Merging Earth Science with Environmental Education for Teachers through Inquiry, Constructivist and Place-based Learning

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Abstract

Recognizing the importance of interdisciplinarity and effective pedagogical implementation, Earth science is incorporated into three of the six modules of an Environmental Education course (EDU452) at Simon Fraser University for teachers, through inquiry, constructivist and place-based learning. The case study research encompasses two pilots with 52 participants in summer 2018 and 2019. Field observations, interviews and pre- and post-course surveys (MESEES) were employed to evaluate the course effectiveness and pedagogies. EDU452 increased students' recognition of Earth Science being fundamental and relevant. Inquiry learning promoted engagement, yet careful design of overarching questions and guidance adjusted according to individual's pre-existing knowledge and the conceptual difficulty are recommended. Constructivist and place-based learning are widely accepted by the participants for offering personal ownership of learning, engaging experiences, impactful visuals, and local relevance of knowledge. Conceptual and experiential learners have different understandings of the role of Earth Science. An integrated teaching strategy is believed to enhance the congruency across subjects.

Keywords: Earth Science; Teacher Education; Inquiry Learning; Constructivist Learning; Place-based Learning; Interdisciplinarity

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List of Acronyms

CTES	Confidence in Teaching Earth Science
ES	Earth Science
EE	Environmental Education
LA	Learning Attitude
LI	Learning Interest
MESEES	Merging Earth Science with Environmental Education Survey
PLACES	Place-based Learning and Constructivist Environment Survey
PDP	Professional Development Program
PLP	Professional Linking Program
ZPD	Zone of Proximal Development

Chapter 1 Introduction

1.1 Significance of Innovative Interdisciplinary Education in Science

Education in Science at the K-12 level is critical for society, as it allows us to engage in discovering and passing on the knowledge of our world to future generations. The responsibilities of educators include not only teaching, but also developing new systems for more efficient and effective education. As the rapid revolution in the education system is accelerated by digital technologies in this century, education must be transformed with innovative pedagogies that support personalized learning to ensure our students adapt to the more connected world than that of the previous generation (BC Ministry of Education, 2018a).

Past research has attempted to investigate effective learning through depicting the learning process (e.g. Kiraly, 2017). In his review paper, Khalaf (2018) summarized that scholars agree the learning process centers around obtaining knowledge and developing problem-solving abilities using knowledge. Traditional learning is typically symbolized by the one-way delivery of unchallengeable knowledge from teachers, and focuses on context and learning outcomes, not the process of constructing active engagement for learners (Rashty, 1995; María & Luisa, 2016, Khalaf, 2018). This results in teaching strictly according to an existing curriculum, ignoring the development of critical thinking, framework of understanding and interdisciplinarity (Rashty, 1995). Many fields within the sciences are interconnected, providing inspiration, various perspectives, processes of thinking, and necessary background information for each other. According to Naiman (1999, p. 292), “an interdisciplinary perspective for understanding and management” is required for “a rapidly increasing human population [that] dramatically impacts ecosystems.” Traditional learning has been criticized by cognitivist advocates for its resulting incompetence for skill development of learners (e.g. Dorier & Maab, 2012).

An obstacle for promoting innovative pedagogies is standardized assessment. Recent studies by American Educational Research Association (AREA, 2014) indicated that teachers in formal education tend to deemphasize areas that are not tested. A more recent study illustrated exams on content knowledge still outweigh assessments that measure engagement and skills used in practices (Egger, 2019). This ‘fixed’ criterion encourages memorization instead of learning, preventing cognitive and hands-on skills that allow for applying knowledge for resolving problems. Since only the examinable content was emphasized, nothing beyond the testable boundaries was often discussed, further causing superficial learning (Entwistle & Tait, 1995; Biggs, 1996). Thus, the incapability of learners educated in the traditional methods to transfer their knowledge to the practical science world is often observed. Multiple studies in the past at school levels have indicated poor performance of knowledge acquisition and a long-term negative impact of memorizing knowledge fostered in traditional learning (e.g. Gibson & Chase, 2002; Farkas, 2003). Strategies that actively engage students during scientific investigations were reported to be advantageous for facilitating conceptual understanding over passive techniques that are usually associated with standardized assessment (Minner et al., 2010). Learning that does not convey knowledge at a personal experience level may result in a greater chance of forgetting. If learners are “performing rather than learning”, then “the process of recall will not stay in [their] memory” (Khalaf, 2018, p. 553). This way, academic learning departs further from practice.

Innovative teaching strategies and reforms to student-centered learning models have been growing since the early 1970s, vastly changing the world previously dominated by traditional education (Khalaf, 2018). Although this research neither devalues nor focuses on criticism of traditional pedagogy, past research has demonstrated that innovative pedagogical approaches are more effective for teacher education in science. For instance, the Education Lab (EOS120 University of Victoria) for introductory geology, which was designed towards teacher education through a constructivist learning model, illustrated a trend in both laboratory, lecture and final grades generally favoring the innovative lab sections over the regular sections during the three-year pilot study started in 2005 (Van der Flier-Keller et al., 2011; Alpert, 2012). Students provided positive feedback on the teaching approach, active involvement, classroom resources, and inspiration (Van der Flier-Keller et al., 2011). Another analysis of 139 research projects between 1984 and 2002 indicated a positive impact of innovative, inquiry-based, engaging instructional practices on conceptual understanding at K-12 level (Minner et al., 2010).

Teaching is framed by culture, tradition, institutions and technologies that encourage an interdisciplinary perspective (Naiman, 1999). If discontinuous segments of knowledge can be woven into a multidisciplinary concept map, information would become more transferable and applicable. Models of education continue to evolve from teaching science through individual subjects to interdisciplinary courses that focus both on the connection between knowledge and inquiry, and problem solving (Mills et al., 2016). Designing interdisciplinary courses in science is therefore very important.

1.2 Differences Between Earth Science and Environmental Education

Difference in Primary Focus

Education in geology has expanded its coverage to a broader view namely "Earth Science" worldwide (e.g. 'The Earth Science Teachers' Association in UK; 'National Association of Geoscience Teachers' in US). Since the proposal of Gaia Hypothesis, many scientists recognize Earth as a complex system with interacting inorganic and biological components (Lovelock & Margulis, 1974; Lovelock, 1979). Earth Science (ES) and its overlaps with Environmental Education (EE) received growing interest in science education as interdisciplinarity became a popular topic of discussion. The distinguishing factors of ES and EE may be generally categorized into two aspects: differences in primary focus and pedagogical style.

Since the Earth as a whole is comprised of elements related to various components such as the atmosphere, oceans and lithosphere, ES therefore is an interdisciplinary study in the sense of content. Interactions between different components shed light on the systematic functioning of the planet, and moreover, the concept of the geological time scale provides insight on recognizing that this system is dynamic. Transformation of a system over time leads to questions such as "what will happen?" and "how can we influence the system?" Much of this knowledge may only be acquired through field explorations and advanced spatial imaging. Since comprehending the past helps understand the future, the knowledge of the changing Earth ultimately acts as the powerhouse for many issue-solving practices in other courses. To summarize, the distinctive attributes of ES curricula involve the holistic system of Earth, the geological time scale, spatial abilities, fieldwork and retrodictive thinking (‘prediction’ of the past) methodologies (King, 2008, p. 188).

While ES focuses on every natural aspect of the planet, from geological history, internal and external processes, to understanding the interconnections within the Earth system, EE integrates multiple science fields intersecting with ecology, sustainability, political and cultural studies under a single framework (BC Ministry of Education, 2007). EE emphasizes the connection between humans and our surroundings in addition to investigating the interdisciplinary content itself, so its learning models are multiform. Since environmental problems are pervasive and deeply connected to our social and cultural behaviors, discussing technology or science alone is insufficient to offer effective solutions (BC Ministry of Education, 2007). Therefore, EE aims to encourage social responsibility, and examines human practices that potentially lead to environmental issues. As humans grew more environmentally influential after the Industrial Revolution, resilience, sustainability and environmental impact have become important topics of discussion. These topics demand higher levels of reasonable foreseeability on environmental issues and capability for discovering solutions. The ultimate goal is to have learners become “ecologically literate” and “act competently to build a sustainable future” (BC Ministry of Education, 2007, p. 6). Consequently, the learning goal of EE involves an increase in scope of both basic understanding and knowledge application.

EE includes identifying environmental issues, processes of problem solving, and social impacts, in contrast to ES which is described by Frodeman (1995) as an “interpretive” and “historical” science that has a greater emphasis on knowledge acquisition to consolidate understanding than social aspects. Such contrast in the primary focus encourages instructors in both fields to adopt different pedagogies, resulting in very distinct characteristics of ES and EE courses in educational systems.

Pedagogical Difference

In the British Columbia Kindergarten to Grade 12 system (the BC K-12 system), “environment” is a relatively new area of learning. EE in public schools was part of science education since the late 1960s, and became its own subject in 1995 (BC Ministry of Education, 1995). Although the plan was to include EE into the provincial curriculum, this document was treated as a “guidebook” for daily lessons (Arai et al., 2001). The document suggests to educators that "environment" should be studied through discussion among professional teams, hypothesis testing and developing connection to a particular place of interest rather than knowledge-based intense reading (BC Ministry of Education, 1995). Therefore, the pedagogical approach of experienced EE instructors is usually place and discussion-based. Little background reading is provided to facilitate inquiries. Environmental educators advocate for integration of subjects, direct experience, critical reflection on a range of perspectives, conceptualization, negotiation, and facilitating a positive learning environment (BC Ministry of Education, 2007). Thus, the learning cycle (a concept of learning through experience in various phases that completes a cycle. E.g. Dewey, 1938) expands from localities to global perspectives to develop understanding based on complexity, aesthetics, responsibility and ethics (BC Ministry of Education, 2007).

In science education at the post-secondary level, ES, which may involve experiential learning in labs, typically faces problems associated with lecture-heavy teaching and correspondingly more passive learning, and therefore stands to benefit from more effective learning models. For example, a previous overview of ES education by King (2008) revealed numerous concerns: lack of extensive research regarding effective pedagogies for ES teaching, under-teaching of spatial awareness, underdeveloped approaches for teaching geological time scale and field techniques, widespread misconceptions, and slow implementation of professional development for ES educators.

ES education in schools is facing many challenges including primarily a lack of teachers with relevant background, and teaching resources in ES (King, 2001; Dawson & Moore, 2011), the perception by teachers that ES is less important compared to other subjects in science (Betzner & Marek, 2014), and a general perception of some ES topics being boring, irrelevant or difficult by students (Dawson & Carson, 2013). These challenges also existed in the BC K-12 system, with ES receiving less focus in the BC school curriculum at higher levels compared to other sciences (Van der Flier-Keller et al., 2011). Feedback from teachers often indicates little motivation towards teaching ES topics, which may be attributed to a lack of appropriate classroom resources and background, and difficulties with field trips (Van der Flier-Keller et al., 2011). Furthermore, it is not uncommon to have ES taught by biologists (Europe), as a part of chemistry (UK), part of general science (Japan, Korea, Taiwan, New Zealand & South Africa) or a mandatory component of geography (Germany) (King, 2008). Throughout the United States, ES content that was mostly missing beyond middle-school level has become a lingering problem, resulting in consequences for higher education (Barstow et al., 2002). Studies of teachers in England in the late 1990s implied poor background knowledge of ES, little to no field experience and that the main source of knowledge was from general science textbooks and colleagues (King, 2001). Such obstacles create adversities for conceptual changes in the educational system, as teachers demonstrate a tendency to favour traditional, transmissive learning models (Scott et al., 1991; Duit et al., 2007) and teaching of science subjects. Some of these difficulties may have arisen through the current teacher-educational system.

The National Research Council of the United States of America (NRC, 2000) announced opportunities for ES to be involved in other science curricula, but this required well-trained teachers who have specialized geological backgrounds. However, teachers report an overall lack of support. Research has shown that only a small portion of students who took ES courses at the post-secondary education level major in geoscience (Martinez & Baker, 2006; Wilson, 2016). This implies that the majority of those who specialize in other fields, including future K-12 teachers, enroll in ES courses to fulfill a general education requirement (Gilber et al., 2012). For example, elementary school teachers in BC require only one laboratory course in first-year university level science, and secondary school teachers require two, with only a few options specific to teaching ES in the K-12 setting (e.g. BC Ministry of Education Bcteacherregulation.ca, 2018; SFU, 2018). Given that teachers have a key role in improving students' learning in ES, well-designed courses for professional development should be highly prioritized (Van der Flier-Keller et al., 2011). Many teachers in training receive their only ES education at a primary college-level, and therefore the introductory courses play a critical role of preparing future teachers (Egger, 2019).

Egger's (2019) research indicated that although ES education has been moving to more active and student-centered teaching strategies, (e.g. the proportion of traditional lecturing has decreased over the years with a parallel increase in active learning strategies such as discussions and activities), more effort is required to further improve learning as the following problems remain: 1) the concept of systems thinking is rarely mentioned and incorporated in introductory ES courses; 2) little time is spent on highlighting human connections with Earth's systems; and 3) engaging with data and practices is relatively rare compared to emphasis on content knowledge. King (2008) concluded that ES education will only progress if ES is more prominent in K-12 classrooms, teachers have adequate preparation in ES, and we continue to invest in researching and evaluating the issues.

1.3 Merging Earth Science with Environmental Education

An Evolution in Earth Science Education

In 2016, the BC Science curriculum was updated to fit a concept-based, competency-driven standard, and now includes a focus on three elements: the Big Ideas, Curricular Competencies, and Content, which are all designed with a hands-on approach in a "knowing, doing and understanding" manner. (BC Ministry of Education Curriculum.gov.bc.ca, 2018a). First, the content and elaboration ("knowing") lists the topics, knowledge, definitions, and examples as well as sets the learning standards in a "cross-cutting" model to apply concepts across areas of study (BC Ministry of Education Curriculum.gov.bc.ca, 2018b). Second, core competencies ("doing") include critical thinking, problem solving, ability to make proper ethical decisions, properly communicate, express opinions, and be socially responsible for caring for the planet (BC Ministry of Education Curriculum.gov.bc.ca, 2018b). The renewed science curriculum facilitates students to inquire, hypothesize, analyze and eventually make reasonable conclusions. Meanwhile, building connections to places, culturally, socially, and historically is encouraged. The Big Ideas, which reflect "understanding", highlight the importance of science literacy by addressing concepts and providing sample questions that suggest "entry points" for students to investigate their science inquiries (BC Ministry of Education Curriculum.gov.bc.ca, 2018b). In all, the new curriculum encourages students to develop understanding and appreciation of science, conceptual, procedural and place-based knowledge, develop good research habits, and finally be science literate (BC Ministry of Education Curriculum.gov.bc.ca, 2018c).

However, such a dramatic change in pedagogy and approach may only be implemented in classrooms following a revolution in the formal teacher education system (for pre-service teachers), combined with appropriate professional development for in-service teachers. As technology advances, more complex and convenient apparatuses such as computers, digital maps, projectors and satellites are available for educational purposes. The recent revolution of pedagogy in ES generally (university and school education) may be summarized as progressing more quickly technology-wise, but more slowly theoretically and methodology-wise (Mills et al., 2016). Developing experience with innovative ES pedagogy requires specialized courses. Fortunately, cases of tentative innovative teacher-education programs have begun to be developed.

The evolving pedagogy is migrating towards a more student-centered, teacher-supported, self-leading, and active learning process (BC Ministry of Education Curriculum.gov.bc.ca, 2018d). For instance, the Science Education Resource Center (SERC) at Carleton College centered in the United States is dedicated to discovery of new pedagogy in ES for both pre-service and in-service teacher training as well as teaching at high-school level (SERC, 2018). Contemporary teaching methods suggested by SERC may be categorized into three sections: teaching with models, teaching with data and simulations, and quantitative teaching (SERC Teaching Methods, 2018; Models, 2018; Quantitative Teaching Literacy, 2018).

Models have versatile usage in illustrating concepts, mathematics, statistics, and visualization (SERC Models, 2018). They are fundamental to ES as it is ideal for systematic thinking and provides an interactive, engaging, self-leading environment (Hake, 2002; Ford, 2009; Ruddiman, 2001). Models are also related to quantitative issues that are critical for ES students to consider (Hancock & Manduca, 2005; Manduca et al., 2008). In Hestenes' (1997, p. 935) words, "scientific practice involves the construction, validation and application of scientific models, so science instruction should be designed to engage students in making and using models."

The use of data is another useful tool adopted for learning in ES. Data supports models by supplying direct observations and scientific evidence. Viewing and analyzing data are basic skills students need to acquire, so teaching with data in the form of activities makes an introductory geoscience course more effective (SERC Teaching Methods, 2018). Furthermore, the application of data introduces simulations to the classroom. Simulations offer students an opportunity to develop deeper understandings of difficult issues by allowing them to observe dynamic processes of how data-sets are formed (Burrill, 2002). Simulations also encourage students to anticipate and conjecture about results, which enhances their inferring and reasoning abilities (Erckson, 2006).

Quantitative teaching in ES ties closely with models and data simulation. SERC (Quantitative Teaching Literacy, 2018) suggests “quantitative literacy” and “reasoning with news” as possible approaches to teaching quantitatively. Quantitative literacy ties mathematical concepts with ES context (SERC Quantitative Teaching Literacy, 2018). Becoming quantitatively literate enables students to become more adept at evaluating and discussing scientific results. Newspapers may serve as convenient resources to find quantitative content on relevant and current issues in society for critical analysis. Newspapers are an excellent resource for case-study in ES, and helps students develop a habit of regularly engaging with nature (Diefenderfer et al., 2009). Recent methods of preparing students for quantitative literacy involve introducing context prior to concepts, multiple representations, emphasis on teamwork and technology (SERC Quantitative Teaching Literacy, 2018).

Another example of evolving pedagogy in ES education is the incorporation of the EDU model, which suggests the three key steps of a learning cycle to be explore, discuss and understand (Blades, 2000; Blades, 2001). This model was the basis for a lab section originally designed for training pre-service teachers in a first year ES course at the University of Victoria (Van der Flier-Keller et al., 2011). Studies also revealed great advantages of this constructivist-based learning model including the long-lasting, profound influence on the participants, who adopted the hands-on activities and explorations in their own pedagogical approach (Alpert, 2012).

Teaching ES in a productive way in schools requires that teachers are well-educated in the first place. Associations like SERC, and learning models such as EDU, are revolutionary at university level for educating teachers in science. Additionally, not only will the programs foster innovative graduates as new teachers, who filter down upgraded pedagogy to the school level, but the designing process itself may provide insight on education in the future. For example, instructors who participate in the process of designing new curricula may expand their own field of interest, and renew their pedagogies and views towards interdisciplinary. Evaluating courses may also promote effective innovative teaching strategies. Just as described by Sinatra (2005), teaching conceptual ideas with cognitive models supports experiential learning, paying increased attention to learners.

One of the goals of studying ES in general is centered around environmental protection and linking knowledge to daily life, indicating a greater chance of progress with interdisciplinary curriculum innovation (King, 2008). Interdisciplinary courses may include hands-on activities to convey messages, and background information placed within context, with discipline content knowledge hidden within activities. These “puzzles” are then used as a teaching method for students to construct their own knowledge. Generally, models and ideas are moving ES in the direction of student-led pedagogies. It is this revolution in pedagogical style that offers the possibility of incorporation of ES and EE.

Incorporation Under the CARE Framework

Although ES may differ from EE in some aspects, they are closely related because of their overlaps in content. To promote student inquiry into environmental issues, background knowledge in ES is critical. It has been argued that ES has “a fundamental role” of “promoting an understanding of the way that nature works as a system,” and boosts the “response of society to current issues” (Van der Flier-Keller et al., 2011, p. 180). The processes of our planet’s geological changes form our environment, and facilitate questioning about the future. ES knowledge helps provide information to understand local and global environmental issues. Given how strongly EE ties to people’s daily lives, EE offers relevance for in-depth ES concepts to be discussed. Therefore, both subjects support the other, and should not be taught separately.

The revolution in pedagogical style offers overlap between ES and EE approaches, as well as potential for the creation of an interdisciplinary course that suits the purpose of educating future pre-service and in-service teachers. The aforementioned pedagogical approaches by environmental educators emphasized making the class relevant to personal lives. With respect to environment, a framework that quickly draws students’ attention and establishes connection to nature seems essential.

