain.

Implications and Recommendations

The developed learning unit was devised based on the idea of pedagogical and epistemological aspects of hands-on Inquiry approaches. Therefore, the patterns can be adapted by the high school teachers for informing the role of randomness in evolution or in other domain like genetic phenomena to demonstrate the casual relationship between genes and traits via protein mediated mechanism. However, as this model is nothing more than a simple design with novice approach, it would likely create more confusion if the following aspects are not addressed by the teachers with precise or more discrete pedagogical content knowledge.

1) Students should be informed that mutation generated by MSB is just an example. Therefore, clear distinction should be made upon how mutation happens in reality due to mutagens.

2) The process of modelling 3-D of protein moieties based on data base are far from the scientific reality. Moreover, linkage of mutation and 3-D protein structure with evolution of silent male crickets are just the mere examples. This should not led the students to take in the real sense, although evolution of silent cricket is a proven fact. Therefore, this must be introduced as the representative idea.

3) The information for modelling reflected in data base are just out of assumption although in accord to the scientific fact. Therefore, it should be made known to students as an example.

4) 12bp employed in normal DNA sequence is too short. Therefore, to make it more engaging, number of bases may be increased to some extent.

5) The gene mutation generated by MSB is a single event as only base at a time can undergo mutation. An improved MSB can be innovated to show multi-mutation taking place at one go.

6) The mutation sites are restricted to only four numbered bases. This may possibly make the students to conceive mutation as the event of restricted sites, although it's a proven fact that more mutation occur in some loci of the DNA molecule such as CpG (cytosine and guanine) island or those that contain more GC (cytosine and guanine) bases.

References

Alozie, N., Eklund, J., Rogat, A., & Krajcik, J. (2010). Genetics in the 21st century: The benefits and challenges of incorporating a project-based genetics unit in biology classrooms. *The American Biology Teacher, 72*(4), 225-230.

Alters, B. J., & Nelson, C. E. (2002). Teaching evolution in higher education. *Evolution, 56,* 1891–1901.

Andrews, T.M., Price, R., Mead, L.S., McElhinny, T.L., Thanukos, A., Perez, K.E., Herreid, C.F., Terry, D.R., & Lemons, P. (2012). *CBE-Life Sciences Education, 11*, 248-259.

Bednarski, A. E., Elgin, S. C. R., & Pakrasi, H. B. (2005). An Inquiry into protein structure and genetic disease: Introducing undergraduates to bioinformatics in a large introductory course. *Cell Biology Education, 4*(3), 207-220.

Beltramini, L.M., Araujo, A.P.U., de Oliveira, T.H.G., Abel, L.D., da Silva, A.R., & dos Santos, N.F. (2006). A new three-dimensional evolution model kit for building DNA and RNA molecules. *Biochemistry and Molecular Biology Education, 34*(3), 187-193.

Bizzo, N., & El-Hani, C. N. (2009). Darwin and Mendel: Evolution and genetics. *Journal of Biological Education, 43*(3), 108-114.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101.

Cakir, M. (2008). Constructivist approach to leaning science and their implication to pedagogy: A literature review. *International Journal of Environmental and Science Education, 3*(4), 196-206.

Cartier, J.L., Stewart, J., & Zoellner, B. (2006). Modeling and inquiry in a high school genetics class. *The American Biology Teacher, 68* (6), 334-340.

Chakraborty, P., & Zuckermann, R. N. (2013). *Coarse-grained, foldable, physical model of the polypeptide chain.* Proceedings of the National Academy of Sciences, 110(33), 13368-13373.

Christensen-Dalsgaard, J., & Kanneworff, M. (2009). Evolution in lego: A physical simulation of adaptation by natural selection. *Evolution: Education and Outreach, 2*(3), 518-526.

Cooperstein, S. E., & Kocevar-Weidinger, E. (2004). Beyond active learning: A constructivist approach to learning. *Reference Services Review, 32*(2), 141-148.

Dauer, J. T., Momsen, J. L., Speth, E. B., Makohon-Moore, S. C., & Long, T. M. (2013). Analyzing change in students' gene-to-evolution models in college-level introductory biology: Analyzing change in students' gene-to evolution models. *Journal of Research in Science Teaching, 50*(6), 639–659.

DeBruyn, J. M. (2012). Teaching the central dogma of molecular biology using jewelry. *Journal of Microbiology and Biology Education, 13*(1), 45-46.

Dobzhansky, T. (1973). Nothing in Biology Makes Sense except in the Light of Evolution. *The American Biology Teacher, 35*(3), 125-129.

Dorji, K., & Sriwattanarothai, N. (2015, March 2nd - 4th). *Hands-on activities to link gene mutations with three-dimensional protein structure for high school students.* Paper Presented at the Proceeding of INTED Conference.

Duncan, R. G. (2007). The role of domain-specific knowledge in generative reasoning about complicated multi leveled phenomena. *Cognition and Instruction, 25*(4), 271-336.

Duncan, R. G., Freidenreich, H. B., Chinn, C. A., & Bausch, A. (2011). Promoting middle school students' understandings of molecular genetics. *Research in Science Education, 41*(2), 147-167.

Duncan, R. G., & Reiser, B. J. (2007). Reasoning across ontologically distinct levels: students' understandings of molecular genetics. *Journal of Research in Science Teaching, 44*(7), 938–959.

Duncan, R. G., Rogat, A. D., & Yarden, A. (2009). A learning progression for deepening students' understandings of modern genetics across the 5th-10th grades. *Journal of Research in Science Teaching, 46*(6), 655–674.

Duncan, R. G., & Tseng, K. A. (2011). Designing project-based instruction to foster generative and mechanistic understandings in genetics. *Science Education, 95*(1), 21–56.

Eterovic, A., & Santos, C. M. D. (2013). Teaching the role of mutation in evolution by means of a board game. Evolution: *Education and Outreach, 6*(1), 1-10.

Fazelian, P., Ebrahim, A. N., & Soraghi, S. (2010). The effect of 5E instructional design model on learning and retention of sciences for middle class students. *Procedia - Social and Behavioral Sciences, 5,* 140–143.

Foster, C. (2012). Creationism as a misconception: Socio-cognitive conflict in the teaching of evolution. *International Journal of Science Education, 34*(14), 2171–2180.