The CARE framework, suggested by the Ministry of Education of British Columbia as an interdisciplinary guide for teachers, depicts multiple forms which environmental knowledge may take, while presenting ideas that lead towards critical thinking (BC Ministry of Education, 2007). The Ministry has used it as a recommendation for organizing and conceptualizing EE. Each category of the framework is described below (Stratton et al., 2015):

1) Complexity: seeing all artificial and natural objects and lives as components of a complicated system

2) Aesthetics: acknowledging the need to cherish nature for its aesthetic value and recognizing the genuine responses we humans have to this beauty

3) Responsibility: noticing the human impacts on the surrounding environment and pondering how to make such influence positive in the long run

4) Ethics: based on the knowledge above, developing the 'moral fiber' that supports student behavior

Since the environment is inseparable from the planet, seeing connections to nature through the above lenses is presumed to be an effective framework for the incorporation of ES with EE.

1.4 Environmental Education 452

Course Context

Education 452 (EDU452) is a field-based, weekend EE course taught by Dr. David Zandvliet for the past two decades. The purpose of the course is to assist students in exploring their surroundings, constructing connections to specific places, helping pre-service and in-service teachers to increase their consciousness of environmental issues, and consequently to develop ideas that help humans to improve and preserve the environment (EDU452 Course Outline, Appendix B). The class of each year examines the understanding and awareness of the environment, and explores the associated historical and contemporary issues through a multi-disciplinary approach. Students are required to complete the course prerequisites: EDU401, Introduction to Classroom Teaching (SFU, 2018) and any first-year science class. Most of the enrolled students are either in Professional Development Program (PDP) or Professional Linking Program (PLP), indicating that they are transitioning to or already in the educational system (Personal Communication with EDU452 students). Class enrollment was 30 students in 2018 and 24 students in 2019. The course is graded on a pass or fail basis (SFU, 2018).

Realizing the substantial connection between ES and EE, the Department of Earth Sciences at Simon Fraser University joined Dr. Zandvliet in his course in the summer of 2017, and this collaboration has continued for the rest of this project. From there, the integration of ES into the interdisciplinary curriculum for EDU452, an upper-year undergrad level EE course has been carried out under the CARE (Complexity, Aesthetics, Responsibility and Ethics) framework.

The redesigned course comprised five modules: 1) Introduction to Topics in Environment through An Interpretive Hike, 2) Water Management, 3) City as A Living Organism, 4) Land Use Issues, and 5) Ocean Literacy. Piloted in the summer of 2018 for a preliminary analysis of content, process and pedagogical issues, a revised version with identical modules was implemented in the summer of 2019 for an examination of improvement. ES topics including natural hazards, water resources, Earth's processes and events in its history have been incorporated into three relevant modules (Modules 1, 2 & 4). The term "case study" in education has been defined differently by many scientists in the past, regarding various aspects, such as the process of research, the instance or phenomenon for analysis (the case), or the purpose of the study (e.g. to evaluate and interpret a phenomenon or to build theory) (Merriman, 1988). The case study in this particular research provides in-depth description of the ES relevant content and pedagogies in EDU452, and presents a qualitative analysis to interpret and advise on the phenomenon observed. Since this is a case study of a collaborative project that spans across 2 years, information gathered during the first pilot is used to evaluate the impact, expand on methodology, and suggest changes to the course for the following year. Details of data collection and the researcher's involvement will be discussed in Chapter 3.

Research Questions

Designing the case study of the ES incorporated EDU452 began with a review of the literature, and information gathering from instructors regarding the 2017 course offering, where two Earth Sciences faculty members attended and participated in two of the EDU452 course modules. This was followed by reflections, feedback from a 2017 student EDU452 focus group, and discussions between Dr. David Zandvliet, Dr. Eileen van der Flier-Keller, a teaching professor in ES and specialist in science communication and Mr. Kevin Cameron, a senior lecturer in ES. The synthesis of content, pedagogy and field trip plans suggested by the three instructors built the foundation of the interdisciplinary experience. The success of the project was studied by evaluating the students' improvement in ES knowledge, views towards incorporation of ES with EE, change in learning attitude, interest and confidence of students, and effectiveness of pedagogical approach and activities.

Recognizing the importance of interdisciplinary contributions, and the new BC Science Curriculum, this project seeks to examine the incorporation of ES into the course curriculum of EDU452. The aim of the case study research is to answer the following questions:

1) How effective is EDU452 as an interdisciplinary course of Earth science and Environmental Education from a student-centered, teacher-supported learning perspective?

2) What is the process or the model of incorporating Earth science into Environmental Education, and how effective is it from a teacher-centered, student-supported perspective?

Chapter 2 Literature Review

2.1 Learning Models

2.1.1 Inquiry Learning

Merging ES with EE is innovative and challenging. Three innovative learning models have been proposed to effectively teach EDU452. One of these is inquiry learning. An early philosopher and educator believed that inquiry learning is rooted in direct experience and basic curiosity, and is essential for critical thinking in scientific research, making knowledge transferable across disciplines (Dewey, 1938). As a process of active learning where students are engaged in questioning and doing, inquiry learning should offer an opportunity that encompasses activities, analyses and multistage discussions, reflecting the way scientists study nature based on evidence (Anderson, 2002). Inquiry learning is therefore seen as a method to simulate professional scientific investigations to build new theories or knowledge (Keselman, 2003). Curiosity has always been a part of human nature drawing us to understand the world, to question and to pursue investigations (Dow, 1999). Some studies promote debates and discussions in the later parts of inquiry process, because they help develop problem-solving skills (Pedaste & Sarapuu, 2006; Pedaste et al., 2012). Although the definition of inquiry learning varies with its purpose for different projects, the common aim is to transform teachers into facilitators and students into self-leading learners. In all, it raises the habit of asking questions and finding evidence to comprehend natural phenomena (Sampson et al., 2011). In his review, Khalaf (2018) recalled the main reasons suggested by National Research Council of the United States of America in 2000 to implement inquiry learning: its facilitation on change in attitude, understanding and skills of learners; its advantage to better engage students in reading, writing and discussion; and its emphasis on critical argument based on logical reasoning. Inquiry learning is meant to help learners gain conceptual understanding rather than direct memorization of facts (Bruner & Kenney, 1966). Inquiry learning seeks a more efficient way to build knowledge and better develop comprehension that differs from the traditional, coercive education through a dramatic change in teaching techniques. The core of inquiry learning is “the nature of student work," "their roles," and teachers' aim for "a climate of collaboration" (Anderson, 2002). Examples of inquiry learning are described in section 2.2 of this chapter.

2.1.2 Constructivist Learning

Constructivism is believed to be one of the fundamental, theoretical underpinnings of inquiry learning (Piaget, 2013). According to DeVries and Kohlberg (1987), a constructivist model aims to foster learning interest, to be experientially engaging, and focuses on the necessity of cooperation between students and instructors. Constructivism also indicates that students have pre-existing mental schema before coming to class (Piaget, 2013). With constructivism, students build their own frameworks of comprehension based on experience and hands-on activities, and the process of constructing knowledge further helps to deepen understanding while correcting misconceptions (Alpert, 2012). However, the process of constructivism itself may also create misconceptions (Alpert, 2012). Teamwork and discussions for reaching consensus are also encouraged in a constructivist environment (Khalaf, 2018). Constructivism involves two central ideas: 1) having students construct their own knowledge, as opposed to simply hearing it from instructors and 2) having students become self-governing or autonomous during their progress of learning (DeVries, 2002). Educators often see students developing concepts without receiving formal lectures. Such beliefs are not necessarily correct, but are results of reasoning from observing physical phenomenon in nature. This process opposes passive learning, where instructors verbalize knowledge and 'pour' it into students' minds. Taking the short-cut by skipping the experimenting section in a learning cycle results in a passive attitude that "switches-off" the observing and reasoning functions of the learners' brain, and eventually destroys their desire for new information. Note that not only beliefs, but the development of beliefs may contribute to a student's personality and morality. A successful constructivist instructor facilitates the reasoning ability of students and helps reduce misconceptions, while maintaining student interest and confidence towards learning (DeVries, 2002). Therefore, the first part of constructivism does not aim for the answer but rather a process leading to the current accepted scientific explanation. The second part involves the optimal environment for the implementation of constructivist learning. Previous researchers indicated that an autonomous morality functions better than a heteronomous one for education (Piaget, 1965). A heteronomous relationship advocates absolute obedience by creating a difference in authority between instructor and students, so it impedes the learner's ethical and intellectual independence; whereas, an autonomous one encourages a cooperative relationship for mutual influence, and this fosters self-governance during learning (Piaget, 1965).

The constructivist model manages to approach teaching scientifically, socially and morally. For teaching in science, constructivism suggests that knowledge should be acquired in the forms of activities or events that lead to self-regulation and practical skills. Teacher responsibilities include allowing students to choose projects, guiding them through, and ensuring students increase competencies and knowledge levels from activities.

Interestingly, this overlaps with some techniques described in inquiry learning. Yet, constructivist learning has a greater emphasis on the change in attitude. Autonomy, which denies a full submission of students to instructors provides an atmosphere of scientific and social communication. Meanwhile, a certain amount of support is required to prevent students deviating towards unwanted behaviours. "Mutual respect" and "mutual consulting" are promoted, so "constructivist learning program may be said to be democratic in nature" (DeVries, 2002).

2.1.3 Place-Based Learning

To retrieve the congruity between knowledge and reality, a model that demonstrates the importance of building connections between students and specific places is needed: the place-based learning model. Place-based learning is a pedagogy that mixes content with physical, social, cultural and economic aspects of a locality to engage students with outdoor activities and environment, and has been complimented for its advantages at improving competency, practical skills and career building (Semken, 2005; Sobel, 2004; Woodhouse & Knapp, 2000; Gruenewald, 2003.) The five essential traits for place-based teaching in ES education can be summarized as 1) focusing explicitly on the geological content and other relevant natural aspects, 2) integrating the place into the class and community, 3) involving authentic experience specific in the place, 4) advocating for ecological and cultural sustainability and, 5) underlining the sense of the place (Semken, 2005). It adopts local community and environment as resources for learning, conveyors of concepts from multiple subjects across curriculum, and opportunities for real-world experiences; it is the "antidote" to textbook reading that "shuts" the Earth outside of the classroom (Sobel, 2004). Gaining a sense of place must benefit ES education as it impacts people's attitude and habits at observing physical and environmental features (Semken, 2005).

Although the definition of place-based education is flexible, educators typically apply it for common purposes and with common techniques. The central perception of place-based education may be categorized into three aspects: realizing social responsibility as an individual, appreciation of the local community and place, and application of a motivating instructional strategy especially when across subjects (Jennings et al., 2005). These goals are set to boost academic achievement, increase respect for nature, and help students to become committed citizens for engineering an environment friendly community (Sobel, 2004). Suggestions on how the model should be employed are summarized to consist of 1) promoting conversation on history of a place, 2) guiding students towards disciplinary-relevant features to support the curriculum and, 3) exploring new perspectives to facilitate further fieldwork or discussion (Zimmerman & Land, 2014).

Previous surveys and interviews with practitioners in Vermont, United States, illustrate a generally positive feedback of teachers' perceptions towards academic, social and teaching practice values of the place-based learning model (Jennings et al., 2005). While being distinct from traditional education, the place-based learning model may be combined with classical classroom practices. For example, in the Vermont case study, none of the teachers articulate that place-based education conflicts or impedes the traditional learning environment (Jennings et al., 2005). In fact, from the absence of instances in which ongoing place-based curricula are being extinguished or new practices are being prevented, it is evident that complementarity between standard and place-based education does exist. Moreover, researchers advocate such complementarity as "helpful" and "generative" (Jennings et al, 2005).

The place-based learning model helps researchers to present and convert locally embedded knowledge into abstract knowledge through community-relevant cultural practices and interactions (Gruenewald, 2003). In such a setting, learners are guided to absorb concepts and integrate them into conclusions on societal, sustainable and environmental issues (BC Ministry of Education, 2007).

In place-based education, students are found to be more socially collaborative, and have deeper understanding and appreciation of the environment (Zandvliet, 2007; Zandvliet, 2009; Ballantyne & Packer, 1996; Bogner, 1998; Cummins & Snively, 2000; Kenney et al., 2003). Place-based learning helps to reframe learners' cognitive structures and improve attitudes, which can be facilitated by a positive learning environment that enhances students' overall experience (Zandvliet, 2009). A place-based learning environment considers the influence of social conditions that dominate learners' perception of the quality of experience and of their learning. Bonnett (2004) supports a science curriculum associated with creative and intuitive activities to improve personal relevance of learning. Other studies also addressed the importance of interpersonal and community factors for a positive learning environment such as being respectful, fair and collaborative during learning (Gruenewald, 2003; Kahn, 1997; Lewicki, 1998).

Previous studies have also underlined how students' perceptions of learning environment contribute to their learning outcomes (e.g. Fraser, 1998). Therefore, constructing a learning environment that from students' perspective positively influences attitudes, academic achievement, collaborative and critical thinking skills is important.

In the past, instruments were developed and adopted not only to study classroom environments, but also outdoor learning, field-trip and community-based experiences (e.g. Houston, Fraser, & Ledbetter, 2003; Zandvliet, 2007; Zandvliet, 2009). For example, Zandvliet in 2009 collected data on perceptions of the learning environment in an experience-involved, localized, place-based setting that highlights constructivist pedagogy by applying the term "classroom" to more diverse settings. This gave rise to the Place-based and Constructivist Environment Survey (PLACES) that assesses students' perception of learning environment in these place-based learning settings. The development of PLACES evaluated and validated the constructs that were expected to influence environmental learning and learning environments.

In designing the survey, focus group discussions were held across diverse communities such as schools, universities and informal education organizations. These eventually established eight constructs that were considered critical to place-based learning settings. These constructs are: Relevance / Integration (RI), Critical Voice (CV), Student Negotiation (SN), Group Cohesiveness (GC), Student Involvement (SI), Shared

Control (SC), Open-Endedness (OE) and Environmental Interaction (EI). RI focuses on the relevance between course content and environmental and community-based activities. CV and SN discuss the extent to which students have a say and may negotiate classroom procedures and activities. GC and SI refer to whether students are supportive of each other, and willing to be engaged in class discussions. SC and OE address the freedom offered by the teacher for students to think, plan and control their own learning. Finally, EI measures the engagement of students in local community-based activities. These constructs work with each other to provide a view of how a positive learning environment may be constructed by factors such as pedagogy and social, environmental interactions.

2.2 Previous Geoscience Learning Models Research

Many studies have demonstrated the strengths and insights of the above learning models for ES education. Both inquiry learning and constructivist learning will be discussed in the examples, since they are commonly adopted together. Place-based learning examples will be presented at the end.

Inquiry learning and constructivism have demonstrated superiority over passive learning around the world. In Taiwan, for example, multivariate analysis on inquiry learning at middle-school level discovered that the experimental group had significantly more favorable scores on exams and developed a better learning attitude towards ES classes (Chang & Mao, 1999). Another study in Taiwan using a five-point Likert scale questionnaire to obtain ES students' opinions towards constructivism during the six-week intervention, showed that the majority maintained a neutral attitude to the learning style, but all demonstrated understandings of the benefits of constructivism (Chang, Hua & Barufaldi, 1999).

The example of the Education Lab (EOS120 University of Victoria) addressed in the previous chapter, demonstrated a successful adoption of both inquiry and constructivist learning models (Van der Flier-Keller et al., 2011; Alpert, 2012). The EDU model implemented in EOS120 echoed the activeness of inquiry learning. It encouraged examining, exploring a topic, followed by identifying issues, and eventually fostering a platform for discussion and critical thinking. The first step was to allow students to explore (acquiring the context), developing initial personal experience on the subject, which fed into more abstract concept development later in the learning (Blades, 2000). The Exploration stage was not limited to students' action and exploration, but also a plan for teachers to explore the extent of their students' pre-existing understanding and prior concepts. For example, have students received any education on some topics prior to the class? Do all students have similar backgrounds and levels of understanding? Teachers' knowledge of their students is often built through asking them questions, observing them during inquiries, and a pre-class quiz or survey. This exploring process helps teachers to discover students pre-existing knowledge and misconceptions, and establish a community for communication. Sometimes, students arrive at their conclusions with doubtful ideas or contradictory concepts based on their previous understandings. Meetings and debates were commonly conducted to spot and correct misconceptions, and present hypotheses. The Discussion stage offers an opportunity for students to share their opinions, be challenged to explain their ideas, and be engaged for further exploration. Students are also encouraged to link their discoveries to social and environmental aspects. Teachers have an increased responsibility to ensure that students stay on the right track during this stage. The Understanding stage of the EDU model aims to assess students' understanding through a variety of assignments or examinations (Blades, 2000). The EDU approach advocates for creative forms of assessment to help teachers examine whether students have fully understood the topic. This facilitates critical thinking and uncovers any remaining misconceptions. For example, writing creative essays, on-stage performances, expressing opinions on particular issues, painting or drawing in science, even designing a research topic may be possible options for open-ended assessments. The benefit of such versatile assessment is that they are directed to the specific learning habits of each student (Blades, 2000). The EDU model supports inquiry learning by prohibiting large amounts of background readings that lure the student to observe the expected results, and instead promotes students to ask questions, and then look for the information they need to answer it. This way, the learning process mimics the scientific research process. The findings of this example were that inquiry-based, constructivist activities promoted better student performance, and were powerful at identifying misconceptions, and above all, improved the attitude towards ES in terms of its relevance to society (Van der Flier-Keller et al., 2011).

At the teacher-education level, the constructivist approach has been used to work with the inquiry-based model in the past to improve students' understanding of scientific concepts (e.g. Slater et al., 1996). For example, the astronomy course, "Space Science for Teachers," was offered in 1993 at the University of South Carolina to 25 in-service elementary and middle-school science teachers with a wide background of teaching experience (Slater, et al., 1996). The study focused on the change in knowledge, confidence, learning attitude and interest toward astronomical science over the 15-week (3 contact hours per week) course duration. Topics covered included ES, meteors, asteroids, space traveling technologies, evolution of stars and galaxies, and cosmological theories. Each class began with a brief short-answer quiz, followed by an exploration activity, and eventually closed with extended group discussions. Constructivism was implemented through inquiry-based hands-on activities and discussions. Students' knowledge and understanding are constructed during these activities and discussions, and misconceptions were revealed. The success of the project was assessed through multiple-choice tests (knowledge), a Likert-style pre & post-course design survey (attitude, interest and confidence) and 2 focus groups (qualitative results). The results illustrated a dramatic increase in knowledge level, positive attitude and improvement in confidence and interest in teaching astronomy. Slater and his colleagues concluded that although no comparison to traditional education was made in this study, they strongly recommend a constructivist strategy for an effective learning environment and benefits in teacher-education in science-related fields.

Acknowledging the previous success of the constructivist strategy on Earth and planetary science (Slater, et al., 1996; Slater, et al., 1999), Riggs and Kimbrough (2002) reconstructed the course "Natural Sciences 412D – Process and Inquiry in the Earth Sciences (NS412D) at San Diego State University for the Spring and Fall semesters of 2000 (82 students altogether) under a constructivist framework for a closer look at the constructivist approach in ES. NS412D was designed for pre-service elementary level teachers with Liberal Studies majors who usually have little to no background in ES. The course covered seasons, solar time, relative dating, and fossils as the main topics. The reconstruction switched the laboratory-based traditional approach to an inquiry-based model with multiple in-class group activities. The implementation of this new strategy started approximately half-way through the spring semester and continued for the rest of the project. A multiple-choice, written answer based traditional examination was done before the implementation and another reflective, problem-driven assessment was done at the end of the semester. The research team kept the questions identical for the fall semester for a cross-semester comparison. The results demonstrated an unexpected, significant drop in performance after the implementation in the spring semester, and a mild improvement in the fall semester after a revamp of the curriculum. The rework included a more explicit introduction to constructivism and inquiry-based learning, plus a learning-cycle approach, which engaged students with their prior knowledge before exposing them to the exercises. From the indications of informal students' comments that could explain the reason for the negative impacts, Riggs and Kimbrough (2002) commented that when applying the constructivist approach for ES with students with a weak background, it is suggested 1) to ensure enough time was spent on each topical exercise for deep learning and real understanding, 2) to ensure the pedagogies were introduced and interpreted thoroughly as some may be unfamiliar with the concepts, and 3) to provide individual homework after in-class group activities to help weaker students overcome difficulties. Lee and Fortner (2003) presented their research where constructivist-based learning was incorporated into the ES curriculum through hands-on activities, and successfully promoted students' understanding and knowledge acquisition.