Frey, F. M., Lively, C. M., & Brodie, E. D. (2010). Selection and evolution with a deck of cards. Evolution: *Education and Outreach, 3*(1), 114–120.

Garvin-Doxas, K., & Klymkowsky, M. W. (2008). Understanding randomness and its impact on student learning: lessons learned from building the biology concept inventory (BCI). *CBE-Life Science Education, 7*, 227–33

Gregory, T. R. (2009). Understanding natural selection: Essential concepts and common misconceptions. *Evolution: Education and Outreach, 2*(2), 156–175.

Henson, K., Cooper, M. M., & Klymkowsky, M. W. (2012). Turning randomness into meaning at the molecular level using muller's morphs. *Biology Open, 1*(4), 405–410.

Herman, T., Morris, J., Colton, S., Batiza, A., Patrick, M., Franzen, M., & Goodsell, D. S. (2006). Tactile teaching: Exploring protein structure/function using physical models. *Biochemistry and Molecular Biology Education, 34*(4), 247–254.

Hirca, N., Calik, M., & Seven, S. (2011). Effects of guide materials based on 5E model on students' conceptual change and their attitudes towards physics: A case for "work, power and energy unit. *Journal of Turkish Science Education, 8*(1), 139–152.

Hott, A. M., Huether, C. A., McInerney, J. D., Christianson, C., Fowler, R., Bender, H., & Karp, R. (2002). Genetics content in introductory biology courses for non-science majors: Theory and practice. *BioScience, 52*(11), 1024–1035.

Kalinowski, S. T., Leonard, M. J., & Andrews, T. M. (2010). Nothing in evolution makes sense except in the light of DNA. *CBE-Life Sciences Education, 9*(2), 87–97.

Kalinowski, S. T., Taper, M. L., & Metz, A. M. (2006). Can random mutation mimic design? A guided inquiry laboratory for undergraduate students. *Genetics, 174*(3), 1073–1079.

Kalpana, T. (2014). A constructive perspective on teaching and learning: A conceptual framework. *International Journal of Research in Social Sciences, 3*(1), 27-29.

Knippels, M.-C. P., Waarlo, A. J., & Boersma, K. T. (2005). Design criteria for learning and teaching genetics. *Journal of Biological Education, 39*(3), 108–112.

Lin, J.-L., Cheng, M.-F., Chang, Y.-C., Li, H.-W., Chang, J.-Y., & Lin, D.-M. (2014). Learning activities that combine science magic activities with the 5E instructional model to influence secondary-school students' attitudes to science. *EURASIA Journal of Mathematics, Science and Technology Education, 10*(5), 415–426.

Marshall, P. A. (2014). From pipe cleaners and pony beads to apps and 3D glasses: Teaching protein structure. *Journal of Microbiology and Biology Education, 15*(2), 304–306.

Ministry of Education. (2012). *Science curriculum framework*. Thimphu: DCRD Publications.

Mills Shaw, K. R., Van Horne, K., Zhang, H., & Boughman, J. (2008). Essay contest reveals misconceptions of high school students in genetics content. *Genetics, 178*(3), 1157–1168.

Moore, R., Brooks, D.C., & Cotner, S. (2011). The relation of high school biology courses & students' religious beliefs to college students' knowledge of evolution. *American Biology Teacher, 73*, 222–226.

Moore, R, Mitchell, G, Bally, R, Inglis, M, Day, J., & Jacobs, D. (2002). Undergraduates' understanding of evolution: Ascriptions of agency a problem for student learning. *Journal of Biological Education, 36*(2), 65–71.

Munmai, A., Ruenwongsa, P., Panijpan, B., Barman, N., Magee, P. A., & Somsook, E. (2011). Using principles of subtractive colors to teach color of pigments: A 5E learning cycle lesson for pre-service elementary teachers. *The International Journal of Learning, 8*(1), 203–217.

Nehm, R. H., & Reilly, L. (2007). Biology majors' knowledge and misconceptions of natural selection. *Bioscience 57*, 263–272.

Nei, M (2005). Selectionism and neutralism in molecular evolution. *Molecular Biology and Evolution, 22*(12), 2318–2342.

Offner, S. (2013). Making the connection – Genetics and evolution. *The American Biology Teacher, 75*(9), 614–615.

Passmore, C., & Stewart, J. (2002). A modeling approach to teaching evolutionary biology in high schools. *Journal of Research in Science Teaching, 39*(3), 185–204.

Passmore, C., Stewart, J., & Zoellner, B. (2005). Providing high school students with opportunities to reason like evolutionary biologists. *The American Biology Teacher, 67*(4), 214–221.

Pazza, R., Penteado, P. R., & Kavalco, K. F. (2010). Misconceptions about evolution in Brazilian freshmen students. *Evolution: Education and Outreach, 3*(1), 107–113.

Rastogi, V.B. (2014). *Srijan biology: Bhutan edition*. Delhi: Srijan Publisher Pvt. Ltd.

Rastogi, V.B. (2016). *Srijan biology: Bhutan edition*. Delhi: Srijan Publisher Pvt. Ltd.

Rice, J., Oslon, J. K., & Colbert, J. (2014). University evolution education: The effect of evolution instruction on biology major's content knowledge, attitude towards evolution, and theistic position. *Evolution: Education Outreach, 4,* 137–144.

Roberts, J. R., Hagedorn, E., Dillenburg, P., Patrick, M., & Herman, T. (2005). Physical models enhance molecular three-dimensional literacy in an introductory bio-chemistry course. *Biochemistry and Molecular Biology Education, 33*(2), 105–110.

Robic, S. (2010). Mathematics, thermodynamics, and modeling to address ten common misconceptions about protein structure, folding, and stability. *CBE-Life Sciences Education, 9*(3), 189–195.

Robson, R. L., & Burns, S. (2011). Gain in student understanding of the role of random variation in evolution following teaching intervention based on luria-delbruck experiment. *Journal of Microbiology and Biology Education, 12*(1), 3–7.

Schauer, A., Cotner, S., & Moore, R. (2014). Teaching evolution to students with compromised backgrounds & lack of confidence about evolution – Is it possible? *The American Biology Teacher, 76*(2), 93–98.