Semken (2005) envisaged a bright future with place-based education for ES for indigenous students in America and Alaska, since place is central to indigenous ways of knowing. He commented that “place-based geoscience could potentially enhance science literacy” for minorities, and “bring more of them into the Earth science profession” (Semken, 2005). Studies have shown that indigenous students tend to approach scientific questions through observations and reflections based on casual questions (Beck et al., 1996; Cajete, 2000). Semken (2005) further commented that Native education systems often have a stronger focus on local places, cultural knowledge and community linked activities than mainstream teaching philosophies; however, the teaching philosophies do not have to be exclusive of each other.

Recently, Gosselin and his team presented three examples (from University of Utah, Metropolitan State University and West Chester University) of incorporating ES with environment, sustainability and society at the undergraduate level using the place-based method in 2015. Their results demonstrate that place-based learning is helpful at merging ES topics to other disciplines (Gosselin et al., 2016). Each example used a different approach to present ES concepts relating to the particular challenge to the local area. All examples supported that place-based learning helped students apply classroom knowledge to their lives. Gosselin (2016) and his colleagues concluded that place-based settings are extremely useful at building problem-solving skills when ES is taught under other contexts such as economy, society, community and policies, since it facilitates critical thinking, questioning, reflections and knowledge and skills acquisition. The three examples are summarized below (Gosselin et al., 2016):

A course at the University of Utah titled ‘Hydrotopia’ emphasized sustainability and water resources (Gosselin et al., 2015). Water resource engineering and ES were taught together with other social and political science disciplines by an interdisciplinary instructing team. Students (30 per enrollment) from upper level undergraduate to entry level graduate with diverse discipline backgrounds (both STEM and non-STEM) were required to work together to explore the connection between ‘water’ and ‘place’ while looking at local issues regarding water management. The aim of the course was to articulate the responsibilities of planning and managing water resources and the importance to society. Topics centered around the supply of clean water while protecting the natural environment. The instructing team used a combination of traditional lecturing, group discussion (e.g. position papers), activities (peer teaching), project-based (e.g. team exercise on selected environmental issues) and problem-based learning modules (e.g. water neutrality problem). The course was highly focused on local place-based themes such as the Colorado River Basin and Salt Lake City Metropolitan Area. Field trips and guest speakers were incorporated to enhance understanding. The course assessment included assignments, discussions and the team project. The evaluation of the initial offering of the course led instructors to exert greater emphasis on subtopics of ES as well as systematic thinking. The students demonstrated consolidated understanding of the place-based water issue and its broader interconnections, and acknowledged fundamental knowledge in hydrology to be necessary to expand their understanding across disciplines. The course was complimented as an overall success for students to use ES knowledge and datasets to solve local water managing issues. Future recommendations include more extensive interaction with practicing geoscientists.

At West Chester University in Pennsylvania, the course Humans and the Environment (ESS102) in the education program, included 32 mainly lower level undergraduate students (Gosselin et al., 2015). The course discussed human survival, limited planetary resources, and recycling capacity of the Earth in an interdisciplinary manner, with a primary focus on cybernetic thinking (organization, communication and control of systems) and sustainability. The course goals are to improve critical and analytical thinking about 'system', thinking across disciplines, and ethical decision-making. The course ultimately aims to change students' existing worldview of current sustainable actions to those that are in pace with humans' consumption rate and our impact on nature. In terms of pedagogy, the instructors paid close attention to interdisciplinarity and place-based education. The course articulates that disciplines are artificial constructs that are informative and convenient for studying, but should be viewed as a part of the system. It is important to admit and realize that each component interacts with others. The place-based experience focused on outdoor fieldtrips. While one class was about walking in the upland areas near a watershed, discussing interconnected natural components and resulting topography, another was in an urbanized area of the campus, illustrating man-built areas and human relationships with nature. Learning outcomes were assessed through end-course surveys. Results indicated that the majority (>90%) of the students agreed that the course enhanced their abilities and over half of the group scored ideal marks on demonstrating capabilities of interdisciplinary thinking, supporting a place-based, systematic pedagogy.

Metropolitan State University has a complex student body of non-traditional age students (Gosselin et al., 2015). The course, "People and the Environment" looked at basic structure of the Earth system, human institutions and their influence on nature, access to resources and scientific understanding of environmental issues (and linkages to students' hometowns). The key theme was sustainability highlighting possible solutions to local environmental issues. The place-based approach to ES introduced issues that were either very local, or related to Saint Paul or Minneapolis and the Upper Midwest. The class had three broad concerns regarding agriculture, mining and watershed management, enriching students' understanding of complex issues. This setting impressed the non-traditional age learners who sought to apply their learning in real world practices. Traditional lectures, documentaries, open-ended laboratory exercises and fieldwork were adopted in teaching. Such a versatile format culminated in student recognition of the complexity of various industries and systems (groundwater, agriculture). Assessment of the class took the format of qualitative course evaluations. Overall, the majority of students' comments showed a positive engagement with course content due to how the fieldtrips and learning were very local, relevant and practical. Student comments indicated appreciation of locality relevant content and practical examples, and many students noted a change in attitude towards environmental problems, and related topics to their homeland.

In all, these examples support that place-based learning facilitates students' critical thinking ability, motivates them through local, social and scientific engagement and helps connect learning to real world practices. Students enjoyed the outdoor opportunities that make their skills applicable. Place-based learning was optimized through careful planning. In addition, it is important to know the student audience. Each of the examples above had very different students with different backgrounds, which influenced their expectations (learning objectives), and determined the nature of the experiences. Therefore, educators need to be mindful of the background of the student body and particular learning goals when adopting place-based pedagogy. Lastly, the importance of system thinking and the requirement of interdisciplinary solutions to environmental issues were consistently revealed in all cases.

Chapter 3 Methodology

3.1 Safety of Research: Ethics Review

The data collection of this case study was preceded by the completion of an ethics review representing the permission of the Office of Research Ethics at Simon Fraser University. The initial documents included the completed application form, a study checklist, a study details document, consent letters for students and instructors, a list of research instruments, a recruitment script, Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2 Core): Completion Certificate, and the first version of Merging Earth Science with Environmental Education Survey (MESEES). After refinements were made according to the first provisos, a minimal risk approval was delegated on April.18th. 2018. Neither the funding source nor the research procedures had been changed for the second pilot. The annual renewal for the study was approved by an authorized delegated reviewer on March.13th.2019.

3.2 Instruments Adopted for Research Approaches

3.2.1 Overview of Instruments

To evaluate the effectiveness of EDU452 and the applied learning models, multiple instruments were adopted to collect data. The research questions were approached from three perspectives: the observer (researcher), the students, and the instructors. Forms of data include 1. researcher's field reflections during both pilots of EDU452, 2. students' informal interviews, 3. instructors' debrief meetings, 4. focus-group interviews, 5. course evaluations, 6. students' final portfolios, 7. pre- and post-course interviews of all instructors (Appendix D), and finally, 8. pre- and post-class MESEES (Appendix A). The first three data forms were collected repeatedly over successive periods of time as formative assessments to acquire immediate feedback on teaching in a "step-by-step" manner, while forms 4 to 6 were collected upon the completion of each pilot as course assessments. The last two forms were collected before and after the entire span of EDU452 with a pre- and post- design to measure the impact of the whole course. The PLACES instrument was also used to gauge student perceptions on the learning environment, yet it was outside of the scope of this research and therefore the results are neither presented nor discussed here. All data were collected for both pilots. Data from the 2018 pilot was analyzed and considered towards the revision of the course for the 2019 pilot. Note that due to the small sample size, a mixed methods approach to triangulating the quantitative data was used. Student comments were used to substantiate trends or patterns made apparent in the survey data.

Table 3.2.1 Summary of data used for the two research questions, their source and time collected. 1 - data used for the 1st research question 2 - data used for the 2nd research question
*** - data used for both**
LA - learning attitude LI - Learning interest CT - Confidence in Teaching BK - background knowledge EE - Effectiveness of EDU452 PE - pedagogy of EDU452 AE - activities of EDU452

Data Source	**In-Course Data**	**Pre-Course Data**	**Post-Course Data**
Researcher	Field Reflections* (knowledge[1], connection between ES&EE[1], the CARE framework[1], pedagogy[2], Learning environment*)	N/A	N/A
Students	Informal interviews*	Pre-course MESEES[1] (LA[1], LI[1], CT[1], BK[1])	Post-course MESEES* (LA[1], LI[1], CT[1], BK[1], EE[2], PE[2], AE[2]) SFU Course Evaluations for EDU452[1] Focus group interview* Final Portfolios*
Instructors	Instructors' Debrief Meetings*	Pre-course Instructor Interview[2]	Post-course Instructor Interview[2]

While data from the students' perspective and the observer's perspective would focus on the effectiveness of the course (research Q1), data from the instructors' perspective focuses on the pedagogy and learning environment of EDU452 (research

Q2). During the data analysis process, all data were categorized according to which question they were supposed to answer (Table 3.2.1).

3.2.2 Data Format and Details

Researcher's Reflections

The researcher was not involved in the development of the course, but was responsible for observing and reflecting during class. The field reflections were written real-time during classes to record student behaviours, quotes or evidence that provide insights on the class performance. The reflections were analyzed under ES knowledge, connection between ES & EE, the CARE framework, pedagogies and learning environment (Appendix E).

Researcher's field notes represent data sourced from an individual who was neither a developer nor a participant in EDU452. However, the researcher brings his own background and perceptions, and therefore could not be considered completely objective. The purpose of including these notes in this study is to triangulate with information sourced from students and teachers to produce most robust conclusions. This analysis sought to determine whether EDU452 interconnected both fields under a well-organized framework, and whether the three learning models adopted contributed to the incorporation in a supportive learning environment that promoted student engagement.

Guided Informal Interviews

Guided informal interviews took place at the end of every ES involved module (i.e. 1, 2 & 4). These were short conversations between the researcher and a pair or a group of three students under an "interview guide approach" (Patton, 1990, p. 288), using 8 pre-determined guiding questions. The questions centered around the knowledge gained, the incorporation of ES content and its role to EE, the three pedagogies, activities and recommendations. The interviews employed a repeated design measure that asked all participants the same set of questions in all interviews.

The interviewer retained the freedom of sequencing and wording the questions, and encouraged students to reinforce their assertions using personal experience. Although the researcher arbitrarily selected participants, each student may participate once for a balance in opinion. All participants were encouraged to speak.

Two interviews were carried out for each ES merged module, making a total of 6 informal interviews per pilot. The interviewees were arbitrarily selected by the researcher, but a student may participate in the informal interviews once. This was to keep a balance of opinion. While the first 4 interviews of the 2018 pilot each had 3 participants, the number of participants per interviews reduced to 2 for the rest. The reason for this reduction was to acquire more personal focused answers under less influence of other members of the group. A total of 28 participants were interviewed across two years. The average time for an informal interview was approximately 10 minutes. These interviews took place when the learning activities were still fresh in students' minds to accurately represent a "weekly standing/feeling" as the course developed.

Instructors' Debrief Meetings

After every ES involved module, all three instructors had a meeting to debrief the situation and their thoughts on student reactions to the activities and pedagogy. The notes taken by the researcher during these meetings helped check whether the feedback from the instructors agrees with the data from students' perspective. This was also a good opportunity for the instructors to share insights on the incorporation of class content and compatibility of pedagogies for each module, and modify their plans for upcoming topics.

Focus Group Interviews

At the end of each pilot, students were invited to participate in the focus group interview. These two end-of-term interviews were "standardized open-ended interviews" (Patton, 1990, p. 289) with 11 pre-determined questions that had a fixed wording and sequence. They were designed to closely represent the measures of MESEES including the learning attitude, learning interest, confidence in teaching, effectiveness of each pedagogy and activities, but also three extra questions on the manner of incorporation, learning environment, and future suggestions. The questions were phrased to promote short answer responses for students to expand their explanation, and focused on exchange of ideas between participants (Appendix C).

All students were welcome to voluntarily participate in the focus group interview, including those who have participated in the informal interviews. The sample size was 10 for 2018 and 7 for 2019. The researcher prepared the same set of questions for both interviews and facilitated discussion during the process. These approximately 20-30-minute interviews provided useful in-depth information on the reasons for some patterns observed on the MESEES, and summarized the overall impression towards the whole course.

Course Evaluations

Students were asked to individually complete a course evaluation upon completion of EDU452. The evaluation requires each student to address the strongest and weakest point of the course and their recommendations for future adjustments. Only the information that was relevant to ES will be mentioned in this study. This data takes a concise format that emphasized the most remarkable features of the incorporation of ES as well as recognizes any underlying problems in such an interdisciplinary curriculum from a student's point of view.

Students' Final Portfolios

The final portfolio is a mandatory end-course project that is meant to reflect students' overall learning from "personal," "professional" and "philosophical" perspectives. According to the course curriculum, students would share self-designed writings, artifacts, lessons, etc. during the last module of the course to demonstrate their learning and development of conceptual frameworks for EE (Appendix B). The portfolio leaves freedom of format of expression to students, and also provides a good opportunity for them to illustrate recognition of the ES content and its relevance to EE. For each pilot, the number of ES involved portfolios was recorded. While pictures and notes are taken for most portfolios, the focus will be on the ones that touched on ES. The evaluation is based on the depth of ES knowledge, the extent of incorporation, development of personal relevance and students' teaching career.

Instructors Interviews

To examine the process of incorporating ES, and the influence of the learning models from the instructors' perspective, "standarized open-ended format" (Patton, 1990, p. 289) pre-course and post-course instructor interviews were employed. The instructors were interviewed individually before and after the first pilot, and again after the second pilot. Each interviewee was asked the same set of questions during the interviews. The instructors were not provided with each other's answers until (s)he had finished the questions to avoid bias (Appendix D). The results were shared on completion of the pilot, and follow-up meetings of the research committee were conducted for further discussion.

The post-course interviews contained different questions from the pre-course interviews as they served distinct purposes. The first interview (2018 pre-course) helped clarify roles and specialties of each instructor in EDU452 (Appendix D). It addressed the basic information of the course as well as the instructors' current standing on the prospect of ES incorporation. The second interview (2018 post-course & 2019 pre-course) sought feedback on the performance of the first pilot and possibilities for further refinements (Appendix D). As part of the case study, reviewing the first two interviews contributed to modifications for pilot 2 (e.g. synchronizing yet maintaining the contrast between the pedagogies). It also allowed for decision making on changing locations and adjusting activities. The last interview (2019 post-course) aimed to acquire feedback on the performance of the second pilot, the influence of this incorporation, level of satisfaction with the learning models, and some perspectives on this interdisciplinary experience (Appendix D).

MESEES

The MESEES survey, designed by the researcher in a "pre- and post- design" format, touched on multiple facets of EDU452 from a student perspective with an emphasis on the ES incorporation. The pre-survey consisted of 4 measures with a total of 24 items addressing: learning attitude, learning interest, confidence in teaching ES, and background knowledge. The post-survey of 41 items included all sections from pre-survey for comparison, and additional 3 measures on the effectiveness, pedagogy, and activities of EDU452. All measures were additive, and therefore included items related to various aspects (e.g. EE, field experience, community etc.) with an emphasis on ES. All items were phrased positively, with one exception, to cross-check and ascertain whether students were paying attention while filling out the surveys. The sample size was 27 for

2018 and 24 for 2019. The MESEES serve as a quantified data-set gauging both the change in various aspects of student perspective and the end-result of the course.

Validity of MESEES is determined from response process validity (Furr & Bacharach, 2014) and content validity (AREA, 2014). Response process validity is determined by triangulating between the survey results and focus group interview results (i.e. do the interview results agree with, support and explain the pattern observed from MESEES), as the interviews were designed to seek more in-depth answers to each measure in a concise conversational manner. The participants who filled out the surveys were considered as "untrained judges", interviewing them sheds light on whether the items were interpreted the way they were phrased. Content validity has been gathered from expert reviews of the research committee and an external advisor (Laura D'Amico, a current research associate at The Institute for the Study of Teaching and Learning in the Disciplines (ISTLD) of SFU). Statistical validations (i.e. internal structure validity; p-test) (Furr & Bacharach, 2014) are not applicable to this research given the small sample size.

The Update of MESEES

Updating MESEES (once called "Earth Science Learning in Environmental Education Survey" (ESLEES)) to version II after the first pilot benefited the action research by providing a more accurate representation of student experience. Version I was updated based on the item correlation and conceptual review. Since MESEES was constructed under an additive items design, Cronbach's alpha coefficient for internal consistency would not be a viable test. The purpose of the updating process was to better organize the items into the "suitable" measure, clarify possible confusion with minor grammatical rewording, while not changing the meaning or objective of the questionnaire. Although statistics were adopted as a tool for problem identification and reconfirmation, the driving force of the update was mainly the conceptual review.

The update review results manifested that some questions may be misplaced under measures while some should be rephrased. All item arrays were correlated to their average array of each measure. Any items with correlations below the average correlation value were reviewed. This method was meant to identify items that were suspected to be unfit to the measure, not necessarily implying a problem with the item.

The suspected items (Questions referring to Version I) have been addressed in one of the following three ways: 1) moved if the questions was more suitable to a different measure (Q8 & Q11 moved to the learning attitude measure; Q12 moved to the learning interest measure), 2) rephrased if the conceptual review suggested possible confusion caused by wording (Q9 & Q11). 3) unchanged if the reasons to low correlations are irrelevant to wording. After all filtered questions had been processed, the whole survey would be reviewed again for grammatical corrections and minor rewording. No meaning of the questions would be altered in all cases, because the questionnaires needed to have the same objective to maintain the ability for comparison across the two pilots. Lastly, a few questions were added to Version II for additional insights, yet excluded from the comparison.

Analysis of MESEES

The analysis of MESEES includes the comparison between pre- and post-course results and the triangulation to qualitative data. The items of the initial version (Version I) were reorganized according to the measures of newer version (Version II) for a uniform analysis across two years. Newly added questions in Version II would be discussed individually.

The analysis includes visual and numerical overviews of class results and detailed descriptions of the two pilots used to triangulate the quantitative findings. The surveys adopted the Likert response style of five options ranging from “strongly disagree” to “strongly agree,” which would score from 1 to 5 respectively (Likert, 1931). Given the phrasing, this research presumes that the distance between each option is essentially equal, and the space in between each option is also meaningful, and therefore treats these scales as if they were interval scales. This allowed the dataset to be analyzed as interval data, enabling the analysis of means. The class mean of each measure was calculated for an overall estimation of the results (i.e. optimal value = 5). The frequency response tables for each measure were illustrated in the form of distributional diagrams for a more detailed contrast between pre-course and post-course results. The background knowledge measure had a “true & false & unsure” format that was analyzed separately. To clarify this, the percentage of correctness, misconception and unsureness was calculated using the count for each option divided by the total input, and the percentages were compared across the pre- and post-surveys.

3.3 Weekly Themes and Activities

3.3.1 Module 1: Education 'In' 'For' and 'About' Environment

Orientation

The class was separated into 2 ES groups and 1 EE group at the beginning of the day. The first two groups focused on rocks and landscape, the third on plant identification. The three groups switched halfway through the hike. The first module ran in a student-centered way, which means the instructors merely drew attention to objects, asked leading questions and supported with hints, while students drew conclusions themselves. The instructors' role was not to tell, but to promote interest and critical thinking.

Earth Science Field Methodologies

The theme of the first module is recognizing locality as part of the Earth system through the CARE approach (Complexity, Aesthetics, Responsibility and Ethics) (BC Ministry of Education, 2007; Stratton et al., 2015). In this module, ES was introduced with environment through the Burnaby Mountain Interpretive hike on its north face down towards Burrard Inlet. Before the hike began, Dr. van der Flier-Keller and Mr. Cameron demonstrated how to locate ourselves using a contemporary ES tool, the Light Detection and Ranging (LIDAR). This technology helped address the significance of mapping to geologists and encouraged conversations that connect personal experience of exposure

Figure 3.3.1 Earth Science instructors are explaining geological features at outcrops.

to other ES related technology.

Till, Outcrop and Scarp

When zoomed in to a small-scale aerial map in LIDAR, the students were able to locate themselves and notice on the map interesting features such as landslides and scarps. This evoked questions like “why are these features here?” and “how were they formed?” and further introduced the necessity of field observation in a geological exploration (Fig. 3.3.1). Along the hike, till outcrops and Eocene sedimentary strata were discovered. These outcrop features not only prompted further inquiries but also were puzzles to the entire geological history of the locality. By leading students through guided inquiry and discussions, the hike helped students to experience what it is like to be a field geologist.

Slope

Hands-on activities were conducted to help solve inquiries and understand formation of features. Some students realized that there was no building construction on the North face of Burnaby Mountain (the scarp side), but could not explain why the mountain was asymmetrical. Eventually, they discovered the answers from measuring slope and bedding dip angle (Fig. 3.3.1 & 3.3.2). Sometimes, these simple activities were prompted by a hint from the instructor, such as “what is that linear feature between

Figure 3.3.2 Instructors and students are investigating an erratic (left), the difference between dip angles of sediments underwater (~18º) and in air (~35º) (middle), and past landslide features (right).

rock formations?" or "how would you tell how steep it is" Such open-ended questions promoted students to devise their own simple experiments like using protractors and applications on phones. Hypothesis development and critical thinking commonly accompanied activities in student discussion. From field observations to inquiries, experiments and explanations, the hike mimicked as much as feasible a scientific research process.

Geological History

To show that knowledge in ES is related and relevant to locality, instructors' questions implicitly guided the students to depict the whole picture of the geological history and geomorphology of the locality by connecting answers acquired along the way. For instance, the paleoenvironment for sediment deposition could be inferred by investigating the dip angles of a cross bedding (Fig. 3.3.2). ES information together with knowledge from EE led to the discovery of past landslides, forest fire, logging, slope stability problems and eventually the Quaternary and Eocene geological history of Burnaby Mountain.

Environmental Artifact Activity: Establishing a Healthy Learning Environment

Everyone brought an environmental artifact of their choice, and shared a personal story related to the artifact. Some were cheerful and exciting, while others were sorrowful or thoughtful. This activity was extremely powerful at creating an ideal learning environment by "ice breaking" between the students, especially when done in the first module. A healthy learning environment where all students were comfortable to approach and communicate with each other was critical for the innovative pedagogies to function.

The CARE framework

The leading questions that were central to the hike were organized according to the CARE framework and were provided to the students in advance. Sample questions in each category included the following:

Complexity: What are the characteristics of this system?

Aesthetics: How does this place make you feel? What are some things you find beautiful, pleasing or unique here?

Responsibility: How do humans interact with the environment? What are some potential long-term environmental concerns about Burnaby Mountain?

Ethics: What might the ethical issues be for economic growth and sustainable development in this place?

The objective is to let students explore and realize through guided inquiries that the locality is complicated because of interrelated physical and ecological features, dynamics, and interactions with human activities. It is also pleasing for us to study this mysterious place. The north side of Burnaby Mountain has an image of “a secret park” that is hiding near our society. It is so close to the campus, yet with seldom seen hikers, seems to be remote. The responsibilities of environmental concerns and social issues raised ethical debates regarding, for instance, the conflict between economy and sustainability.

Changes for the 2019 Pilot

The changes to Module 1 were based on the feedback on the 2018 pilot students’ and instructors’ interviews. In short, the instructing team decided to revamp the schedule and group management for 2019 to address critiques on organization of the previous pilot. This time the class was divided into 2 even groups. While one group was introduced to ES first, the other was exposed to botanical knowledge as a part of EE. Halfway through the hike, the 2 groups switched instructors. Dr. van der Flier-Keller and Mr. Cameron cooperated to lead the ES group. In the afternoon, water quality content was added to the EE side of the course for a better linkage to water resources for the second module. This setting also allowed for a more focused observation on the different reactions among groups, as the class was less segregated, and all students experienced both aspects as equally as possible.

3.3.2 Module 2: Managing A Slippery Resource

Recalling and Observing

Mr. Cameron began his introduction with a recalling activity to develop connections to the previous module. He prompted the students to notice any difference of land features between Lynn Canyon and Burnaby Mountain, and purposefully emphasized the agents of erosion and deposition. The connection offered by the recalling process allowed the instructor to suggest key terminologies to understand the local topography, which helped prepare for the inquiry process. Thought sharing subsequently drew out interest in the shape of the valley, the flow of the river and the tectonic setting in western British Columbia. All discussions eventually led to “what is the reason for Lynn Canyon’s topography being so different from Burnaby Mountain?” Reviewing the rocks’ different resistance to erosion and the influences of the depositional agents, students were able to point out that Lynn valley was probably a result of river erosion and deposition on weathered bedrock. The key for continuing learning under the constructivist framework is to always discover the correlations for recapturing previous information.

Developing A Formula for Discharge

Since erosion and deposition by water contributed to the formation of the local landscape, understanding the dynamics of how the river changed through the field area was important. The activity involved discovering the relationship between flow speed, cross-sectional area, discharge and carrying capacity (Fig. 3.3.3). The students received a short introduction to key features at 3 observational spots along the river: on a cliff above the narrow stream, next to a turning wide channel, and close to an island in the middle of the river. They were then dispersed as 5 groups of 6 for exploration. The instructors did not follow a particular group, so students relied on their abilities for planning inquiries and problem solving. Most students realized that flow speed is related to the width and depth of the channel. They then concluded that the cross-sectional area of the river is inversely proportional to the flow speed, and the total discharge, which varies at different locations, is equal to the product of cross-sectional area and flow speed. The larger the discharge, the greater the carrying capacity.

Finding Supporting Evidences

As a follow-up activity to the hypothesis, students were required to discover evidence to help them figure out the relationship between variables for constructing the flow velocity formula and design their own activities for proof. Some discovered an increase in rounding and a decrease in grain size downstream. This indicated that the

Figure 3.3.3 Developing a formula for discharge (left), an erratic, and a discussion on the connection between ES and EE.

river has a higher carrying capacity for smaller particles, and the more eroded a rock is, the longer the distance it has been travelled. Very large boulders that seemed to exceed the maximum carrying capacity of water, could only be deposited by glaciers. Near the station of the island, a group of students found some undercuts and exposed tree-roots as indications of past flooding and erosional events. These discoveries helped to depict the history of the island by changes in discharge.

Interview with A Rock

The “Interview with a Rock Activity” required students to arbitrarily select a rock and propose questions as though interviewing a “celebrity.” There were no criteria on what was to be asked, and the answers could be artistic or scientific. The point of this exercise was to simulate how geologists identify and categorize rocks through a creative thinking process. For example, questions regarding names could help suggest how a rock might have formed, and questions regarding ages could be connected to absolute dating. This activity conveyed a message that “you do not need to be specialized to discuss geology. That’s how accessible and ubiquitous it is” (Personal Communication with Cameron, 2018).

From Environmental Education Discussions to Earth Science

EE discussions were often found to help link to ES concepts in a place-based setting (Fig.3.3.3). After identifying red alders on an island, students referred to the characteristics of pioneer species and inferred that the island was barren or completely covered by water fairly recently. Place-based learning in Lynn Canyon makes EE inseparable from ES. For example, since cedars grow near streams and streams always flow downhill, hikers look for cedars to find their way down the mountain. As flowing speed decreases, channel width and rock rounding increases as rivers exit valleys and enter plains. This connection is commonly used for survival in mountainous areas. When Dr. Zandvliet asked the class to name the “oldest plant” in the locality, he mentioned there were 3 theoretical answers. Looking at genetics, moss was the most primitive species, and therefore could be the oldest. Likewise, if the answer was based on thickness or the depth of roots, then red cedar and salmon berry would be the best answers. Similarly, multiple or even contradictory conclusions could be drawn in ES depending on evidences and localities, and this discussion demonstrated very well how “place” is vital to both subjects.

Project Wet Activity

The last activity of the day highlighted the Water Management theme. This class activity demonstrated the scarcity of accessible drinking water in the world. Dr. Zandvliet used 1 liter of tap water to represent all water content on the Earth, and sequentially narrowed down its quantity to total freshwater (~3%), non-frozen freshwater (~1%), groundwater (0.6%), unpolluted, surface drinking water directly accessible to use (0.003%) at each pouring stage (Worsley, 2014). All students were stunned realizing there was only 0.003% of potable water readily available to use.

The CARE Framework

The CARE framework was reiterated in this module and inquiries included:

Complexity: What features do you see that are fascinating and puzzling in this locality (i.e. water / ice as agents of deposition; size & rounding of particles; volume, velocity & discharge of water)?

Aesthetics: What do you see that's magnificent or exciting about this place?

Responsibility: How would tourism, deforestation, landslides influence Lynn Valley?

Ethics: What should we do for a smart water management (i.e. quality & usage)?

The instructing team used questions relating to "complexity" and "aesthetics" of the "CARE Framework" to initiate inquiry learning, and "responsibility" and "ethics" for critical thinking and reflections. Together, these overarching questions wove together the theme of water management.

Changes for the 2019 Pilot

To encourage discussion and knowledge sharing between students with diverse background within groups, the class was divided into 3 groups of 8 for this pilot. The instructor no longer provided introduction at each designated location but instead provided overarching questions and hinted at some key features, making the experience more open-ended. Students were also encouraged to raise extra questions on the way back. Mr. Cameron debriefed with the class in a student-led manner. Each group would share what they had discovered, and additional questions or concerns were further addressed. Then, Mr. Cameron would share additional information and insights.

3.3.3 Module 4: Land Use Issues – Living with What We Have

Recalling and Observing

The incorporation of ES at Deas Island focused on the human influences on natural environments. The students were asked to notice some features of Deas Island that were different from previous localities to link their learning to other modules. Dr. van der Flier-Keller directed the class to the physical characteristics of the system and some evidence of human interventions on the ecosystem. She further questioned "is the system static or dynamic, and what are some examples of this?" Based on erosional features and topography, students hypothesized that Deas Island is a flat area in the middle of a meandering river and probably is very dynamic. Dr. van der Flier-Keller then associated this hypothesis to the "big picture" with questions such as "where is Deas located in Greater Vancouver and how would this dynamic system tell us about what happened to Vancouver in the past?" Beyond that, how can humans effectively and safely use this land? These critical questions shaped the ensuing discussions and activities.

Resource-Product Pairing Activity

As the interaction between natural systems and humans became the center of the discussion, Dr. van der Flier-Keller introduced the Resource-Product Pairing Activity (Fig. 3.3.4). The class was divided into 3 groups of 9, each with a set of materials. These

Figure 3.3.4 Materials (left) and discussion on Resource-Product Pairing Activity.

materials included minerals, rocks and their relevant products or usages. For example, quartz is the mineral used to make glass. Similarly, oil shale is the source material for a plastic bottle and other synthetic packaging. Students were required to couple the materials based on common sense. Dr. van der Flier-Keller offered clues to suggest connections when a group was confused. After 3 rotations, students coupled all materials and voluntarily debriefed on their learning. Mr. Cameron described how closely the foundations of our society are based on non-renewable resources from mining and the petroleum industry. This activity related what is seemingly remote to our lives, to 'stuff' people rely on every day, sending a message to students that "geology is right next to you."

Coring Activity

In the afternoon, Mr. Cameron and Dr. van der Flier-Keller demonstrated the procedures for using soil samplers to perform simple coring (Fig. 3.3.5). Coring is one of

Figure 3.3.5 Field guidance (left) and analysis of sedimentary layers in Coring Activity.

the most commonly used procedures in the petroleum industry and Quaternary geology to understand underground lithology and morphology. Soil samplers are hands-on, learner-friendly, and close representations of industrial corers. The instructing team aimed for students to describe the paleoenvironment and present-day local landform through strata interpretations. Students were again separated into 3 groups, and each group would arbitrarily select a location on the island to core. One group coring at the western "tip" of the island observed interbedded sand and mud layers. The other two groups cored in the middle of the island, where they acquired some dry sand sequences. With the three cores, the class discussed how Deas Island was formed and changed as a result of deposition, undercutting and migration. The coring activity provided the first chance for many students to consider what is underground. It was about opening another door for those who have never viewed the world through the lens of ES.

The CARE Framework

A list of core questions for the CARE framework for this module are:

Complexity: What are the characteristics of this system and how is it different from Lynn Canyon? What is the evidence of natural processes influencing this Delta system (i.e. physical aspects of the system are dynamic)?

Aesthetics: How does this make you feel? What do you find beautiful/ unique/ humbling here (i.e. slow-flowing river, grassy flat land)?

Responsibility: what are some human influences and future issues or concerns associated with the natural environment here?

Ethics: What do you feel about the tension between economic growth (i.e. urbanization, infrastructures) and land preservation for this locality?

Further detailed questions such as “Why is there a dyke and why did people build a tunnel instead of a bridge?” “Can EE be politically charged?” and “What might our decisions in future bring to the ecosystem?” facilitated critical thinking.

Figure 3.3.6 The debrief at Iona Beach (left) and a student digging a hole to investigate sediments in an intertidal zone (right).

Changes for the 2019 Pilot

The changes for the 2019 pilot aimed to emphasize 1) some background information on the geology of Greater Vancouver, 2) local natural hazards such as liquefaction and earthquakes and 3) the blurred boundary between nature and city. Before this module, the researcher was invited as a guest speaker to introduce the western Canadian

Cordilleran geology, the geological time scale and Vancouver's geological hazards to the class. The purpose was to set the stage for the "land use" module by supporting the students with more ES background. The presentation included a series of visuals and conversations with the class, not a one-way delivery format.

The module was moved to Iona Beach in western Richmond. This location closely relates to the end of the delta system near Deas Island, but with a longer coastline that is less artificially disturbed. The class was divided into 2 groups of 12 students, and each group was assigned to pair 10 products to their natural resources. Four samples related to building construction and camping uses were added for a strong connection to society (countertops, facing stones, lava rocks etc.). An additional stage Mr. Cameron added during the debrief was to have the class separate the samples into "confirmed, unsure and unknown" piles. A follow-up inquiry was facilitated for each pile. Asking students "why are you sure or unsure about your conclusion" and "what are some other possibilities you see here" simulates the process of having additional hypotheses and

Figure 3.3.7 Before (left) and after (right) the simulation of an earthquake. The impact of liquefaction is obvious.

approaching research questions from various perspectives. The groups switched after the debrief so that each student got to see all samples.

"Simulating Liquefaction Activity" was added for extra visuals and engagement for the natural hazard theme. The class was led to an intertidal zone. Mr. Cameron first wanted students to dig a hole using shovels and observe what is underneath their feet (Fig. 3.3.6). Emphasis was on the saturation and change in grainsize of the sediments. Next, he required students to jump continuously on the supporting muddy land. Many soon found themselves sinking into the ground, experiencing a "mini-version" of liquefaction with their feet. Grabbing a handful of sand, Mr. Cameron explained, "when water content is present in sandy or muddy beds, it helps with the cohesion between grains. But with excessive water and disturbance, the grains will lose contact with each other and start to slide." Such disturbance can be triggered by, for instance, an earthquake. The class was again divided equally into 2 groups, each with a bucket, some woodblocks, empty water bottles, ping-pong balls and chopsticks. Students were asked to fill the bucket with local sediments, typical for Richmond and Delta, and shape the surface to form a topography. The objects representing buildings and other infrastructure features were then placed on top or just under the surface of the sediments. An earthquake event was simulated by knocking the bucket on the side with a soft mallet (Fig. 3.3.7). During an earthquake, unconsolidated water-saturated sediments behave like a fluid and "flow" whereby the water separates from the sediment and rises causing the surface to fail. The debriefing for ES activities for this pilot took a student-led approach, making information more practical, more cross-curricular, and less in-depth and overwhelming. The debriefing was visual and discussion-based.

In the afternoon, the class walked to the end of the jetty and debriefed on the relationship between nature and city. The central debate was on "whether Vancouver is inside or outside of nature." The purpose of the liquefaction activity was to present a powerful visual that ties the geological setting to our lives: humans establish civilization in nature and segregating from this linkage is impossible.

Chapter 4 Formative Evaluation

4.1 Summary of the Researcher's Field Reflections Regarding Earth Science in EDU452

This section provides a summary of the researcher's field reflections on all ES incorporated modules for 2018 and 2019. For detailed supporting evidence, observations and quotes, see Appendix E.

The introductory module functioned well as a "spotlight" on ES to engage the class. Fundamental ES knowledge such as plate tectonics, bedding, superposition, erosion, and slope stability were addressed. Most of the class recognized that ES and EE are reciprocal to each other. Many also had their first realization that nature is much more complex and interesting than they thought, e.g., that over 1km of ice existed over our current topography during the last glacial maximum; the travel of an erratic; and the 4.6-billion-year age of the Earth). Student responses and engagement indicated that fascinating ES features created a stronger interest towards nature. Local evidence of logging and the salmon hatchery led to critical thinking on humans' responsibility to nature and the importance of environmental ethics.

Inquiry learning worked well. The instructing team directed attention to interesting features and created suspense, thereby helping to facilitate student learning interest. The process was enhanced in 2019 through clarification of the purpose and definition of inquiry learning upfront. Students with stronger background in ES also helped to facilitate group conversations in 2019. Constructivism was widely accepted and took place through a "notice, ask, discuss and answer" process. Explanations were aided by analogies, hands-on activities and connection with relevant contemporary topics. Learning at the personal level may best be developed in place-based settings. Disassembling the formal classroom into small groups outdoors promoted teamwork and tied the science content to real life. The first module established a supportive learning environment by spending time sharing personal experience through interactive activities to enhance the group cohesiveness (e.g. The Environmental Artifact Activity).

“Managing a Slippery Resource” (Module 2) provided additional ES knowledge, and insights on incorporation of ES into EE. The class covered depositional and erosional features, carrying capacity of a river, past glaciation, as well as water management. Evidence of landslides and flooding demonstrated the relevance of ES. Many students realized the influence of geological factors on surrounding environments. Nature’s complexity was highlighted by the energy variations of the river and the diversity of the local rocks (i.e. the “Interview with a Rock” activity). Lynn Valley provided a dynamic location different from Burnaby Mountain. Given the scarcity of accessible drinkable water sources (which students learned about during the Project Wet activity), human responsibility and ethics around water management were discussed.

A recalling stage before the inquiry activities helped the learning process. Although many students acclimated to the observational process and demonstrated a preference for a more student-led, teacher-supported inquiry, some students occasionally were unsure about what to do or to focus on. An open-ended self-leading discovery could then be a double-edged sword, so careful design of overarching questions and background information are important for the experience. The constructivist process was found to help produce more inquiries and contribute to discussion during the debrief activity. Presenting real-world examples made ES concepts more straightforward to understand. Critical voice, open-endedness and shared control in a healthy learning environment were demonstrated when Dr. Zandvliet stepped back to facilitate communication and introduced debates from the side that was less supported (the unpopular view).

In the “Land Use Issues” module (Week 4), success in some respects was achieved, though there is room for improvement. Topics covered include non-renewable resources, lithology, physical characteristics of the delta, and potential natural hazards associated with a delta system, and basic concepts of coring. The connection between ES and EE was reiterated. For example, diatoms are often used as fossils in ES studies and a source of silica intake for scouring rushes. The Resources and Product Pairing activity was excellent to demonstrate the complexity and aesthetics of nature, as well as how dependent humans are on non-renewable resources. Discussions around energy, material consumption, and human intervention in nature helped improve awareness of social responsibility and development of ethics.

As more abstract concepts (e.g. 3D visualization, bedding and paleoenvironments) were introduced, students without a strong background in ES struggled to produce quality inquiries. The degree of guidance for inquiry learning must therefore be adjusted according to background understanding of individuals and the conceptual difficulty of the topics. Although in a few scenarios, students struggled with the process, constructivism continued to demonstrate its advantage at building understanding and autonomy in learning. Students expanded their knowledge construction using their five senses, stories and field evidence. Place-based learning in this module focused on developing the linkage between knowledge and places, appealing to personal memories, involving indigenous stories, and connecting with contemporary issues. ES-content incorporated curriculum was seen to be more relevant to the world around us. The 2019 pilot improvements included a shorter, more visual, student-driven and more place-based debrief compared with the long descriptive one in 2018.

4.2 Students' Informal Interviews

4.2.1 2018 Pilot

Module 1

The Content and Incorporation of Earth Science

All participant responses suggested that students learned a lot from the Burnaby Mountain hike, especially since most of them had little background in ES. Many of them mentioned about how startled they were to realize how little they knew about the place, and impressed by how much information they gained by the end of the hike. While some participants claimed that the conversations on the landscape and plants have left the strongest impression, others appreciated the chance to touch the sediment, ask questions, and perform simple experiments to test their hypotheses (e.g. depositional environment).

The participants from both groups agreed that ES is the foundation of the local environment after been exposed to illustrations of how it pertains to the larger framework of society, history and nature. A student noticed that most people seemed impatient in the beginning, but soon were captivated by the landscape and ecosystem. "People are usually not 'attentive' enough to care about details when there is a lack of acknowledgement that the locality is more complicated than they think," she said. Two participants confessed that they "were distracted in the beginning" and "had a hard time slowing down," but were finally able to "to stop for the geological sequence and its effect on the ecosystem" after the involvement in peer discussions. They commented that it was "valuable and interesting to see the layers and the giant rock (erratic)." Overall, the feedback indicated that the ES portion of the first module was eye-opening and very hands-on.