Sickel, A., & Firedrichsen, P. (2013). Examining the evolution education literature with a focus on teachers: Major findings, goals for teacher preparation, and directions for future research. Evolution: *Education Outreach, 6*(23), 1–15.

Speth, E. B., Shaw, N., Momsen, J., Reinagel, A., Le, P., Taqieddin, R., & Long, T. (2014). Introductory biology students' conceptual models and explanations of the origin of variation. *Cell Biology Education, 13*(3), 529–539.

Staub, N. L. (2002). Teaching evolutionary mechanisms: Genetic drift and moms. *BioScience, 52*(4), 373–377.

Sundberg, M. D., & Dini, M. L. (1993). Science majors vs non-majors: Is there a difference? *J. Coll. Sci. Teach. 23*, 299–304.

Sutinen, A. (2007). Constructivism and education: education as an interpretative transformational process. *Studies in Philosophy and Education, 27*(1), 1–14.

Tanner, K. D. (2013). Structure matters: Twenty-one teaching strategies to promote student engagement and cultivate classroom equity. *Cell Biology Education, 12*(3), 322–331.

Taskin, O. (2011). Can willingness and hands-on work together? Teaching Biological evolution and dealing with barriers. *Evolution: Education and Outreach, 4*(3), 467–477.

Thörne, K., & Gericke, N. (2014). Teaching genetics in secondary classrooms: A linguistic analysis of teachers' talk about proteins. *Research in Science Education, 44*(1), 81–108.

Wagler, R. (2012). Assessing the framework for kindergarten through fifth grade biological evolution. *Evolution: Education and Outreach, 5*(2), 274–278.

White, B. (2006). A simple and effective protein folding activity suitable for large

lectures. CBE-Life Sciences Education, 5(3), 264–269.
White, P. J., Heidemann, M., & Smith, J. (2013). A new integrative approach to evolution education. *BioScience, 63*(7), 586–594.
Yamanoi, T., & Iwasaki, W. M. (2015). Origami bird simulator: A teaching resource linking natural selection and speciation. *Evolution : Education and Outreach, 8*(1), 2-11.
Yamanoi, T., & Sakura, O. (2010). Analysis of the Japanese high school Biology II textbooks with special reference to the four keywords: Evolution, natural selection, mutation, and species. *Biological Science, 62,* 39–45.
Yamanoi, T., Suzuki, K., Takemura, M., & Sakura, O. (2012). Improved origami bird protocol enhances Japanese students' understanding of evolution by natural selection: A novel approach linking DNA alteration to phenotype change. *Evolution: Education and Outreach, 5*(2), 292–300.

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BOOK REVIEW

Kyetse… A Destiny's Call: A Review

CHOEDA AND SUJATA THAPA

Abstract
This review on Chador Wangmo's novel Kyetse…a destiny's call presents a personal commentary on the content and craft of storytelling by a Bhutanese author. Apart from interpreting the themes and meanings of the events that take place in the novel, the authors also critiques the unique writing style of Chador Wangmo. The review not only highlights the authentic story of 'Bhutanese women' in the era of transition from a simple rural life to changing lifestyles as a result of modernization but also comments on the uniqueness of the novel's narrative style.

Key words: Culture, Narrative, Spirituality

Introduction

If one wants to learn about the East and its culture, Chador Wangmo's second novel, Kyetse is one that helps bring clarity and understanding. 'Kyetse' literally means birth calculation done by a 'Tsip' (astrologer) in which a predestined course of life of a newborn is revealed based on timing of the birth. The author neatly intertwines within the theme of kyetse, aspects of rural life, aspects of modern developments and changing life styles of the people in the society. The episodes in the protagonist Sonam Dema's life are woven into a skilful narrative that takes readers through the vicissitudes of human experience. However, having already acquainted with Sonam Dema's grim kyetse, readers are kept apprehensive of what events are going to unfold for her in the process of moving from one chapter to the next.

Summary

As per the kyetse statement, Sonam Dema is bound to encounter adversities at ten days, ten months, and ten years of age. Further, it also mentions that when she turns eighteen, she will meet another disastrous adversity that will change the course of her life. If she surpasses those adversities then she will live her life inclined more towards the spiritual aspect. As predicted in her kyetse, her father sends her with a stranger Ani who claims to have come looking for children to be enrolled into spiritual practices.

Sonam Dema and her best friend Pentang are taken to Nepal the birth place of Buddha with three other girls from their village - only to discover the fraudulence of the Ani. As time passes, Pentang and Neten disappear one after another. She cannot ask the Aniabout the whereabouts of her friends. When Sonam Dema is also being led by Ani to Phuntsholing from Nepal in the same fashion of her lost friends, she flees to her village sensing the danger. Upon reaching her village safely, she decides to go to Trashigang and live with a restaurant owner's family as housemaid to make money for her family. That is where she realizes that there is no meaning in her life. She decides to take the spiritual path and start living in a goenpa as an anim. However,she encounters Kuenga at Goenpa with whom she falls in love. She gets lost between her chosen spiritual life and her young heart's temptations. She often questions, "Is the heart beat in other women any different from the one in an anim's chest? She only has questions but no options."

Commentary

Apart from the gripping narrative, the abundant use of Sharchogpa expressions and some Dzongkha words contribute to the liveliness of the novel. The author has skillfully integrated the Sharchogpa expression into English narrative, posing no difficulty for the readers in understanding the text. The words such as memey, abhi, trowlee, changlumin, kolokpa, mongshi abhi and expressions as yangchi yangchi kuluktang, khar shigpay odo remain with the readers long after reading.

The use of superstitions is another interesting feature of the novel. There are rich descriptions on beliefs in the society related to animals, plants, birth, death and black magic. The cultural practices of marriage, games, welcoming the newborn and mourning the dead are beautifully depicted. The culture of mourning the dead by way of crying in singing tone or talking to the dead or having a dialogue with the dead would perhaps remain only in this book. There is a paragraph from chapter one that reads thus:

> The village of Lungten Zampa stood in serene silence. Except for the roaring Gamri, no human sound filled the air. This snaking river roared with more ferocity when it was swollen up during summers. Occasionally cicadas could be heard singing of the sultry sun. Howling afternoon wind ushered in the sharp, tangy smell of the lemongrass that swished abundantly above the road. Silence of this place was broken by the roar of the monstrous engine that passed through the town twice each day, ferrying people to and from Trashigang.