Pedagogy

All pedagogical approaches adopted for this module received positive feedback. Both groups enjoyed the inquiry process, and preferred having leading questions over pre-readings. An interviewee commented "you can only get so much from pre-readings, [but] you might connect to the readings more if you actually go out there and ask questions." Constructivism was described as a way of "feeling the Earth" and "helping reinforce knowledge." The importance of deduction was underlined by the "pistol-bottom tree" example. Some enjoyed how Dr. van der Flier-Keller promoted inquiries and thinking without being text intensive. Others enjoyed how Mr. Cameron reversed the constructivist process by "offering answers to raise more questions," so that more in-depth inquiries could be addressed from "on-spot" knowledge. Either way, guidance was important. Lastly, place-based learning was complimented by all participants.

Suggestions

The participants repeatedly asked for improvements in organization. One complained about the triple group switch halfway through the hike that led to one group having some repetition and missing other topics (e.g. some students had 2 ES sessions and no EE). Another added that the slow pace could also demotivate learning. The students suggested to either divide the class into 2 groups each with a "target subject focus," or to hike as a class with different instructors covering specific sections of the trail.

Module 2

The Content and Incorporation of Earth Science

The interviewees in general believed that the content was enriching. Many gained "geological language" and inference on "how materials and sediments were transported through a river system," "rock type, size, and sorting" and "formation, flow and width of a river channel." These helped explain the change in flow speed and the impressive topography at Lynn Canyon. The participants learned how to observe and think using scientific approaches from geological perspectives.

The connection between ES and EE was reiterated in this module. More than one participant originally believed that they were separate subjects, and that merging them together could be unnecessary or confusing. However, even the simplest questions such as "why do you think the environment appeared the way it is?" showed the benefit of interdisciplinary knowledge. Students emphasized that "you need ES to back up EE, [and] there is just so much overlap that you cannot ignore the interconnection."

Pedagogy

Unlike the previous module, inquiry learning became the center of debate in Module 2. Most participants noticed that the activities were inquiry based, but more open-ended. Students liked the short introductions at each station to offer a precise overview that quickly helped immerse learners in field experience, and being in control of the inquiry process. This was also the first time that voices advocating for frontloading (information beforehand; e.g. pre-readings) were heard. A participant envisaged that he would have enjoyed having more preparation before coming to the field. He further described his frustration as follows:

There was a gap between what I know and what I was trying to explain, and if pre-readings were provided, there could be more efficiency, more excitement, more tribute and more understanding, especially for students with no science background. Discussions afterward could help to fill in what was difficult [to understand], but some front loading would be good.

His partner then suggested having a reasonable amount of frontloading. While overwhelming pre-readings would take away from the lesson, no pre-readings could negatively affect the depth of inquiries. This student would like to be empowered so that at the beginning of the class, they “know what to look for, what to ask, where to explore,” and then advance to the investigation and critical thinking.

Constructivism was complimented for having “both structure and freedom.” They felt that “there was an ownership” when people “actively learn by themselves.” Some remarked that this self-challenging process of knowledge construction was quite enjoyable. Both groups asserted that seeing, and immersing themselves in, the real world is the most efficient way to learn, and that readings would be helpful but not indispensable. They were willing to mimic Dr. Zandvliet’s pedagogy, a combination of constructivism and place-based learning. Constructivism and place-based learning were widely accepted, and students had varied opinions on aspects of inquiry learning.

Suggestions

The interviewees believed that better selection of locality and design of on-the-spot guidance may further support peer discussion. Although the organization of the ES activities was rated higher than the last module, many participants recalled there were too many people on the narrow walkway, contributing to difficulties with getting to stations on time. Others could not properly hear or ask questions because of the loud sound of the river. The students in this module also suggested a reduction in the number of groups from 5 to 2, so that half of the class could self-explore while the other received instructions.

Module 4

The Content and Incorporation of Earth Science

The participants found the content of this module to be refreshing and interesting. One student commented that the Resource Product Pairing activity provided an opportunity to “dig into the Earth,” and “discover the products made from rocks.” Another shared some thoughts on how these activities contributed to a change in his learning attitude:

I used to not think too much about Earth science. I was only interested in environmental education. That was why I took the class, but after [doing the activities], I *started to realize that you can't really study one without the other. The contents were just so well-merged and necessary.*

Some also reported that the leading questions and geological maps were helpful at connecting subtopics to the greater geological setting, social and environmental aspects of Vancouver. Noticing more abstract topics "beneath the surface" (i.e. core analysis) were discussed, many students reflected on a steeper learning curve in this module. The debrief was generally considered to be lengthy and overwhelming, as too much complicated information on the geological history of the greater Vancouver area was introduced in a lecture format.

Pedagogy

The two interview pairs had very split opinions on pre-readings for this module. The first pair was comfortable with the current pedagogical approach, and claimed that too much theoretical content might take away from the experiential learning and demotivate students. The second pair demanded more pre-class preparation, and guidance during inquiries, because it was difficult to begin with "good inquiries" without some degree of preparation. They stressed that the instructors "jump in" when they realized a group can no longer handle it. A participant noted, "usually it is just a little bit of information you need to go a step further."

The participants reported various levels of frustrations during the constructivist process, but all understood the purpose of it. A participant noted that "although it was more of a personal problem," he had "nowhere to begin with," but he insisted on "figuring out the answers [himself]." Another enjoyed the constructivist process and was satisfied with a sense of accomplishment after consolidating their understanding. All participants demonstrated a strong interest in peer and student-teacher communication, and opposed simply memorizing verbalized knowledge from instructors.

Furthermore, some students brought up the importance of fairness or evenness in instruction between groups. Many students felt that they missed out on some information during the coring activity while others had an advantage of knowing "where and what to core." This resulted in part of the class feeling "left alone" with no expert leadership, which negatively impacted the experience.

Both groups commented that introducing ES topics that are specific to the locality linking them with social and ecological issues of the local community helped students to build personal ties to Deas Island. Everyone enjoyed the opportunity to learn in-place.

Suggestions

The organization was again reported to be the main problem. Some interviewees asserted that lunch time could be shortened to extend time for self-directed exploration. Lack of direction took away the momentum for studying, and group attention was also lost during the debrief activity. The students recommended better management of the class in large groups, to allow enough time to digest new information, and to have concise, discussion-based debriefs. Lastly, the instructors should start conversations after everyone's arrival, and include all groups to avoid having part of the class falling behind and not being able to catch up.

4.2.2 2019 Pilot

Module 1

The Content and Incorporation of Earth Science

The interviews of Module 1 indicated a successful introduction of ES, and also identified significant differences between learners in this EDU452 cohort. Although this was a group of students with very diverse backgrounds and levels of pre-existing understanding on ES, all participants articulated strong interest in learning ES.

The participants were impressed by different aspects of the content. One student liked how an introduction to native plants and their usage by indigenous people helped connect with topography, aspect, slope and depositional agents. "The coal seam stood out for me" he said, and "actually seeing landscapes carved out by erosion [was] pretty cool for me." His interview partner gained vocabularies of features at various scales including "sediments, clay, deposition, plate tectonics, continental and oceanic plate density."

Incorporation of ES content generated different opinions among the students. The first pair agreed that ES was useful, but did not feel a specific tie to EE. One of them said "I felt it was like talking about one thing and just continue to another." "Either show us how they are coming together or have us figure it out would be nice; otherwise it felt like jumping between things," his partner added. The hike felt slightly rushed to them, allowing little time for students to go back to previous topics. This resulted in separate discussions, leaving an image of "this is ES; this is EE." However, the second pair saw ES naturally fitting into EE. They pointed out that, "one success of the ES activities was that they didn't look like activities." The information "came out naturally" as the class was just "doing science," making the walk resemble "a chat" with a friend who knew a little more than the class. One student asserted that ES required knowledge but relied more on interpretation. Although ES was more abstract and required imagination for visualising three dimensions and processes, he sensed that the activities went hand in hand. "How can you teach environmental education when you don't have the knowledge of the natural world?" he concluded.

Pedagogy

The two interview pairs had contrasting opinions on inquiry learning. The first pair struggled a little during the inquiry process, but enjoyed how the activities were conducted. One of them "[saw] good use of kinesthetic learning," for example "when [we] learned about sediment deposition, getting a handful of dirt, dumping it out and actually measuring the angles familiarized [him] with the contrast between underwater and terrestrial deposition." The other followed up by addressing the significance of using the senses (e.g. seeing and touching). A student from the second pair, however, preferred more information beforehand for a richer experience: "if I had more knowledge I could have learned more from [asking] better questions." His interview partner commented that it was "well laid out" and appreciated "the opportunity to put in effort and figure it out [themselves]." He considered inquiry as "a useful skill to gain," but noted that, "still the answers matter in the end."

The interviewees also had distinct feedback on constructivism. While one student preferred active learning over learning from a textbook, his interview partner didn't mind both. They recommended experiencing upfront and leaving the option for further readings after class. In this order, learning interest would be maintained. They also highlighted how the process requires an effective debrief: "when you flipped the page and there are things you still don't understand, you'll need a debrief." The second pair described the constructivist process as "entertaining, peaceful and basic" for the botanical content, but “challenging” for sediments. They felt a frustration when they sensed the instructors “were holding back the answers.” To them, the “perfect scenario” was to have fair amount of on-the-spot guidance that interweaves experience with explanations, reaching a good balance between students’ deduction and teachers’ scaffolding.

All interviewees cherished the rare opportunity at the university level to experience and explore in ways people usually do in their childhood. The hike was effective because it brought knowledge to life in a way that is not possible in lecture halls.

Suggestions

The feedback indicated an improvement in organization with even the simple logistics well managed. Suggestions included that instructors give clear, optional pre-readings; that in terms of group management, instructors designate a switching spot to avoid groups having to backtrack; that “hooks” or leading questions could be offered to quickly engage the class at different outcrops; and that field booklets or identification charts should be provided for features examined on the hike.

Module 2

The Content and Incorporation of Earth Science

Just as in 2018, most participants enjoyed a deeper look into ES in this module. The first pair of interviewees were fascinated by “the broad strokes of geological theories” and “how they shed light on the formation of Lynn Valley.” Focusing in on place-relevant topics such as “water resource management and occurrence of ice ages” was a bonus. “Rocks and change in flow along various sections of the river” was more impressive to the second interview pair. In all, the module helped learners to observe a place through the lens of geological events, switching the commonly adopted biological perspective to a geological one.

The incorporation of ES was seen by all interviewees as a theoretical support for the EE perspective on nature. A student described how environmental educators could approach learning from the geological perspective:

I really appreciated the ability of the Earth science perspective to give you a stronger sense of a place, and in place-based education I think it's equally important to start with that… like why things were formed and how things were formed and how that influenced [the way] people lived in a place and how things are important…which really shapes our perspectives of environmental education, and our uses of that space. I think the geology part of Earth science has a really fundamental role to play in this actually.

Another participant asserted the value of presenting the theoretical background to merging ES and EE. He imagined a scenario in which students may perceive a disconnection between the subjects if not enough theoretical connections were established, and students were not genuinely interested in ES. This idea was affirmed by the second pair when they confessed that they "were a bit rebellious to ES in the beginning" because they didn't understand "why there was a relationship." Field trips slowly have them realize that learning about geological events and how that resulted in local topography makes everything a natural progression.

Pedagogy

Discussion around inquiry learning in this module centered around its structure. Most feedback indicated that students enjoyed how inquiries helped them to make detailed observations and think critically about the environment and natural dynamics. Yet, everyone had a preference for how and when the inquiries could be supported. One participant noted regarding the amount and timing of guidance:

Our group was fortunate to have a girl who majored in geology… and I personally am interested in geology. That made the experience positive for me, because she was like a real wealth of information, and helped to guide some of the questions that people had… so in that way sometimes I felt like we were in a "really unstructured" experience that people wouldn't necessarily get as much out of as when you have somebody that kind of helps focus your questions a bit more or turn your eyes to things you wouldn't necessarily see. You can be reminded of that later, but it's kind of different when you were in-situ, from spot to spot. It's easier to look at them when somebody says, "did you look at this," than when you all meet up in the end and people remind you "when you were there half an hour ago did you notice this"

His partner added that in an upper-level undergraduate course, instructors could assume the class was well enough educated in general to understand basic scientific concepts that allow useful conversations. He felt that the inquiries were more of an "appetizer" learning, as opposed to being based on information-rich, quality conversations and reasoning. He would have preferred the "main dish," i.e., more in-depth understanding, either from readings that supplement conceptualization or during the inquiries. The next pair of interviewees enjoyed the opportunity to explore by themselves, but had contrasting ideas about the inquiry structure. They believed the amount of information provided should depend on topic and place. Most importantly, instructors need to carefully offer the information in a way not to impair the field experience. They favored well-structured activities first and in-depth information afterwards as part of the debrief.

The ideal constructivist process described by the first pair begins with a "light frontloading" to inform students with what to critically investigate and help facilitate "smart inquiries." Students then build their understanding through critical thinking, deduction and discussion. A short debrief in the end concludes learning and further promotes curiosity. ES to them was not a subject in which answers could be developed without guidance. In their opinion, constructivism would be similar to building a house with no bricks if no previous knowledge was present, impeding learners from asking focused questions, and reducing the efficacy of constructivism. If the instructors still have to lecture in the end, the authenticity of constructivism and inquiry would be lost in that sense. The second pair believed learning from self-reasoning makes more sense than memorizing information. They liked how the instructors led them out of their comfort zone. In-depth knowledge could be offered during explanations, but only in the end so that the information would not overshadow the student-led inferring process. Constructivism pushed their inquiry to another level.

The interviewees felt that place-based learning is different to and more effective than textbook-based learning. Matching theory to real life examples was considered valuable. The majority recommended a combination of both.

Module 4

The Content & Incorporation of Earth Science

In this module students reported learning about the natural sources of items used daily, and potential geological hazards at Iona Beach (e.g. earthquakes and liquefaction). Most feedback in this module contrasted with previous comments by stating that EE is the foundation to ES. Most interviewees preferred to be exposed to EE prior to ES, because they considered environmental issues to be more relevant. These issues often brought up points the general public outside of ES fields wouldn't necessarily think or care about (e.g. composition of Earth materials; damage resulting from earthquakes to a sewage pipe at the outer subaerial edge of a delta system etc.) The first pair of interviewees believed that EE establishes a relevance for ES to offer the technical and complex portion of nature, facilitating critical thinking about a place. The environmental topics therefore provided the impetus for these students to want to learn more about the ES of the location:

If that (earthquake) came out of the blue, I don't care. I really don't care what's going to happen. But because we were looking at the land and the use of the land knowing that that area is a wetland, and it supports all the environment and habitat… and that's where all our waste is. And hey, if there's an earthquake here, that pipe (sewage outlet) is going to be destroyed, and all of this is going into the Georgia Strait (Salish Sea). Then this does matter and provides deeper learning of the place.

Her interview partner added that learning about the "superficial" environment is more experiential than meters down the sediment, so going over the environmental content relaxed her by making things not strictly scientific. She knew the surroundings would sink during a liquefaction event, but couldn't understand how the system works. She claimed to have learned the most from activities, but the scientific explanation behind the experience was definitely a plus to deepen her understanding of the causes of some environmental issues. The second pair also saw the value of discussing ES in the context of EE. One of them said, "I never thought about specific natural resources to the items I use." The interdisciplinary content made the subjects reciprocal.

Pedagogy

Most interviewees strongly preferred to begin their learning with inquiries supported by backloading (information afterward; e.g. post-class readings) rather than frontloading. Inquiries helped promote learning interest for more meaningful learning. One student insisted that, “you can plan all you want, but if the content was put up front and I am not interested in it, I will just tune out during discussions.” Despite having a strong preference for backloading, she further expressed her appreciation towards what she called “smart frontloading.” She was engaged during the information session (presented by the researcher before this module) that provided an overview of Vancouver’s geology, but only because of the firm ties established to the locality; if that frontloading wasn’t as place-based, she would not have been interested in it. The second pair disagreed with each other on the optimal amount of frontloading, but both preferred learning to be inquiry and exploration focused and supported with additional information for reviewing.

The participants described their ideal constructivist process as starting with a full immersion in the activities, with the experience designed to prioritize the relevance and usefulness of the knowledge gained. Facilitated interest would become their momentum for further inquiry and critical thinking, and a debrief activity would supply the learning resources to summarize the day. It was the experience that made them want to dive deeper to construct their knowledge. For example, all groups observed different results for the rates and patterns with which the model buildings fell during the earthquake simulation activity. This variation promoted hypotheses and debates. Eventually, water saturation, magnitude and location of the earthquake focus were concluded to be the critical influencing factors for damage during liquefaction. This learning was self-governing and practical.

Both groups emphasized the importance of knowledge being place-based. For example, landslides would be less impactful if introduced at Iona Beach compared with at Lynn Canyon. The key is to introduce concepts that are locality-specific. The students were confident in remembering the ES knowledge because it tied to Iona Beach. One described her excitement towards place-based education:

Every weekend I shared something with my family [about] what I learned. This experience has brought the class together… it’s just so different from sitting in a *classroom. I think I have learned so much more being out and in different places than in a whole… like long semester of one class sitting in a room, reading textbooks. I can read a thing 3 or 4 times to fully memorize it but I feel in a week it's gone. I am totally an experience person. I need an experience to go on with something and be able to understand. When I look back, I can be like 'Ok, I get this'. Thinking about this place, I remember all the stuff I learned here.*

Suggestions

Overall, students suggested improvement in logistics around the debrief activities and a stronger tie between the activities and the themes. ES activities did not have connections to all themes. For example, liquefaction simulation connects to Iona Beach's geological setting well, yet the connection to waste management was missing. An elaboration on the connection between EE and ES upfront, and having activities focusing on the overlaps were believed to better attract learning interest.

Organization of information was critical during debriefs. The student-led debrief was said to be engaging, but disjointed. The randomness of some questions made it difficult for learners to figure out the point of the conversation. Therefore, a sequential presentation of conclusions after the constructivist process was required for a clear, well-structured debrief. Reasoning and debate "left an image," but "not as much knowledge as [they] would have expected." For example, the Resource Product Pairing activity could be supported with memory cards after debriefs. That way, details including elements in minerals could be conveniently introduced.

4.3 The Instructors Debrief Meetings

4.3.1 2018 Pilot

Burnaby Mountain

All instructors believed the pedagogies generally functioned well and were widely accepted. The team inferred that the problem of time management was due to having 3 groups each moving at very different speeds. Dr. Zandvliet proposed a smoother transition by dividing the class in half, and let Dr. van der Flier-Keller and Mr. Cameron co-teach one group. He further commented that some ES content was slightly “heavy,” possibly shocking students with little background.

Lynn Valley

The module received overall positive feedback from Mr. Cameron and Dr. Zandvliet. The reference book, “A Field Guide to the Identification of Pebbles” (Van der Flier-Keller, 2005) was complimented for offering information on commonly seen rocks in the field in a learner-friendly manner. Organization of the module was the main issue. Mr. Cameron pointed out that the observational stage during self-discovery required more time, since the place was noisy and very crowded with tourists. Having 6 groups of 5 together for the introduction at each station made the situation rather chaotic. Perhaps, reducing the number of groups and introducing topics to groups one by one would be a good resolution. Lastly, Mr. Cameron suggested that some pre-readings would be helpful for those who lack a background in ES.

Deas Island

All professors believed this module was vital to the course as it connects all previous content. However, out of all ES incorporated modules, Deas Island was criticized the most for the overly long lunch and issues with the coring activity. Instructors noticed that students without guidance were evasive about ES discussions, which could be a result of unbalanced information across groups.

4.3.2 2019 Pilot

Burnaby Mountain Hike

All instructors noticed a clear difference in engagement and opinions on the connection between ES and EE between the two groups. Mr. Cameron and Dr. van der Flier-Keller presumed that the group that started with ES was more engaged because of 1) the order of introduction of ES and 2) the stronger ES background of the group. They felt that ES provided the foundational knowledge for environmental content, so it could be difficult for students to see their relationship if EE was introduced first. Also, the second group was more rushed and many people were tired at this point in the hike. Going over points and not leaving enough time for inquiries could also impair the experience. Mr. Cameron suggested offering a prompt reading before the hike to help engage students. Dr. Zandvliet suggested to introduce topics through stories and personal experience instead. Dr. van der Flier-Keller stressed that teaching should be discussion-based to make activities natural and fluent. An alternative in the future considered by the team was to focus on sections of the trail that present the best ES examples and link to EE in later parts of the module. Lower sections of the trail with few outcrops could then be excluded.

Lynn Valley

Dr. Zandvliet and Mr. Cameron agreed that the activities at Lynn Canyon this year worked better than the 2018 pilot. It was a good example of how being open-ended on inquiry learning created a positive influence. Students seemed to be more relaxed and casual when instructors were not assigned to each group. Dr. Zandvliet commented that "they were prepped and willing to ask more questions; asking their "own" questions facilitated the will to learn." This explained that discussions and the debrief activity expanded to multiple fields through critical thinking. He was surprised at how much students were uncovering by themselves, and described this as "unfolding simple activities revealed the complex stories behind it."

Iona Beach

Iona Beach was discovered to be a better location than Deas Island for discussing natural hazards and waste management. The instructors believed the relatively non-disturbed, long coast provided more physical space for students to explore. The earthquake simulation activity was believed to be remarkably more impactful than the Coring Activity in 2018. Mr. Cameron commented that, "this group was very inquisitive. I could tell how engaged they were based on how many were interested in what I was saying." Dr. Zandvliet noticed the organization required further improvement because "when you had only 1 Earth science instructor around and 2 groups, there was lots of standing around." He believed the place illustrated the interface between city and nature very well.

Chapter 5 Pre- and Post-Design Results

5.1 MESEES Results of 2018 and 2019

The quantitative analysis provided an overview of the course impact and class performance of each pilot. The results are evaluated by percentage and changes in 1) Strongly Agree (i.e. 5 on the Likert Scale) and 2) the sum of Agree and Strongly Agree (i.e. 4 & 5 on the Likert Scale = Total Positive Response). The total positive response is prioritized if there is a conflict between 1) and 2) (e.g. 1) drops while 2) rises). The following description focuses on the pattern of the results, and is meant to be triangulated with, and explained by, other qualitative information, not for a detailed statistical analysis.

The results of the 2018 pilot (Fig.5.1.1) are based on 27 participants for the pre-course and 28 participants for the post-course survey. The majority of the cohort demonstrated a strong positive learning attitude (LA) (i.e. 5 = 67%; 4 & 5 = 93%). After the course, 5% of the responses shifted from 4 to 5. The mean of LA before and after the course were 4.60 / 5 and 4.65 / 5. The responses for the Learning Interest (LI) measure formed a more spread out left-skewed pattern. The class was dominated by students with mild (4) and strong (5) positive LI (i.e. 5 = 39%; 4 & 5 = 73%). After the course, 5 increased its popularity by 10%, and there was a total increase of 8% in 4 & 5. The means before and after the course were 3.98 / 5 and 4.21 / 5. The Confidence in Teaching Earth Science (CTES) measure illustrated close to a normal distribution. Most of the class had a tendency towards a neutral standing on CTES (i.e. 5 = 12%; 4 & 5 = 39%). After the course, the data demonstrated a slightly left-skewed distribution, making 4 the most popular option. While 5 experienced a 7% increase, the sum of 4 & 5 had a total of 17% increment. The means of pre-course and post-course results are 3.11 / 5 and 3.52 / 5. This reflects that the LA measure had the highest scores with the least improvement. The CTES measure demonstrated the least favorable overall distribution.

There were 24 participants who responded the MESEES in 2019 (Fig.5.1.2). The participants had strong LA before the course (i.e. 5 = 70%; 4 & 5 = 95%). There was an 11% increase in 5 and an overall 2% increase in the sum of 4 & 5 after the course. The means are 4.64 / 5 and 4.78 / 5 before and after the course. The LI measure also

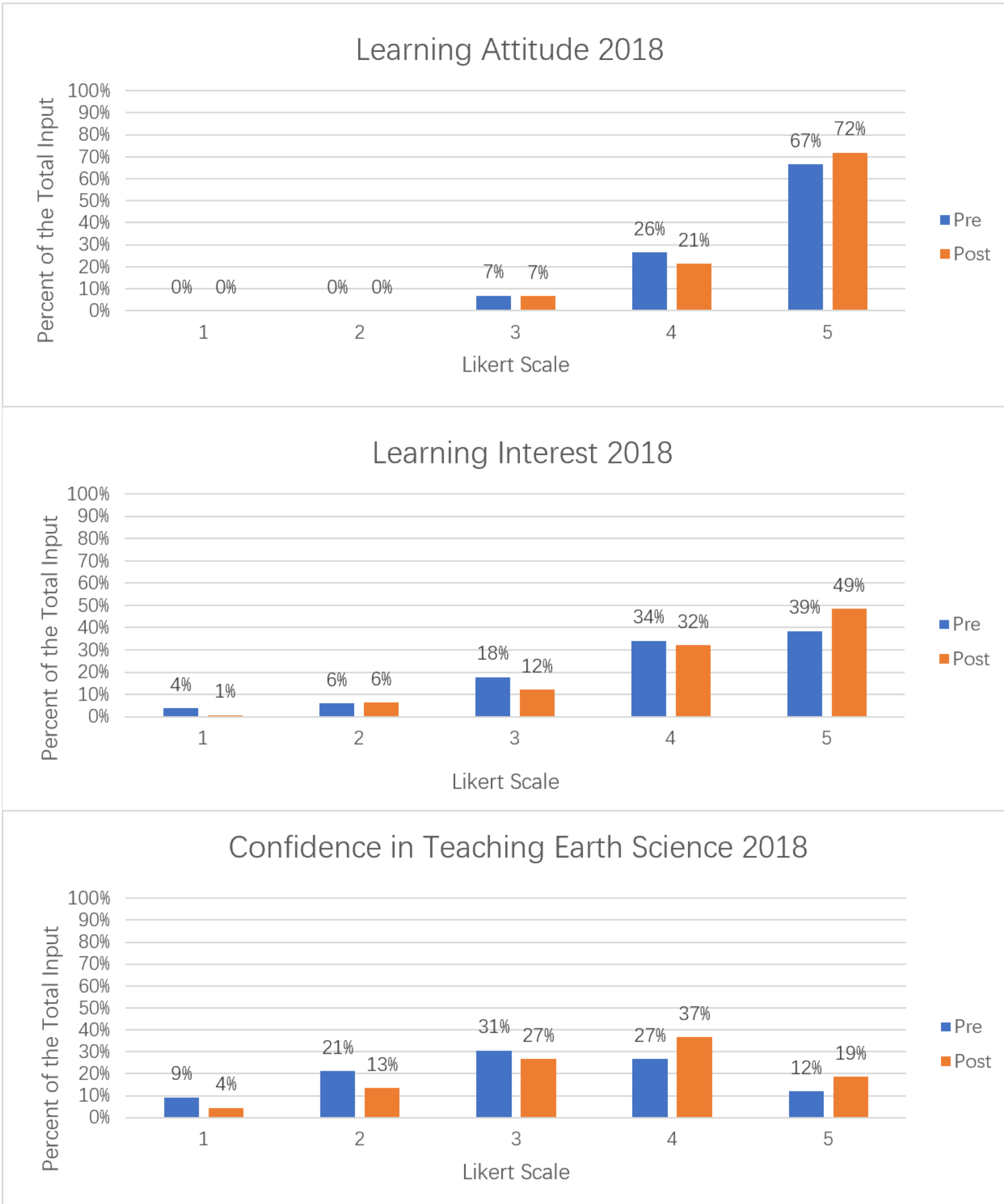


Figure 5.1.1 Distribution of Students' learning attitude, learning interest and confidence in teaching Earth Science before and after EDU452 of 2018. The higher the number on the Likert Scale, the more positive the input is. The pre-course results are shown in blue and the post-course results in red.

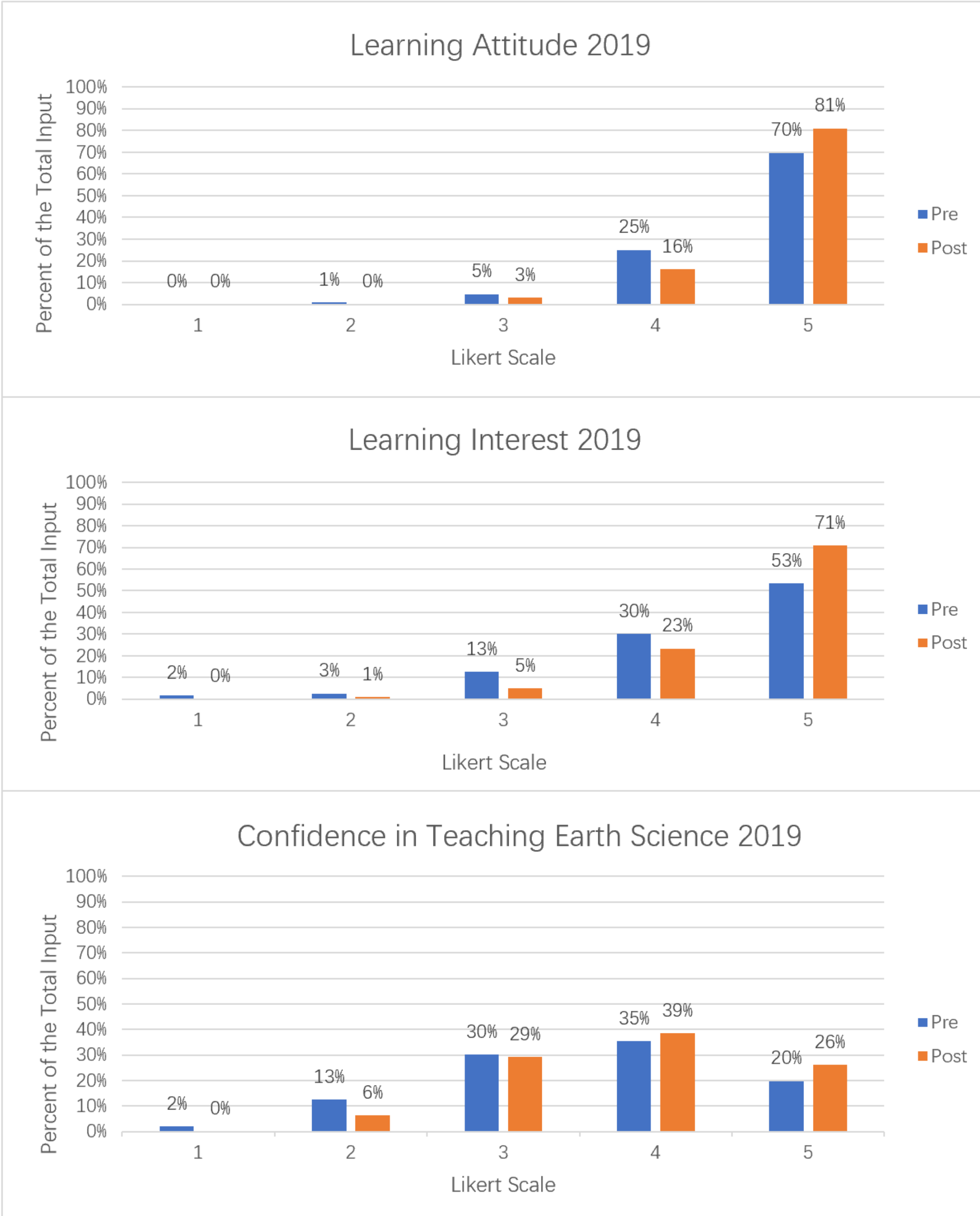


Figure 5.1.2 Distribution of Students' learning attitude, learning interest and confidence in teaching Earth Science before and after EDU452 of 2019. The higher the number on the Likert Scale, the more positive the input is. The pre-course results are shown in blue and the post-course results in red.

received mostly positive results (i.e. 5 = 53%; 4 & 5 = 83%). The post-course results illustrated an 18% increase in 5 and a total of 11% increase in 4 & 5. The pre-course and post-course means are 4.31 / 5 to 4.64 / 5, respectively. The CTES measure, closely representing a normal distribution, was the poorest out of the three measures (i.e. 5 = 20%; 4 & 5 = 55%). After the course, there was a 6% increase in 5 as well as a 10% increase in the sum of 4 & 5. The pre-course and post-course means were 3.58 / 5 and 3.84 / 5. Learning Attitude and Learning Interest both potentially suggest satisfactory post-course results. Confidence in Teaching Earth Science demonstrated the least favourable distribution out of the three.

The Effectiveness, Pedagogy and Activities measures demonstrated satisfactory distribution (i.e. 4 & 5 dominant) and mean values (4.52 / 5, 4.56 / 5, 4.61 / 5 for 2018; 4.84 / 5, 4.50 /5, 4.76 /5 for 2019) for both pilots, which might indicate that ES incorporated EDU452 functioned well from the student perspective. In all, the post-course results seem to show that EDU452 was effective at boosting learning attitude, interest and teaching confidence. A greater impact on learning interest and confidence than attitude was observed, and this pattern was manifested in both pilots. For a more detailed view of the frequency response table for each item under all measures, see Appendix A. For both pilots, the post-course results might indicate better results than those of the pre-course.

The Background Knowledge Measure

In 2018, the Background Knowledge measure received undesirable scores. For the short answer questions (Q17-19), 23 of 27 participants were able to list 3 or more topics related to ES. Common ES-related topics listed include “earthquakes,” “volcanoes,” “planets,” “oceans,” “minerals” and “geology.” Some students simply addressed other subjects, such as “chemistry,” “biology,” “physics” and “science.” Fourteen participants could tell the difference between a rock and a mineral, with a simple understanding of “minerals form rocks”. Nobody addressed the key definition of a mineral. Only 1 participant knew the largest source of drinking water globally was groundwater. The most common misconception was the belief that glaciers were the largest contributor. In the post-course surveys, 25 students were able to list more than 3 ES-relevant topics. More diverse, in-depth, ES-focused terminologies including “deposition,” “sediments,” “glaciation,” “mining,” “erosion,” “plate tectonics,” “rock composition” and “coring” appeared. Twenty-one students not only explained the difference between a rock and a mineral, but also related it to mining industry and described how different mineralogy produces different rocks. Eight participants could correctly identify the largest source of drinking water, yet most people still maintain the misconception.

On average, out of the 5 True & False questions asked (Q20-24), each student answered 1.52 (30.4%) questions correctly, 1.15 questions incorrectly (23% misconception), and were unsure about 2.30 questions (46%). This indicated a failing average grade in geological knowledge of the enrolled student teachers before the course. After the course, 2.54 (50.8%) questions were answered correctly, producing a "passing grade." While the incorrect answers rose to 1.39 questions (27.8%), the popularity for unsure option dropped to 1.07 questions (21.4%).

In 2019, 20 of 24 participants could name three or more topics related to ES (12 could name 4 or more) before the course. Similar to last year, most of the terms were either introductory (e.g. water, rock, geology, soil, land, volcanoes, maps etc.) or relatively irrelevant (e.g. biology, chemistry, pollution, atmosphere). Fourteen students could recognize minerals as substances or materials in rocks, but many had misconceptions confusing minerals with molecules or elements. Five students knew that groundwater and underground aquifers were the largest source for drinking water. In the post-course survey, the relevant number increased to 21 of 24 (16 could name 4 or more). Common terms mentioned varied from geological terminologies (e.g. "sediment," "erosion," "geological time," "plate tectonics," "glaciers" and "rock formations") to applicable topics (e.g. "petroleum," "liquefaction," "mining"). The participants further expanded to EE relevant issues such as "climate change," "resource management," "water-cycle," "urbanization" and "ecology." Sixteen students could distinguish minerals from rocks, as well as from elements and molecules (1 still had the misconception on mineral & element). Twelve students could identify underground aquifers or groundwater as the largest source for drinking water across the globe. The other half of the class either did not know the answer (2 of 24) or had misconceptions (10 of 24). The most common misconception were glaciers and lakes, which are the largest source for drinking water for Vancouver, not the whole planet.

Students in 2019 before the course on average could answer 2 questions (40%) correctly, 1.54 questions (30.8%) incorrectly and were unsure about 1.46 questions (29.2%) in the True and False section. These numbers were changed to 3.08 (61.6%), 1.13 (22.6%) and 0.79 (15.8%), respectively. The misconception rate in 2019 dropped to 8.2%, considerably better than 2018.

5.2 Instructors' Pre-course and Post-course Interviews

5.2.1 The 2018 Pre-course Instructors' Interviews

Overall

The course modules and schedules were generally consistent through past years of EDU452. For the preliminary incorporation in 2017, Dr. van der Flier-Keller and Mr. Cameron led the activities on Deas Island, and Mr. Cameron was also involved at Lynn Canyon. Pre-readings were minimized except on the theoretical components for EE. Dr. Zandvliet emphasized the purpose was to demonstrate a learning cycle (i.e. Dewey, 1938) that includes exercise, experience, adventure, open-ended activities, and resources afterwards for further study.

The overarching theme was to model EE and ES learning through experience. Dr. Zandvliet carefully chooses locations for place-based learning as other instructors choose their textbooks. The instructors wished the students to understand that science is embedded in environments, to know their communities and why it is important, to think about ecological footprint and ES in a local area, to begin making ES observations and interpret their implications. Earth processes, formation of the Earth, geological history, natural hazards were covered. The collaboration sent an important signal: science is a big, interdisciplinary topic.

Incorporation

All instructors agreed the incorporation was generally successful. Although the involvement was still in its exploratory stage, Dr. van der Flier-Keller and Mr. Cameron believed this "try out" was useful to help gauge where the students were at, familiarize with Dr. Zandvliet's pedagogy and identify what to develop for the 2018 pilot. Dr. van der Flier-Keller's understanding on Dr. Zandvliet's goal was to get students to think about the ES process while exploring a place, complementing the biological aspects with ES.

Pedagogies

The instructors seemed to have contrasting opinions towards how the learning models could be supported. Dr. Zandvliet would like each activity to send a clear message, to be experiential and inquiry oriented, and supported by backloading. He also pointed out that activities on Deas Island needed to be more augmented, less lecture-based, and therefore requires improvement. "The coring activity should be inherently scientific with inquiries, but less front-loaded," he said. On the other hand, Mr. Cameron realized that many students were not prepared due to lack of background, and therefore advocated for some information beforehand. Furthermore, Dr. van der Flier-Keller noticed the students were interested, but would rather be provided with more solid, practical implications through (to adopt in their career) concrete activities. Each instructor should have a distinctive role in the course, yet with good coordination. All instructors agreed that every activity should be related to the general theme of the course, but each of them had unique and distinctive pedagogical approaches.

Suggestions

The instructing team highlighted the significance of choosing locations that fit well with ES components, field support, clarifications of instructional models in the beginning and continuously collecting student feedback. Adding non-renewable resources and Earth materials could be an option to help students think about Earth processes. Better visual aids could be used in the field (i.e. large, scanned, laminated diagrams and graphs for demonstration). Yet, the instructors had split recommendations on supporting field experience. Mr. Cameron recommended frontloading of some basics of geology and clarifications of learning goals before each activity. Dr. Zandvliet emphasized the importance of having scientific learning based on inquiry and investigation instead of lecturing. He suggested developing activities that are congruent with the models and supporting them with additional resources.

5.2.2 The 2018 Post-course and 2019 Pre-course Instructors' Interviews

Overall

All instructors believed the improvement of 2018 was noticeable, yet there is more to do. Mr. Cameron underlined the importance of social interaction and taking time to establish strong bonds within the class (i.e. the overnight retreat at Mossom Creek) to ensure field engagement. Dr. Zandvliet urged for better organization and collaborative teaching. The team should aim to capture interest before learning, and support students with follow up resources that are explicitly available. In the 2018 pilot (i.e. Deas Island), students occasionally faced difficulties to decide what to ask or look at. All ES instructors shared their main concern on the tough balance between over-frontloading and making students stranded. They reiterated that they were conscious about EDU452 being an EE course, and aware of their influence on the context.

ES and EE Incorporation

Dr. van der Flier-Keller and Mr. Cameron believed the incorporation of ES was important and beneficial to EDU452, because it made the curriculum more coherent by relating to theories behind nature. To Dr. Zandvliet, this incorporation was not necessary in a required sense, but was desirable. He pointed out that the instructing team needs to be mindful about the depth of students' ES knowledge, and the various backgrounds students possess:

We should have just scratched the surface and give them (students) the resource. This is the practical conflict between capturing interest and teaching. We want to offer enough without making [our students] say 'enough, I don't want to know more.' Knowledge level is not homogenous. There is a connection [between EE and ES], but if you dive too deep, you will lose what's on the surface. The most interesting part is between the substrate and the living organisms. This, is the 'interface!' The key was to confine it to the big topics, and hook them instead of overwhelm them.