The author also uses foreboding in her narrative with the repetitive dreams about Pentang that visits the protagonist. The reader also wonders what happened to her friends who disappeared. As the narrative quickens and puts together all the missing pieces, readers' expectations also draw to a close. The story although has a simple plot, it is quick in gaining attention of the readers by twisting and turning the story

Recommendations

This book is for both young and old. The old can instantly relate with the incidents in the novel, right from Chapter One. The ones who are born in the early 1970s or late 60s can readily connect with the Bhutan Government Transport Service truck mentioned in the starting sentence of the novel for it was the main public transport during those times. The book is also for the young because of its amazing story line. The theme of kyetse reverberates throughout the book indeed.

It is a tale told of ebb and flow of an ordinary girl's life but signifying the essence of spirituality.

About the author

CHOEDA has done his Masters in Education from Edith Cowan University in Perth, Australia in 2007 and Postgraduate Certificate in Education from Samtse College of Education in 1998. He has served as a teacher as well as a vice principal in a secondary school in east Bhutan for more than 8 years prior to joining Samtse College of Education. He has published research articles in the field of teaching skills and strategies as well as ICT in education in national as well as international journal.

SUJATA THAPA is a second year B.Ed student specializing in primary education at Samtse College of Education. Apart from deep interest in teaching primary kids, she has passion for reading and doing creative writing.

INTERVIEW

An interview with Leslie Cook, Senior Director of Educator Development, Teacher Learning Center of Teton Science Schools

LESLIE COOK

Educational Innovation and Practice (EIP): What is Placed Based Education? Why does Place-Based Education matter?

Leslie: Place-Based Education (PBE) is an approach that connects learning and communities in order to increase student engagement, academic outcomes, and community impact. Place-Based Education, while new as a term, is not new as a practice. For as long as humans have learned from one another, education has been place-based - where "curriculum" (what is taught) is directly connected to the local community. Originally, this was out of necessity, as survival depended on understanding the local flora and fauna, cultural norms, landscapes, and seasonal changes of a particular area. During the industrial age of education over the last 125 years, despite occasional use of place-based approaches, formal education has largely separated from place with a standardized curriculum for all students that honored little about local economy, culture, and ecology. However, during these industrial model years, "informal" educators, located in parks, museums, camps, and environmental education centers, frequently immersed participants in local places to provide a deeply experiential model that founded learning on the richness of the surrounding community.

Teton Science Schools (TSS) began fifty years ago as a programme to teach students in the vast outdoor classroom of Jackson Hole, Wyoming, USA. Over the last twenty years, TSS has embraced Place-Based Education and defines the practice as connecting learning and community to increase student engagement, educational outcomes, and community impact. We define place broadly to encompass the ecological, cultural, and economic components of a community. A new mission for TSS, adopted in 2016, reads "inspiring curiosity, engagement, and leadership through transformative place-based education." This mission change allowed the school to better encompass the work being done in a greatly expanded organization, including two independent schools, a graduate programme, and a teacher professional development center in addition to the original field education programmes.

In our half-century of implementing Placed-Based Education, we have seen the results from our approach again and again. Students leave with an improved appreciation and understanding for this place and themselves, while also departing with new tools to better understand, engage, and impact their own community. We believe that effective Place-Based Education increases student and teacher engagement, boosts academic outcomes, and results in meaningful community impact.

EIP: Your role in Placed-Based Education and how did you get into it.

Leslie: I got into Place-Based Education when I was beginning my master's degree in 2004. As I was teaching and taking academic courses at the start of master's programme, I learned about Place-Based Education as a way to help learning be more relevant and meaningful and impactful to students. So, I designed my master's thesis research to help me understand more about Place-Based Education and how other educators were using it.

Now in my role as Director of Educator Development at Teton Science Schools, I get to lead professional development for teachers focused on Place-Based Education and how to apply it into their teaching. I have spent the last nine years working with pre-service teachers, in-service teachers, informal educators, and higher education faculty to integrate place-based approaches into their teaching.

EIP: Please comment on your association with the Royal University of Bhutan and Ministry of Education as a facilitator/promoter of Placed-Based Education in these two institutions.

Leslie: Since 2008, Teton Science Schools has worked with the Royal University of Bhutan (RUB), Ministry of Education (MoE), and Royal Education Council (REC) in Bhutan to support the implementation of Place-Based Education in Bhutanese schools, curriculum, and teacher training. I have gotten to host and work with five delegations of Bhutanese educators, lecturers and education leaders from these three agencies as well as the Royal Society for the Protection of Nature (RSPN) when they have visited Teton Science Schools for 2-3 weeks at a time. I have also worked with the seven graduate students who came to spend a year at Teton Science Schools learning about and practicing Place-Based Education. I have also been four times to Bhutan (planning the fifth trip now), to lead workshops for teachers there.

By the numbers, here are all of the points of impact that Teton Science Schools' has had since 2008 with Bhutanese educators:

i. 204 teachers, lecturers, and curriculum officers attended training (ranging from 3 to 10 days) in Bhutan taught by Teton Science Schools in January 2013, 2014, 2015, and 2016. (1122 participant days; averaging 5.5 days per training)
ii. 31 teachers, school leaders, Ministry of Education staff, Royal University of Bhutan lecturers, and Royal Society for the Protection of Nature staff have attended 2-week programmes at Teton Science Schools in 5 delegations.
iii. 7 graduate students have completed the 1-year-long Graduate Programme at Teton Science Schools. Of these, 3 have gone on to the University of Wyoming to complete Master's degrees.
iv. These teachers teach in over 50 different schools, and the lecturers teach at Bhutan's 2 Teacher's Colleges.
v. 8 visits by representatives from Teton Science Schools have been made to Bhutan to advance the work for the partnership and conduct Place-Based Education programmes

EIP: What Does Place-Based Education look like in practice?