In EDU452, the goal is to improve learning attitude and interest rather than have students become literate in ES. The format of incorporation was complimented as it added experience in the field of each professor's expertise. Interdisciplinary teaching provided a good opportunity to have students thinking about ES and EE in the same context. However, the incorporation was only well connected in some parts, and still requires expansion to become more formal and explicit.

Class Content and Activities

All instructors shared a similar positive feedback on the themes of activities and some concerns on guidance, coordination and framing of the activities at Lynn Canyon and Deas Island. Mr. Cameron and Dr. van der Flier-Keller liked the balance between ES and EE contents on Burnaby Mountain. Dr. Zandvliet commented that the "Interview with a Rock" activity was intriguing, creative, open-ended, and impressive. The Resource Product Pairing Activity and the Coring Activity were said to be "creative and powerful," and were "well connected to the 'Land use' theme" as most materials used to produce everyday items come from mining and the petroleum industry.

Guidance and organization were the main problems. The activities at Deas Island did not go according to plan. Instructors didn't know if a point (s)he wanted to mention would better to be brought up at a later location or by other instructors. The format of debriefs should have been that students shared their discoveries under instructors' prompting questions. The sharing should have related back to the leading question under the CARE framework, and be supported with concrete information sheets that they could immediately use. When a lot of lecturing was involved (i.e. Deas Island), it did not help them to develop understandings. Mr. Cameron and Dr. van der Flier-Keller both addressed that more guidance would be helpful, but more attention should be paid to how, and also the depth of information that was provided.

Suggestions

All instructors recommended a detailed, specific plan for projects and activities at each place. Reconnaissance trips and pre-planning for detailed inquiries would add to the coherence of activities. Although difficult, Dr. van der Flier-Keller would like to see students taking the lead in overarching questions and demonstrations. Mr. Cameron suggested that for students with different levels of background knowledge the instructors could offer different intensity of frontloading. The instructors could let the students choose whether they wanted to be frontloaded, in what aspects and to what level.

Dr. Zandvliet and Dr. van der Flier-Keller proposed to replace Deas Island by a less disturbed, more typical delta system (i.e. Iona Beach). The tectonic setting from a land use point of view was missing. This was important because it has implications for many land use choices. Iona Beach could be an awesome location to incorporate the "big picture." If the coring activity were to be done again, a demonstration of corers and sample analysis should be done at an ideal location (i.e. the tip of Deas Island / Iona Beach with minimal human influence). Then, students could take full control over the process, which would empower them for other similar activities to be done elsewhere in a more constructivist way. An alternative tool to replace corers was shovels, which are straightforward, and better at exposing large cross-sectional areas after digging a hole.

Pedagogy

During the interviews, all instructors explained their unique ways of teaching. Mr. Cameron is a very information-rich lecturer who usually offers knowledge under leading questions. On the other hand, Dr. Zandvliet encourages group discussion and story sharing supported by debriefs in the end. Dr. van der Flier-Keller's strategy is to investigate topics through guided inquiries and supporting evidence that leads to conclusions. Their commonality is to utilize real-world examples frequently and relate personal experiences to keep the audience intrigued. Together as a team, the 3 instructors exhibit a wide spectrum of pedagogies. Mr. Cameron stated a potential benefit to help students develop pedagogies for interdisciplinary courses as teachers in training: "demonstrating this spectrum leaves the freedom for the potential future teachers to decide what kind of teachers they want to be."

All instructors were open-minded about learning each other's pedagogical approaches. Mr. Cameron said that he had learned a lot from his journey, and was willing to adapt his pedagogies to be more in line with a student-centered approach (i.e. shorter introduction & inquiry-based debrief). All instructors agreed that inquiry learning promotes engagement, yet requires the most rework. It could be compensated by explicit introductions and enhanced guidance. The learning experience could be consolidated by recaps during the activities. Students tend to retain learning through constructivism by building up their own "learning blocks." The ES instructors believed "how to investigate" is a valuable, long-term skill, so the team needs to be more careful to provide evidence rather than answers. Sharing learning among students should be encouraged (i.e. how could they use this experience in their teaching). Dr. Zandvliet added that the frustrating process was necessary even for those who resisted constructivism. “The process could be disruptive, but to unlearn their misconceptions and to admit cognitive dissonance was the first step in constructivism,” said Dr. Zandvliet. Everyone asserted that place-based learning was central to EDU452. The relevance it addresses immediately grabs learners’ attention and makes content matter. It offers a framework to consider both subjects in the same context, and relative to particular localities. Therefore, place-based learning was said to be the powerhouse of making learning active and self-reinforcing.

5.2.3 2019 Post-course Interviews

Overall

The 2019 experience was said to be enriching and greatly improved from 2018 by all instructors. The improvement was largely due to greater congruence developed among pedagogical strategies, course instructors and selection of field locations (i.e. Iona Beach) that mitigated earlier problems that occurred on Deas Island. Tensions in the teaching styles dissipated as all instructors became more comfortable with the format and process of incorporation, and developed a more inquiry oriented instructional style. Iona Beach was believed to be a location that offers optimal examples for natural process, deltaic sediments and influence of tectonic setting. The ES instructors noticed that most students seemed enthusiastic to learn about ES and were eager to incorporate it into their environmental learning, even those with a minimal science background. Students with stronger background in ES added to engagement by providing peer support. This was revealed in the debrief at Lynn Canyon and Iona Beach, where much more engagement, participation and sense of understanding were observed by Mr. Cameron. An overall better experience and more recognition of the integration of contents and pedagogies were reflected also in the final portfolios when more students included ES to a greater extent. This perhaps meant that the addition of the information session before Iona Beach and a more integrated teaching strategy were responsible. Dr. Zandvliet commented that “the way ES modules were implemented did a lot to stimulate interest and positive attitudes towards the content.”

ES and EE Incorporation

The ES instructors saw ES as a natural fit to EE. Students gained a well-balanced perspective and more of a broad-based science beyond just ecology to think about environmental issues and sense of place. Both appreciated the opportunities of involvement and are looking forward to future participation. Dr. Zandvliet thought ES was a very valuable addition and its broad scope integrates nicely with the interdisciplinary nature of EE.

The instructors had similar and complementary views toward the format of incorporation. The ES instructors wish for a more integrated teaching strategy that enhances the congruency of the two subjects. Mr. Cameron recommended "pre-game planning," or pre-module meetings for roles of each instructor to "know what to cover, and by whom." Mr. Cameron and Dr. Zandvliet also shared their ground this time on the advantage to limit the depth of ES covering only "big ideas" and then making more detailed and teacher-friendly resources available afterwards. Dr. Zandvliet and Dr. van der Flier-Keller believed the strongest impacts were noted during the inquiry exercises. Plenty of opportunities for students to discuss across groups and with instructors helped them approach questions from multiple perspectives. These interactions during inquiry made the incorporation more fluent and relevant. Dr. van der Flier-Keller specially enjoyed the place-based framework. When the concepts were made applicable to place, students could immediately see the relevance and use of them.

Class Content & Activities

Activities conducted on Iona Beach were complimented by all instructors. This open locality was ideal to provide a good overview of the lower mainland, linking all previous modules (e.g the change from northern mountains to a massive delta). Earthquakes, mineral usage and liquefaction were relevant to the locality and easily connected to the land use theme. The design of these hands-on activities successfully generated enthusiasm in the class. Mr. Cameron believed there was "just the right amount of frontloading" (i.e. the pre-module info session) to allow students to work their way to logical solutions, and collaborate among themselves in each activity. In addition, the first part on Burnaby mountain received positive comments from Dr. van der Flier-Keller. The collaboration between the two ES instructors worked well both pedagogically and content-wise, and efficiently captured learning interest.

However, timing and scheduling of the ES activities was repeatedly addressed as the largest remaining challenge by the instructors. This is specifically uncovered in the disengagement of the second group on Burnaby Mountain (i.e. the one introduced to EE before ES). Furthermore, Mr. Cameron worried about a disconnection between the learning goals when ES and EE topics were addressed separately (e.g. on Burnaby Mountain). This separation was due to a seemingly unmanageable large group size, but the downside was that having limited interactions with Dr. Zandvliet left students an impression of disjunction, and wondering what was the purpose and take-aways from the ES activities. Dr. Zandvliet noticed that Lynn Canyon remains problematic as a site for discussion owing to the fact that it is often crowded with tourists and overwhelmed with background noise. Yet, the positive physical attributes of the site may outweigh this disadvantage. In all, the instructors were affirmative about the modifications on activities for 2019, but minor rework on group and time management may be required in future.

Suggestions

The aim of all instructors was to integrate ES more broadly across the modules, so that ES would be clearly recognized as an integral part of the course that is important to all aspects, not an add on at particular locations. How to introduce more ES topics effectively in other appropriate places in EDU452 requires careful planning. Mr. Cameron proposed to increase the time available for ES discussion on Burnaby mountain (Module 1) and “wrap-up sessions” on Gambier Island (Module 6) for additional involvement as well as better attachment to the learning goals. Dr. Zandvliet and Dr. van der Flier-Keller envisaged that an integration of ES into the City Module (3) (e.g. building stones) and the Ocean Literacy Module (5) (e.g. climate change, fossils & evolutionary history) would be beneficial going forward. Geological resources (e.g. Resource-Product Pairing Activity) might be more relevant if introduced in the City Module rather than at Iona Beach. These new contents could be supported by an explicit statement on the purpose of integration, ES context (e.g. clues on the roles of tectonics, the Earth’s materials, process and history of places and their connection with EE) and a mapping exercise on how ES influences land use (e.g. siting of infrastructure away from soft deltaic sediments). Relations to indigenous aspects could also be an addition to the whole course. Dr. van der Flier-Keller shared additional insights on how the extent of integration between the subjects could be improved:

> *Further to the above, it might be an interesting idea to do ES and EE activities all together to better integrate leading questions and discussions. This full integration will be useful to erase the image of 'this is ES activity; that is EE activity'. Also, I'm wondering if it might be useful to have some ES theoretical readings before the first module just like EE. The role of Frank as the researcher with a continual presence for scaffolding or short presentations was important. This provides the students with an ES source to go to if they have questions or ideas, sending a message that "ES is always with us." Otherwise the ES is just there for collaborations in 3 modules. The key is to have 1) a resource person, 2) presentation beforehand, and 3) focused guide all the way through.*

Pedagogies

Inquiry learning was said to be well adopted at Lynn Canyon and Iona Beach. Dr. van der Flier-Keller enjoyed her role to support or scaffold the students, and lead them to conclusions. This gave the students control to initiate their learning. Mr. Cameron added that inquiry learning is "critical for getting students to be thinkers and active learners rather than passive bystanders in their education."

Constructivist learning was phrased by Dr. Zandvliet as the "cornerstone for pedagogy in this course." Mr. Cameron had a similar opinion that helping students to be capable of managing their own learning is critical for anyone that is thinking about becoming a teacher. While acknowledging the benefit constructivism offers in aiding students to correct misconceptions and obtaining ownership of knowledge, Dr. van der Flier-Keller pointed out how it could be perfected with careful planning. She recognized that students occasionally felt they were "left in the lurch" when lacking support. Being aware of this, the instructors should look into how each student with distinct backgrounds could be supported differently depending on their learning styles without compromising any of their experiences. Constructivist learning was well demonstrated in every module, and all instructors would like to model this philosophy continually to the student-teachers.

All instructors considered that place-based learning made all activities immediately relevant and meaningful in the students' day-to-day lived experience. Students also have the opportunity to revisit the place to reinforce their learning. The only concern of Dr. van der Flier-Keller was schedule challenge of being able to spend whole days or weekends. To Mr. Cameron, "just looking at pictures, or talking about a topic in a classroom does not do ES or EE topics any justice, because both topics need hands-on experience, which could be achieved by place-based learning."

These strategies will help student teachers to connect student learning to real world contexts and problems. The instructors believed that having seen innovative pedagogies like the ones implemented in action, they will be more likely to adopt them in their own teaching, because the first way a teacher teaches is how (s)he was taught. Otherwise, pedagogies that ignore the uses of actual samples or localities will be perpetuated and remain in the educational system. The well-modeled pedagogies in EDU452 are anticipated by the instructors to be very positively influential.

About the Instructors

All instructors are looking forward to continuing and expanding this incorporation in EDU452, as well as to a closer relationship bridging ES and EE. The ES instructors also suggested to formalize the involvement of ES through a TA-ship or co-teaching. Dr. van der Flier-Keller appreciated the valuable opportunities to co-teach and observe how different instructors support learning. She gained recognition of the importance of learning environment from Dr. Zandvliet where everybody is comfortable to inquire and express their points of view. Mr. Cameron has been trying to incorporate constructivist teaching strategies in his own classrooms, and encourage students to think and problem solve by themselves. Dr. Zandvliet has renewed interest in ES personally, and has begun to notice rock and soil formations a great deal more than in the past, as an environmental educator. All instructors evolved either pedagogical styles or perspectives towards the subjects. To them, learning is a life-long experience.

Chapter 6 Course Evaluation

6.1 Focus Group Interview Results

6.1.1 Focus Group Interview of 2018

Learning Environment

The student group appreciated the relaxed, fair, democratic and accessible learning environment. Many participants believed the overnight retreat and the Environmental Artifact Activity offered an excellent opportunity for Dr. Zandvliet to establish a community that is safe and comfortable for expression. Ample time was spent building bonds between students. Group cohesiveness was critical for place-based ideology. The participants also enjoyed presenting their final portfolios in their preferred, characteristic manner. This open-ended system was complimented the most. Dr. Zandvliet was described as a very caring instructor who prioritizes connections and emphasizes overlaps and differences in opinions. In one participant's own words, "I liked how he (Dr. Zandvliet) started with the unpopular view of captive orca. [It was] a good demonstration of how you have to create a safe place to speak. Like… it's okay to say what I want to say."

Change in Learning Attitude and Learning Interest Towards Earth Science

The participants agreed that EDU452 had caused them to develop a strong sense of curiosity towards ES, from wondering about rock textures and formations, inferring geological history, to the applications of ES in various fields. Students shared how their impression of ES had been changed in the course of only 6 weeks. One student pointed out the reason why they felt geology has always been one of the "unpopular" subjects to teach:

Earth science is a difficult subject, because [in] a lot of cases it comes very knowledge based. To be like into it, you tend to be someone… it's almost like people love comics… to really, truly understand something you get so deep into it right? But then when we *start to share that with someone who's outside of that world, it doesn't translate very well. Earth science, I found was one of those areas. It's hard to get people so engaged."*

However, this student added that when he investigated ES topics, and began to discuss with his classmates, he slowly realized that he was enjoying it. He commented "I feel very nerdy right now. I am informed by it." He also shared how these discussions expanded to where ES intersected with more practical, economic issues. He spoke of how irresponsible it is to build a house near a scarp, and how many still do it for money, ignoring the importance of natural hazards. This student felt that to enhance the significance of geology, "we need to construct a tie with practice" or aspects "that would physically harm us." Such "ties" addressed by Dr. van der Flier-Keller were considered to be inspiring.

Other students pointed out another reason why ES is unappealing, namely the vast amount of memorization that was required even for introductory topics. This is intimidating for beginners because they "need to memorize all this to actually even start talking about the subject!" Therefore, this created a discouraging image of ES, especially "around those who know a lot and are proud of their knowledge." Something EDU452 successfully achieved was making students feel comfortable and confident at talking about ES. As elaborated by a participant, "[Students] were never told [they] were incorrect," but were supported through the learning process and "felt like [they] were being led into a new interest."

Another student who originally had absolutely no interest in ES, admitted that EDU452 gave her lots of motivation for learning it: "Because I am learning this (ES) from the lens of education, I know I will be responsible for the knowledge," she said. She wanted to "ensure [her] kids (students) have this opportunity to foster this passion," and now she could see "education [as] the window to [her] Earth Science experience." This led to an enjoyment of ES that may otherwise not have happened.

Most participants believed the subjects were well blended and learning one without the other would be difficult. Although superficially, the overlap may not be prominent, students recognized the "serious overlaps" when they discovered that "the explanations relied on both parts." "I can learn rock formations without talking about trees, but I can't learn waste and pollution, without understanding its influence on the Earth," said a participant. The focus group believed that the ES and EE content "go hand in hand" and concluded as "you may learn the subjects separately, but not properly."

Confidence in Teaching Earth Science

Confidence in teaching ES related content varied among the focus group but was generally neutral. A participant explained that she had a neutral standing because the course offered detailed explanations of some fundamental ES concepts, which allowed her to be more confident and qualified to answer particular questions that could be asked by her students, but not enough to teach ES as a subject. However, she sensed the need for ES and wanted to know more. EDU452 was a breakthrough for her to feel comfortable continuing inquiring about and learning ES. This comment was supported by all other participants, who wished to involve ES content in their own teaching. They saw the opportunity to incorporate ES not only in EE, but also in other fields.

Effectiveness & Activities of EDU452

The activities of EDU452 were said to be effective overall, but each ES incorporated module was rated differently. Most participants recalled that the Burnaby Mountain hike provided a well-organized overview of ES, and the Lynn Canyon module was rich in information. Learning sedimentary beds and their orientation on a steep, scarped slope next to the SFU campus was seen as relevant and important. Investigations on river channels and past glacial events were descriptive and intriguing. However, the content on Deas Island was described as "disorganized and hard to follow." Although the Resource Product Pairing and the Coring activity were praised for an illustration of a practical usage of ES, many students sensed that they were perhaps done "at the wrong place and wrong time." The connection between sediments and the locality was not explicit because most coring locations did not contain typical examples. The students also felt a lack of set up and in-field guidance to hypothesize on abstract topics (i.e. core analysis for paleo-environment interpretation). Overwhelming amount of facts were introduced altogether during the overly long, lecture-style debrief, which resulted in loss of attention and difficulties at figuring out the "take-home points." "People were 'done' at that point. No longer in a state to take in more information" said a participant.

Pedagogies of EDU452

The pedagogies were considered to promote inquiry and discussions, and link learning to localities, but occasionally the students felt "there was a lack of science knowledge." This drew out a concern around the extent of frontloading. While some students preferred to begin a topic without pre-readings (especially if (s)he had prior knowledge) to protect the authenticity of inquiry learning, others advocated for more information beforehand to deepen their questions. One participant claimed that she could not determine a perfect balance, but would like some terminologies before the module, and guidance during it. The aim is to support students with just enough information to promote inquiries and critical thinking for constructing their own conclusions. Frontloading in different formats such as handbooks, images or cue cards were also welcomed by the group, but the consensus was that the class should concentrate on inquiries, concise debriefs and post-class resources. This format could be supported by more on-spot explanations and terminologies offered to consolidate scientific deductions during activities. The trade-off depends on (as one student noted) "do you want to leave your students with interest in ES or with ES facts?"

6.1.2 Focus Group Interview of 2019

Change in Learning Attitude and Learning Interest Towards Earth Science

Most participants changed their attitude towards ES because of its importance in understanding places and usefulness in making connections to the "big picture." A participant believed that she has improved her ability to infer about a place using "ES thinking." Another student appreciated the additional insights ES provides. Gaining some knowledge in ES engaged him with the structure and formation of a beautiful rock photo he took in Scotland, which he previously only admired for its aesthetics. He was amazed at how much more he could see through a different lens. Furthermore, all focus group participants believed that ES contributes to solving environmental issues by offering rationales behind EE concepts. A student who has an ES degree commented that in spite of being familiar with some ES topics already, the connection to EE illustrated the "bigger picture," demonstrating the advantage of interdisciplinary learning. This interdisciplinary focus also sparked discussion on how teachers in training could adopt the curriculum in their own teaching career, especially given the new BC curriculum.

Therefore, understanding the “big picture” is essential to develop good ethics that support behavior.

Interest in ES was significantly increased, and this was primarily attributed to the format of the ES incorporation in EDU452. A student realized that inspired by the ES hands-on activities, students began to stop and ask those (students or instructors) with more knowledge for interpretations on interesting features they observed. In simple words, “there was a lot more noticing going on.” The learner-friendly course setting made it interesting, and made her want to learn more. Students also reported that they liked how ES was field-based in EDU452, as opposed to the “classroom components of ES” that are common in universities. Therefore, their enjoyment of ES appears to be format dependent.

Confidence in Teaching Earth Science

Most participants were willing to adopt some activities (e.g. the simulation of liquefaction), yet were hesitant to articulate an increase in confidence towards teaching ES more generally. They believed the course demonstrated ideas about what to include in their teaching to get their future students to notice and think about natural features, which participants felt would prepare them well for higher education. EDU452 as an introductory course prompted their teaching interests, but most felt that more learning is required in future.