Leslie: Place-Based Education can take many forms in practice. Six principles guide what Place-Based Education looks like:

i. Local to global context: Local learning serves as a model for understanding regional and global challenges, opportunities and connections.
ii. Learner-centered: Learning is personally relevant to students and enables student agency. The teacher serves as a guide or facilitator of learning.
iii. Inquiry-based: Learning is grounded in observing, asking relevant questions, making predictions, and collecting data to understand the world through economic, ecological, and cultural lenses. This approach allows for individual truth seeking based on evidence.
iv. Design thinking: Design thinking provides a systematic approach for students to solve problems and make meaningful impact in communities.
v. Community as classroom: Communities serve as learning ecosystems for schools where local and regional experts, experiences, and places are part of the expanded definition of a classroom.
vi. Interdisciplinary approach: The curriculum matches the real world where the traditional subject area content, skills, and dispositions are taught through an integrated and frequently project-based approach where all learners are accountable and challenged.

Two successful examples of how Place-Based Education has been implemented in Bhutan are Dr. Tashi Gyeltshen at Samtse College of Education revising a unit that he teaches on love and marriage to begin with his students (who are studying to be teachers) interviewing a family member or friend about what love and marriage is like for them in Bhutan. From that relevant foundation, the students then read a modern Nigerian short-story and 18th century British novel about love and marriage with a greater curiosity of what love and marriage might be like in other places and cultures. This example highlights the principles of local to global context and inquiry-based approaches.

The second example took place in a primary school classroom in eastern Bhutan. In this science classroom, the students learned about and built small scale water filters. The teacher assessed the student learning and skills, and they demonstrated competency in the topic of water filters. However, the students wanted to see if they could build a full scale water filter that the school could actually use to create another drinkable water source for the school. They were eager to apply what they had learned into a relevant and meaningful context. The students did build a filter and presented it to the school at an assembly with great success. This example highlights learner-centered and design thinking principles of Place-Based Education.

EIP: Where is Place-Based Education possible?

Leslie: Place-Based Education is possible anywhere - that is why it is such an important approach to education! From small, remote schools in eastern Bhutan to central schools in Thimphu and Phuentsholing to schools across the United States, Place-Based Education can be applied in all settings.

EIP: Placed-Based Education first started in Bhutan in 2008 with the visit of Bhutanese delegation led by Vice Chancellor of the Royal University of Bhutan to TSS. What are your views on the development/ implementation of Placed-Based Education in Bhutan?

Leslie: Since the first delegations from Bhutan visited TSS and from TSS visited Bhutan, I have seen the attention on and need for Place-Based Education in both locations become more focused. I hear and see more educators and administrators and lecturers talking about place-based approaches and making plans to apply those approaches in their classrooms. This could be making learning more hands-on and less lecture-based, it could be taking students outside and into the community, or it could be bringing community members into the classroom to share their knowledge and expertise. All of these things are happening in Bhutanese classrooms and they are becoming more associated with place-based education.

The two most exciting recent developments are the inclusion of Place-Based Education as a focal point in the new M.Ed programme at Samtse College of Education and the interest by curriculum developers and professional development trainers with the Royal Education Council in integrating Place-Based Education into the entire curriculum and training all 11,000 teachers in Bhutan in Place-Based Education.

EIP: You along with the team from Teton Science School and University of Wyoming played an instrumental role in the development of the M.Ed in science and maths programme at Samtse College of Education. What are your views and experiences working on the programme with counter parts from Samtse College of Education?

Leslie: Working with the faculty at Samtse College of Education as they have developed the curriculum for the M.Ed programme and prepared to implement the programme has been an incredible opportunity to push my own and TSS's understanding of Place-Based Education. Seeing how Dr. Tashi Gyeltshen implements Place-Based Education in his English literature classes, Mr. Tandin Penjor facilitates learner-centered inquiry-projects in his physics modules, and Dr. Nandu Giri encourages all Samtse College of Education faculty members to consider new place-based approaches, has exposed me to new ideas for the forms that Place-Based Education can take.

All of the lecturers and tutors at Samtse have been working so hard to prepare to implement the M.Ed programme, and I am eager to see and hear how it goes.

EIP: How is a class that adopts Place-Based Education different from a class that does not adopt Place-Based Education in terms of student's engagement and learning?

Leslie: Anecdotally, characteristics of the classroom of a teacher that uses Place-Based Education in their classes include:

i. students driving the learning process with the teacher acting as the guide,
ii. students asking questions and solving problems as part of their learning process,
iii. fewer transitions between subject area times and more integration of content in an interdisciplinary way,
iv. guests coming into the classroom, invited by students to share their knowledge

and experiences, and

v. students going out into the community to learn about what is going on in the area around them.

In addition and more formally, TSS is doing some research and evaluation of the impact of our professional development on students and teachers. Over the past three years, teachers in the United States, who have been part of professional development programmes with TSS, have given their students engagement surveys (adapted from https://ies.ed.gov/ncee/edlabs/regions/southeast/pdf/REL_2011098.pdf). We now have over 2300 student responses to the survey and 49 teachers who have completed their own reflective survey on student engagement. The results are shown in the Figure 1 and Figure 2 below.

On average, 78% of the teachers felt that students improved in each category below in the Place-Based unit/lesson. Students also noticed differences in these units/lessons, with an average of 65% reporting positive growth in each area depicted below. The teachers' surveys showed the most positive results in increased student engagement, improved understanding of place, and increased teacher comfort trying new things. The strongest positive results from the students' survey were on improved understanding of place, increased understanding of content, and increased student comfort trying new things.

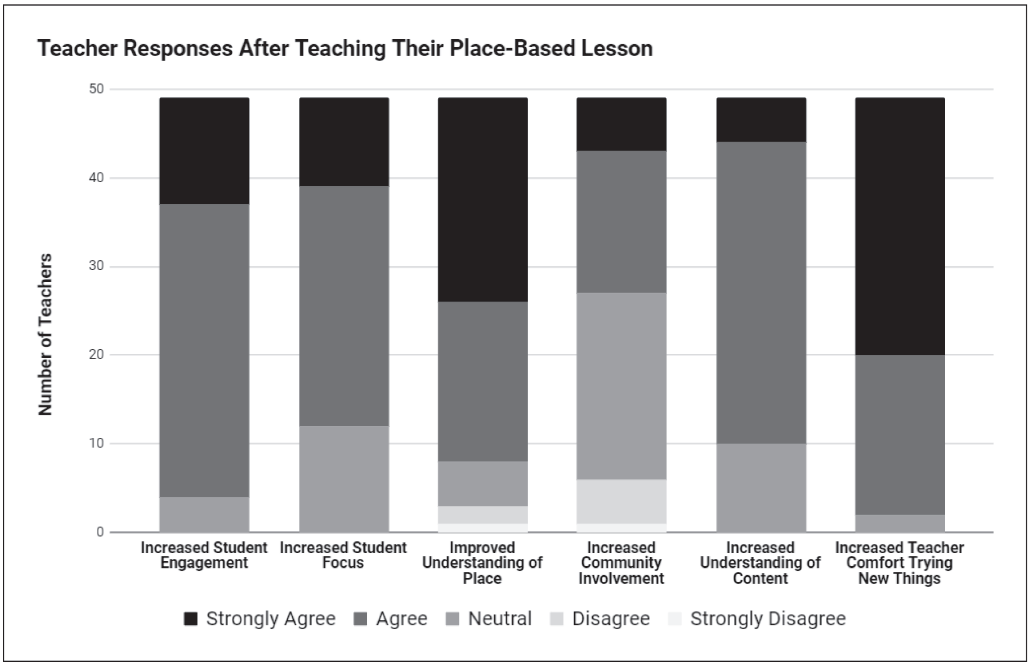

Figure 1. Teacher responses after teaching their place-based lesson

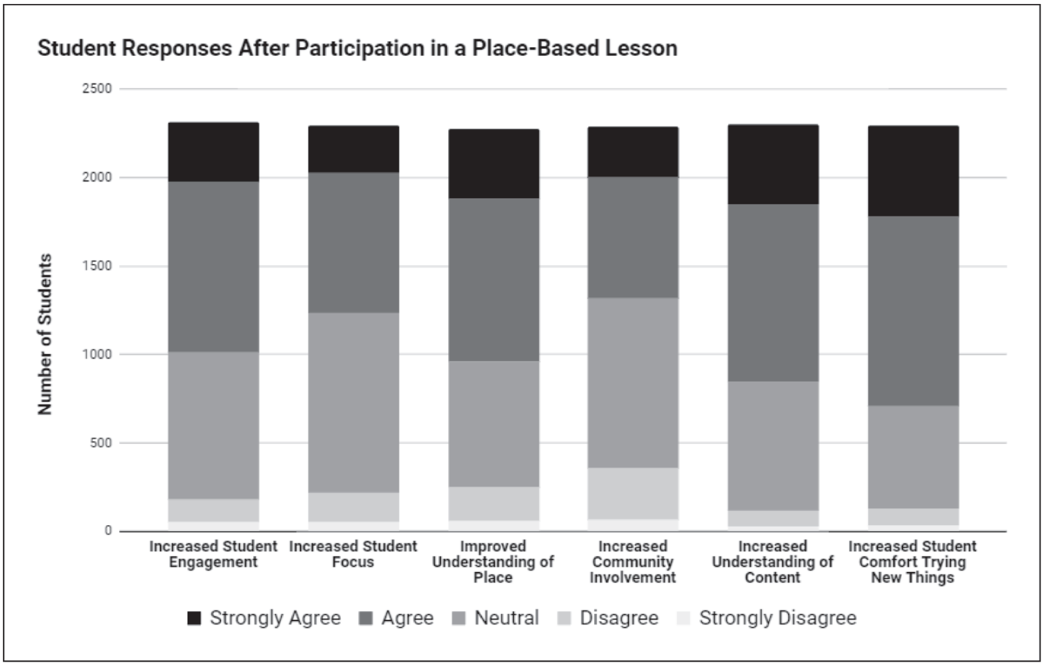

Figure 2. Teacher responses after participation in a place-based lesson

EIP: There are lots of commonality between Placed Based Education and the philosophy of Gross National Happiness (GNH). Please comment.

Leslie: Teton Science Schools' looks at the three legs of the place triangle - economy, ecology, and culture of place - as being central to understanding a place better. These three lenses (economy, ecology, and culture) fit very well with the four pillars of GNH - good governance, sustainable development, preservation and promotion of culture, and environmental conservation. When we teach about Place-Based Education in Bhutan, we try to emphasize how well it supports the efforts of education for GNH currently going on in schools. Place-Based Education is another approach that Bhutanese educators can use to promote education for GNH in their classrooms.

EIP: What is the future of Place-Based Education in Samtse College of Education in particular and Bhutan in general?

Leslie: In the most immediate term, we are thrilled by TSS representative Emma Griffin traveling to Bhutan and SCE to spend from August to December 2017 with the implementation of the first cohort of the M.Ed programme. After many years of discussing having a TSS representative spending a longer-period of time, Emma will be the first representative from TSS to take on this opportunity. Her time at SCE will support the infusion and integration of Place-Based Education into the M.Ed programme as well as into the Postgraduate Diploma in Education where she will teach a biology module as well.

Other next steps with the Royal University of Bhutan and SCE include a 5-day training in January 2018 for lecturers at Paro College of Education as well as an anticipated visit to SCE during September or October 2018 to see and support the M.Ed programme in action.

In our work with schools in Bhutan, with the support of the Royal Education Council, TSS has plans to work towards training all teachers in Bhutan in Place-Based Education by 2025 and to integrate Place-Based Education into all curriculum for pre-primary through class twelve students.

The dual approach of working with and training new teachers at Paro and Samtse Colleges of Education in addition to training in-service teachers and revising curriculum with the Royal Education Council seems like a strong strategy to "Bhutanize" the curriculum.

During the fall 2018, we also hope to send another TSS representative, like Emma in 2017, to support the implementation of Place-Based Education in the M.Ed programme.

EIP: Some people are still skeptical as to whether Place-Based Education is to be used as a content knowledge or pedagogy? What do you have to say on this?

Leslie: Place-Based Education is an approach, or in the way you ask a pedagogy, to use in teaching any topic, subject, or content. In working with staff from the Royal Education Council, Ministry of Education, and with lecturers from Samtse College of Education and Paro College of Education over the past 9 years, I see Place-Based Education being part of larger initiatives (called Transformative Pedagogies by the REC and MoE) that serve the bigger goals of Gross National Happiness and the United Nation's Sustainable Development Goals. Below is one image (Figure 3) that we created for use in our programmes to help show the links between these initiatives in the Bhutanese education system.

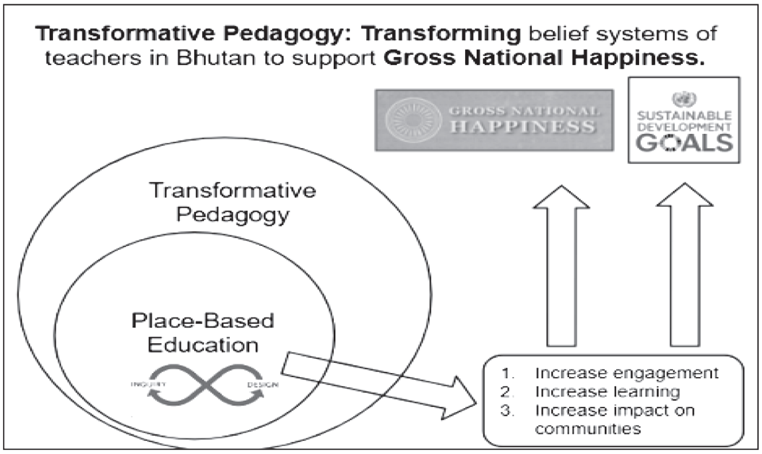

Figure 3. Transfromative pedagogy to transform belief systems of teachers in Bhutan to support Gross National Happiness.

About the author

LESLIE COOK is a Senior Director of Educator Development, Teacher Learning Center of Teton Science Schools. USA. She has MA in Environmental Education, Prescott College, B.Sc in Biology, Davidson College, and Certificate in Environmental Education, Wolf Ridge's Graduate Programme, University of Minnesota.

Since her arrival at Teton Science Schools, Leslie has been a part of the Teacher Learning Center, facilitating trainings for in-service teachers and coordinating the Wyoming Stream Team programme. She also oversees Teton Science Schools' initiatives to reconnect children to the nature of Wyoming, including the Wyoming Youth Congress on Children and Nature and the Children and the outdoors statewide survey. In her free time Leslie enjoys anything that she can do in or near water.

Teton Science Schools has been working with the Royal University of Bhutan (RUB), Ministry of Education (MoE), and Royal Education Council (REC) in Bhutan since 2008 to support the implementation of Place-Based Education in Bhutanese schools, curriculum, and teacher training. Since then, she worked with five delegations of Bhutanese educators, lecturers and education leaders from these three agencies as well as the Royal Society for the Protection of Nature (RSPN) when they have visited Teton Science Schools. She has also worked with the seven Bhutanese students who went to Teton Science Schools learning about and practicing Place-Based Education. She has been four times to Bhutan to lead workshops for school teachers and college lecturers there.

REFLECTION

Cultivating Basic Goodness – Cultivating Buddha Nature

AGATHE STEINHILBER

Abstract

Scientific researches have shown that through meditation, there are alterations in neuroplasticity and changes in the concentration of grey matter of the brain. Evidence based research too shows that contemplative practices significantly change brain structure, resulting in substantially effecting well-being, social competence, academic achievement and cognitive enhancement. Therefore, advocating, fostering and implementing the personal development of its faculty, the students, including the staff through mindfulness/awareness practices and by cultivating Buddha nature.

Key words: Buddha nature, Happiness, Meditation, Basic goodness

Introduction

Contrary to outer research which one is typically engaged in, this article deals with inner research, with individual innovation and individual development. To link the exploration of the outer research with the inner research is a great adventure. The merging of research and contemplative practice are not only crucial for one's individual development, but are key for the maintenance of good social cohesion.

Looking outward and looking inward - not being afraid of who we are, and making friends with ourselves, the principle of basic goodness, will not only impact our individual lives, but will transform society at large.

As future educators and counsellors we will experience that profound knowledge individually, we will impart that knowledge to our students in the classrooms, into society, the country at large; we will plant that seed.

Altering beliefs such as "I am not lovable", "I am flawed" etc. to "I am basically good – I am good enough", are life changing, mind shattering realizations.

Buddhists all know, that on an ultimate level, BUDDHA NATURE means that all sentient beings are endowed with the seed of enlightenment. Another term for BUDDHA NATURE is BASIC GOODNESS.

The question to consider now on the relative level, the conceptual level (which is the level most of us function: I like, I don't like, I don't care), is how one can EMBODY this view on the level of our daily lives? How to EMBODY basic goodness into our current lives?

Cultivating Basic Goodness - Cultivating Buddha Nature

Striving for excellence through research is a must. Striving for excellence in the realm of personal development is also a must.

One of the visions of the Gross National Happiness index (GNH) is providing happiness for its people by balancing development with values; e.g. through economic growth, good governance and spiritual practices; honoring people's values, people's diverse cultures, people's ancestral roots, their sovereigns and the unseen world.

Bhutan, without exemption, not being spared of the decay of its values in these rapidly changing times, (through television, internet, phones),values like: deeply engrained devotional practices, contentment with one's life, etc.; needs to find additional ways for the personal development of its people towards achieving HAPPINESS.

Actually, HAPPINESS is a misleading term. All people want to be happy. I'd rather coin the term CONTENTMENT. If people are content, happiness entails.

So, what are the ways of achieving contentment? How do we achieve contentment? Is it through economic growth, access to free healthcare, free education, research, devotional practices? Certainly. However, it is not enough. We need to advocate, foster and implement the external, as well as the consciousness related internal conditions.

Bhutan, through its visionary good governance, its culture, its sets of beliefs, is not only predestined in taking a leading role in the global community through the GNH index, but also in regard to advocating, fostering and implementing personal development of its people. Through Bhutan's deeply engrained devotional practices, people's minds are open to contemplative works.

Samtse College of Education, through its excellent reputation as one of the best colleges in education in Bhutan, is primed to take the leading role in advocating, fostering and implementing contemplative education in Bhutan. Advocating, fostering and implementing the personal development of its teachers, the faculty, the students and the staff is a must.

The Integration of Science with Contemplative Practices are the Vision and the Goal

The ripples will not only be felt on an individual level with your partners, husband/wife, with your children, with your neighbours, with your students, with your clients, professionally with your business partners, with your employees. They will be felt socially, regionally, nationally, and in the long run, I dare to say even internationally.

At this point, I'd like to share some relevant background information. For the last 30 years and longer, eminent researchers in the West, like Richard Davidson, Jon Kabat-Zinn, the Mind Life Institute in collaboration with His Holiness the Dalai Lama, Mathieu Ricard, the Naropa University and countless others, have successfully conducted scientific research and applied experimental research of mindfulness/awareness practices.

I would like to highlight some of the findings of Richard Davidson: Dr. Richard Davidson, a neuroscientist at the University of Wisconsin, was able to show that through meditation, not only does the neuroplasticity increases (alterations of the brain that occur in response to meditation), but also the concentration of grey matter changes. In addition, there is evidence based research showing that meditation significantly changes brain structure, resulting in substantially effecting well-being, social competence, academic achievement and cognitive enhancement.

Some two decades ago, people who were teaching contemplative practices were regarded as freaks. Nowadays, contemplative practices have become mainstream. In the West, many notable academic institutions as well as well-known firms like e.g., Google, advocate, foster and implement personal development through contemplative mindfulness/awareness practices. Contemplative practices are offered to students in notable academic institutions like Harvard and Yale, to name but the most prominent. As far as I know, in the US and in Switzerland, Google facilities are equipped with meditation rooms on site for its employees.

Meditation has nothing to do with religious practices. Meditation has been practiced since antiquity. It translates into Sanskrit as bhavana – to cultivate, and into Tibetan as gom – to familiarize, to habituate.

In discussing the cultivation of basic goodness – cultivating the Buddha Nature, like farmers who cultivate their fields in order to harvest, we, in meditation, cultivate our monkey mind. We familiarize ourselves with whatever arises, with whatever we have:

through the breath, the 5 sense perceptions. We familiarize ourselves with sensations, emotions, thoughts, cognition, pain, agitation, sleepiness, boredom. We train the mind. We change unsound habitual patterns and harmful sets of beliefs. In other words: we transform. We cultivate sublime attitudes, like loving-kindness, compassion, sympathetic joy and equanimity.

Cultivating basic goodness, also invites change in regard to the set of beliefs, as in: “I am a failure”, “I am no good”, “I am not lovable”, to name but a few, into

I AM BASICALLY GOOD – I AM GOOD ENOUGH (Carl Rogers).

Therefore: we are cultivating basic goodness – we are cultivating Buddha Nature: we are good enough, we are worthy individuals; we are basically good. So, one of the ways in fostering and implementing personal development is through meditation or contemplative mindfulness/awareness practices.

Recommended and well adapted practices are shamatha/vipassana (also known as shiné), anapanasati (breathing), Kinhin (walking meditation), body scan exercises, Tonglen practice (sending and receiving), Bodhicitta practice (the practice of empathy and compassion, exchanging self and other), aimless wandering/wondering, lectures, group discussions, MI (Meditation Instructor) meetings, dyads etc. The possibilities are manifold.

At this point, I would like to share the following story:

The grandparents are speaking about life with their grandchildren. They confide to them:

Grandparents: Two wolves rule our lives. One is gentle, kind and compassionate – the other one is mean, aggressive and cruel.

> ***Grandchildren:*** Which one is winning?
>
> ***Grandparents:*** The one you feed!

What does the story convey? The story tells us about choice. We do have a choice. From moment to moment: we choose. We choose where our mind chooses to go.

However, in order to be able to choose we need to gently acquaint ourselves with ourselves. It takes courage and fearlessness to look inside. As I said earlier, not being afraid of who we are and making friends with ourselves, the principle of basic goodness, will not only impact our individual lives, it will transform society at large.

Students' Feedback

I enquired from some PgDCCP students, who took part in a 5-day retreat a month ago in the college: "Whether the retreat affected their current life – and if so, in what way?"

One of the students responded: "I am more aware of my speech", "I feel more present", "I feel more relaxed", "I am less judgmental of others including myself, since I know that I am basically good".

Recommendations for how Samtse College of Education can advocate, foster and implement contemplative education into the College.

- Organise five days retreats annually for faculty members; taught by mature, experienced individuals. Time made available by the college. Funded. Concurrent with students' retreats.

- Ongoing meditation classes for faculty members every Wednesday afternoon, led by Center for Contemplative Counselling Education and Research [CCCER] faculty).

- Annually, 5-days retreats for all students, built-in into the curriculum. Funded. Concurrent with the retreat of the faculty.

- Weekly, ongoing meditation classes for all students, built into the curriculum; under the supervision of CCCER, e.g., on Wednesday afternoon, led by CCCER faculty and/Postgraduate Diploma in Contemplative Counseling Programme [PgDCCP] students.

- Through mentoring: each PgDCCP student mentors two students from other programmes.

About the author

Professor Agathe Steinhilber was a visiting professor at Samtse College of Education from March – June, 2017. Agathe holds an M.A in Contemplative Psychotherapy from Naropa University. She is trained in E.M.D.R. (Eye Movement Desensitisation and Reprocessing) from the E.M.D.R. Institute, Palo Alto, CA; she is a certified PBSP therapist (Pesso Boyden Systems Psychomotor), trained by Al Pesso, from the PBSP Institute, USA/Switzerland, and a Gestalt Therapist, from the Gestalt Therapy Institute, Los Angeles, USA and its European Training group. She received training in Breath Work from the Atem-Institut Ilse Middendorf, Berlin, Germany. She is a certified Movement Educator, and a certified Federal Business Administrator, all received in Basle, Switzerland.

Agathe's contemplative practice has been informed by Buddhist and Hindu teachers since 1973. She is a student of Sakyong Mipham Rinpoche since 1997, a practicing Vajrayana student, and a Vajradhatu/Shambhala Buddhist Meditation instructor.

During her short stint with Samtse College of Education, she taught meditation classes for the Postgraduate Diploma in Contemplative Counselling Psychology students, lead retreats at the college, presented papers during the college research convention and also played an active role in the greening and development of the college campus.