Effectiveness & Activities of EDU452

All 3 modules received positive feedback, and the majority claimed their favorite module was Iona Beach (Module 4). Most compliments were on the linkage the activities had to daily life and their demonstration of how geological aspects of the natural world impact society. The concepts of change and relevance were well developed in this module. Students respected that the instructors didn’t force information on those with little background, but let students take the lead in deciding what they wanted to know more about. The instructor’s enthusiasm was infectious.

Pedagogies of EDU452

The majority of the focus group opposed receiving more information prior to the field modules, but advocated for resources for further study afterwards. Everyone appreciated how activities were interwoven with content-rich discussions and supported by a “set-up” lecture. However, debates were around the extent of each. The following conversation during the interview demonstrated a sharp contrast in participant views:

Student A: I liked having both lecture and experience in teaching. If it was only experiences, I would have wanted to know more. If it was only lecture, it wouldn’t be as impressionable or lasting. So, having both was reciprocal.

Student B: I thought the only lecture he (Frank, the researcher) did was on the Geological Time Scale and Earthquakes. I felt that was the only one, and I was grateful that was the only one. Because I’m a more experiential person.

Student A: Oh, really. I would rather have a dozen of both, but that’s probably me.

Student C: I appreciated that we incorporated a lot of ES into the experiences, because I think you can’t learn ES through lecture alone.

The content could be difficult and complex from time to time. Most students understood the frustration and advantages of constructivism, and a few suggested we could further support students with more on-the-spot insights and discussions. Diverse student backgrounds added to the discussions as students brought different perspectives. However, with such a diverse group it was challenging to decide how much to present and how much to hold back for students to construct by themselves.

Place based learning was reported to make the ES content accessible, especially through demonstrations of practical application. Being place-based effectively made ES content locally relevant and matter to those who were new to ES. (i.e. Earthquakes and liquefaction potentially affecting the safety of your house). One participant stated that, “when I was shown features at specific localities instead of reading in textbooks or being lectured to in classrooms, I remember them.” Others also addressed how place-based learning could be flexible, which leaves these student teachers the freedom of choosing other locations for their own teaching. Many commented that they did not take away as much in their undergrad classroom-based classes as in this experience-based, condensed 6-week class with outdoor hands-on field activities.

A successful implementation of the pedagogies further facilitated desire for more incorporation in future. Students felt that ES should be merged using the same method into all six of the EDU452 course modules, making the interface between EE and ES more broadly based. The focus group suggested a complete integration of ES, even if just informal discussions, in all modules. Some noted that, for example, Gambier Island was a missed opportunity for ES. “Even though we learn from each other from the portfolios. I don’t think the last weekend should be devoid of learning. ES should be pervasive,” said a student. “EE is everywhere we go, so should ES be, I want more intersection between the two subjects,” added another. If cross-curricular learning is not uniform in all modules then there are missed opportunities.

6.2 Final Course Evaluation on Earth Science Related Content

6.2.1 Evaluations of 2018

Strengths

Pedagogy was the most praised aspect of the 2018 pilot. Many students enjoyed the modeling of inquiry and place-based learning. A student mentioned “[the] opportunities for inquiry and hands-on activities,” and wrote “getting us out of our comfort zones was helpful.” Another commented that (s)he “[was] able to make connections [and] build on familiar knowledge” indicating the effectiveness of constructivism. Many students appreciated how Dr. Zandvliet facilitated discussions, continually modeled place-based learning and allowed opportunities for students to practice their own teaching. Multiple students appreciated the sense of community developed. They believe this helped them to stay engaged and promoted peer learning.

Weaknesses

The depth of some Earth science content was criticized. A student wrote, “the ‘Earth science’ days had too much information,” sometimes accompanied with “difficult terminologies,” and the instructors “assumed that students knew what [they] were talking about." Another similar comment was "had I not taken a geology course as a recent pre-requisite to PDP, I would not have had a decent amount of familiarity with the terminology and material." Yet, another student wrote "not as much geology as I would have hoped." Overall, students felt there was not enough emphasis on the overlaps or connections between the subjects, but overwhelming information at certain points in the modules. A few other students questioned the structure of some Earth science activities. One of them wrote, "time wasn't used effectively," and supported that with an example of how the learning was interrupted by "too much downtime for lunch [at Deas Island]."

Recommendations for Improvement

All recommendations sought additional ES resources and more widespread incorporation. The class had very varied preference on inquiry learning. Some believed that limited prior knowledge to inquire was an issue, and suggested "some readings, context or vocabulary prior to the activities" so that quality questions could be asked. A student "felt like [they] were just guessing and it seemed pointless." Others preferred "more resources afterwards to back up what [they] have learned."

6.2.2 Evaluations of 2019

Strengths

Many students commented that the learning community was well established, and reported that the class enjoyed the well-structured, well-paced and creative activities. The majority of the compliments were on the pedagogical approaches (especially constructivism and place-based learning). Dr. Zandvliet's encouragement on the ownership of knowledge facilitated inquiries and deep learning. His ability to know when to step back and step in was praised by one of the students as "top notch." Other instructors were said to have made learning comfortable and relaxed through informal discussions and real-world examples. The open-endedness of instruction allowed students to learn from one another and from localities. Lastly, the freedom for open-ended portfolios provided an excellent opportunity for the class to demonstrate their learning in an interdisciplinary course.

Weaknesses

The only weaknesses mentioned were time management for activities. Some had a difficult time with supplies, arrangements, physical endurance and frustration in inquiries.

Recommendations for Improvement

Students asked for more hands-on activities when learning Earth science, and that information and details of activities be made accessible beforehand. Some believed the class should have a stronger investment in indigenous voices.

6.3 Final Portfolios of 2018 and 2019

Statistics / Overview

In the 2018 pilot, 9 of 30 (30%) participants included ES content in their portfolio. The numbers increased to 12 of 24 (50%) for the 2019 pilot. In 2018, most ES-involved portfolios took the format of technology-supported storytelling (5 of 9, 55.6%). A few created artifacts (2 of 9, 22.2%) or performing arts (2 of 9, 22.2%). In 2019, most students who integrated ES in their portfolios chose various forms of artifacts (8 of 12, 66.7%) and performing arts (1 of 12, 8.3%) to express their learning in a more unique, artistic way, rather than booklets or slideshow presentations (3 of 12, 25%).

Format of Incorporation and ES Content

In 2018, many students adopted videos, websites and booklets to illustrate geological structures, the importance of maps, the significance of inquiry, debrief and place-based in learning ES and teaching ES topics in the BC curriculum (Fig. 6.3.1). Students who created artifacts (e.g. blanket and model) focused on the relationship between city and nature. Those who performed to the class emphasized their feelings about the planet after learning more about ES. For example, a student sang a self-written song to express his apology to Earth. Another took a creative and interactive approach that personified city, land, ocean, forest, sky and glacier, and invited the class to participate in a play he wrote.

Portfolios in 2019 represented stronger personal and professional ties to ES compared with 2018 (Fig. 6.3.2). The students chose their format based on personal

Figure 6.3.1 Examples of 2018 Portfolios: a student's presentation on her lesson plan (top left); a hand-knit blanket (top); story sharing (top right); a model of "city" with local materials (bottom left); a booklet (bottom); a comic of a student looking at sedimentary beds.

relevance, and highlighted aspects of ES that were most significant to them. For instance, two students who travel a lot made booklets that described their journey in EDU452. Another student who intends to become an ES teacher created a unit plan for a Grade 11 ES course she hopes to teach in the future. Her detailed plan and how she connected it with her background were impressive.

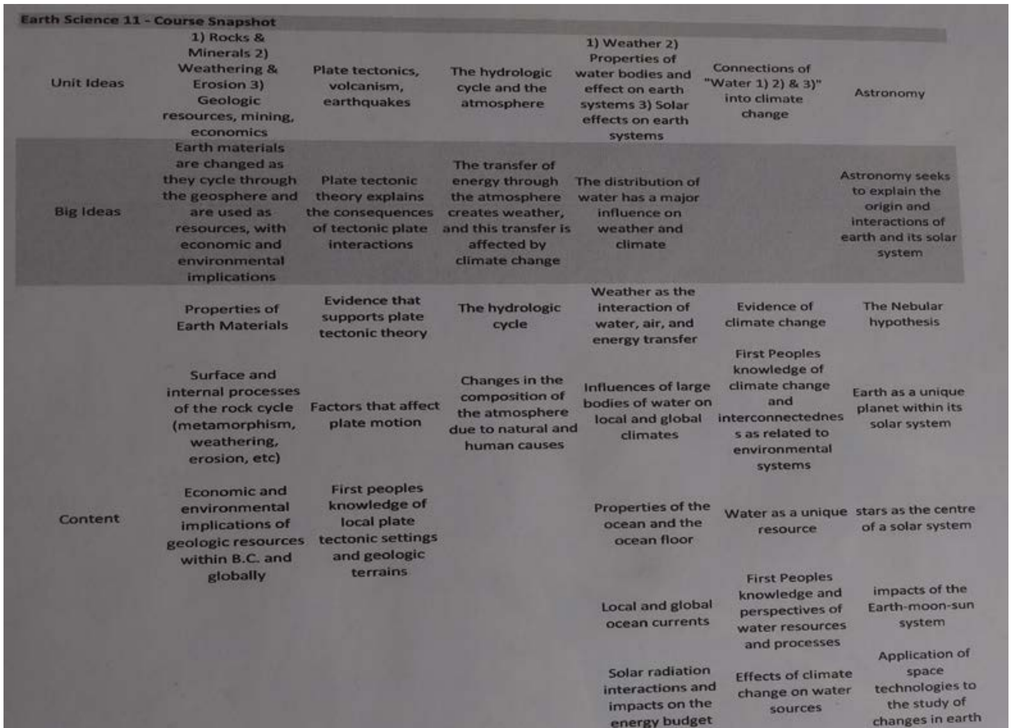
The 2019 ES-integrated artifacts were far more diverse than in 2018: community maps, posters, sketchbooks, comics, paintings, models and dolls. Community maps illustrated the importance of locality and how much ES concepts support EE arguments. Posters emphasized the pervasiveness of ES. Most pieces were inspired by personal experiences (i.e. linked to personal interest in history; immigrant experience etc.). Other artifacts such as Russian Dolls and "Naming the Plastic City" (i.e. a handmade model) activity were also innovative and thoughtful. Lastly, similar to 2018, a student sang a song to encourage people to listen to nature. "If you listen quite close, you will find, even rocks are alive," he wrote. In all, "personal" and "professional" aspects of the portfolio showed significant improvement over 2018.

Depth of ES and Student Uptake

The majority of the 2018 uptake centered around basic ES knowledge and acknowledgement of its connection with EE. The students appreciated the versatility of rocks, recognized the complexity of nature, and cherished the beauty of the dynamic environment. Many recalled the geological history of Burnaby Mountain, the erosional agents at Lynn Canyon, and the importance of utilizing the land wisely. They recognized that the rock and water cycle are important components of environment, setting the stage that supports all life, and having lasting effects on ecosystems. "The environment sets and depends on the Earth, observe carefully and slowly enough, you can always find something new every time you go out" was one of the main takeaways. Some other thoughts reflected in the portfolios were on ES learning and pedagogy. The incorporation in EDU452 inspired many students, and cleared up their skepticism on how ES could play a role in EE. They realized the importance of re-looking and reflecting in interdisciplinary courses.

The 2019 group generally demonstrated more uptake on personal connections to ES, critical thinking outside of the curriculum and detailed applications of ES compared to 2018. "ES philosophy" and its linkage to multiple fields were highlighted. A student created self-made botanical and rock identifications to illustrate "when you look in detail, nature is an infinite number of interconnected, complex systems." Global connection was considered in stories that depict how Earth was colonized by various organisms and eventually humans. Many reiterated that "learning should be holistic, and that no fields could be discussed exclusive of other subjects."

During the portfolio presentations, many students reiterated their personal feelings to ES. Rocks are "imagination, record of time, part of our home" that gave us a sense of urgency for protecting the planet (e.g. from plastics). From environment to recreation, "rocks resonated with me," a student said "although coming from a social science background, ES was actually my favorite part of the course. Science was just fascinating, and this course did a fantastic job of making it appealing." The course changed students' perspective of looking at nature.



Earth Science 11 - Course Snapshot

Unit Ideas	1) Rocks & Minerals 2) Weathering & Erosion 3) Geologic resources, mining, economics	Plate tectonics, volcanism, earthquakes	The hydrologic cycle and the atmosphere	1) Weather 2) Properties of water bodies and effect on earth systems 3) Solar effects on earth systems	Connections of "Water 1) 2) & 3)" into climate change	Astronomy
Big Ideas	Earth materials are changed as they cycle through the geosphere and are used as resources, with economic and environmental implications	Plate tectonic theory explains the consequences of tectonic plate interactions	The transfer of energy through the atmosphere creates weather, and this transfer is affected by climate change	The distribution of water has a major influence on weather and climate		Astronomy seeks to explain the origin and interactions of earth and its solar system
Content	Properties of Earth Materials	Evidence that supports plate tectonic theory	The hydrologic cycle	Weather as the interaction of water, air, and energy transfer	Evidence of climate change	The Nebular hypothesis
	Surface and internal processes of the rock cycle (metamorphism, weathering, erosion, etc)	Factors that affect plate motion	Changes in the composition of the atmosphere due to natural and human causes	Influences of large bodies of water on local and global climates	First Peoples knowledge of climate change and interconnectednes s as related to environmental systems	Earth as a unique planet within its solar system
	Economic and environmental implications of geologic resources within B.C. and globally	First peoples knowledge of local plate tectonic settings and geologic terrains		Properties of the ocean and the ocean floor	Water as a unique resource	stars as the centre of a solar system
				Local and global ocean currents	First Peoples knowledge and perspectives of water resources and processes	impacts of the Earth-moon-sun system
				Solar radiation interactions and impacts on the energy budget	Effects of climate change on water sources	Application of space technologies to the study of changes in earth

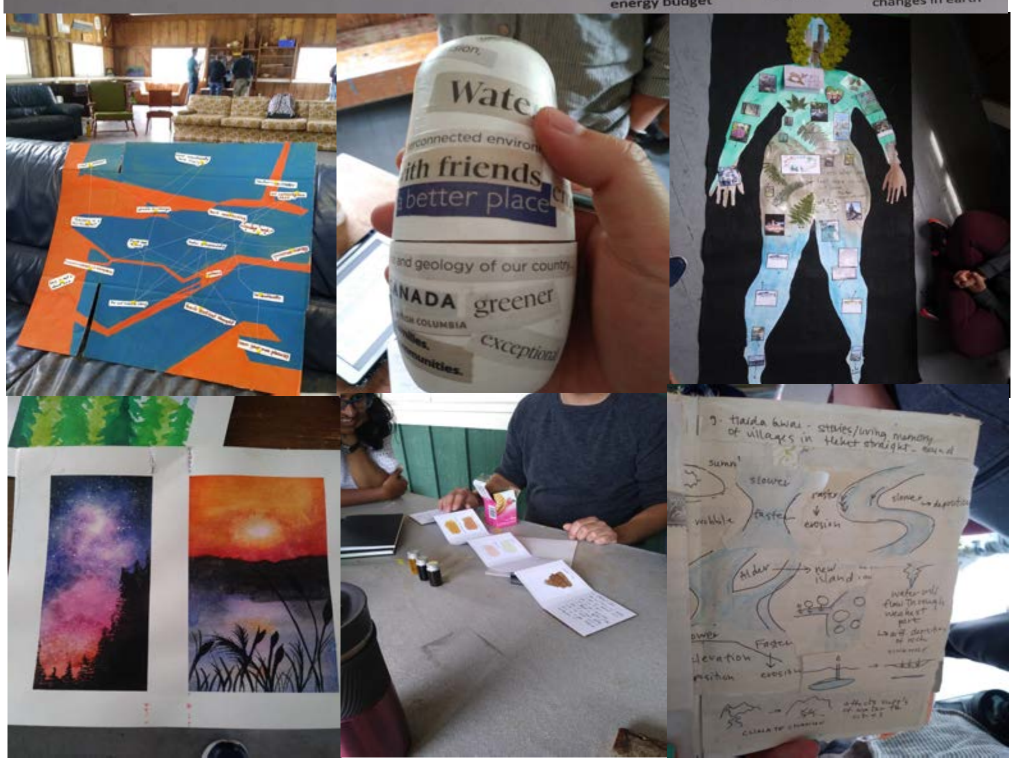


Figure 6.3.2 Examples of 2019 Portfolios: a student's lesson plan of Earth science 11 (top); a map of Vancouver connecting all places EDU452 has been to (middle-left); core of a Russian-doll representing ES (middle); a student's body composed of ES and EE concepts (middle-right); water color showing the connection between Earth and environment (bottom left); homemade ink using coal (bottom); a diagram showing how rivers form (bottom right).

Beyond that, the function of ES as expressed during the portfolio presentations was not limited to philosophical and personal aspects, but also the professional facet (e.g. educating others). Some students mentioned that the core of their learning is rooted in ES concepts. This core supports their acknowledgement of unceded territories and helps understand hydrosphere, biosphere, ecosphere, society and their interactions. This understanding also contributes to place-based teaching practices. Other students presented innovative ideas for ES applications in their future teaching career (e.g. handmade ink). A few other students for their portfolios, developed lesson plans that focused on "[ensuring their] students to understand that what we are wearing and using mostly comes from mining or petroleum." They wanted their students to think about their connection to the Earth, make learning personal and prompt the development of action plans. As a part of their lesson plans, they suggested to adopt Dr. Zandvliet's student-led and discussion-based pedagogy to address the open-endedness of learning - "there is usually more than one right answer in scientific research." The 2019 portfolios had stronger, more explicit recognition of ES, and had more personal relevance, producing a larger "interface" between the subjects.

Chapter 7 Discussion

7.1 Research Question 1: How effective is EDU452 as an interdisciplinary course of Earth science and Environmental Education from a student-centered, teacher-supported learning perspective?

7.1.1 Learning attitude, Learning Interest, Confidence and Knowledge

The MESEES results seem to imply that both pilots of EDU452 produced a positive influence on students' learning attitude, learning interest and confidence in teaching ES. However, students demonstrated generally weaker attitudes and interest in ES compared with EE, since ES relevant items under these measures (e.g. Item 2, 6, 8 & 10; see appendix A) received noticeably lower scores than those related to EE, and for example, field experience and environment. This pattern was observed in both pilots. The interviews and field reflections support the MESEES results, and suggest that less favourable responses to ES (especially in the pre-surveys) were due to the lack of recognition of 1) ES's fundamental role in explaining environmental issues, 2) its relevance to daily life, and 3) the unfamiliarity of seeing EE through the lens of ES. Most negative responses to ES were not because of the content, but rather reflected perceptions and experiences of how ES has been taught (Focus group interview, 2019; e.g. memorization & lecture-based teaching).

Interview feedback suggests that learning attitude may be enhanced when the "interface" between subjects is clarified to demonstrate the usefulness of ES in interdisciplinary education, and learning interest in ES may be promoted when ES is taught through engaging, student-driven pedagogies (Focus group interviews 2018 & 2019). Many students were hesitant to discuss ES because of its intimidating image of being jargon-rich and knowledge-heavy. However, if the instructing team conveys a message of "you don't need to be a professional to discuss ES," students would be more relaxed stepping out of their comfortable zone. Approaching ES from artistic and social perspectives may also improve the confidence of non-ES major students in engaging in the subject (e.g. Interview with a Rock 2018 & 2019; final portfolios). The redesigned EDU452 highlights system thinking, connections between humans and Earth's systems and engaging with practical issues and samples, which are critical aspects mentioned by Egger (2019) to improve learning and better prepare future teachers.

Establishing a tie with practice (e.g. places that are vulnerable to geohazards) further sparked interest in investigating ES. The EDU452 experience demonstrated these points well when the student teachers actively engaged in ES topics in debriefs and began to consider how to empower their future students in learning ES, as shown in a number of the final portfolios and development of lesson plan ideas that incorporate ES. Overall, students were excited to see the overlaps between the two subjects, as indicated both in the informal interviews, which reflected the immediate response to modules, and by the focus group interview results that reflected their cumulative experience.

EDU452 caused students to be more likely to use ES activities in their teaching (Focus group interview 2018 & 2019) by providing an opportunity to be exposed to and learn about ES. Yet, the incorporation in only 3 of 6 modules, at an introductory level, was not enough to make the students confident in teaching ES as a subject. This was revealed by an approximately neutral stance in the CTES measure, which is lower than the learning attitude and learning interest measures. Students seemed to be more comfortable to explain the connection between ES and EE, and teach ES-involved activities through innovative, hands-on activities than ES knowledge itself (i.e. Item 14, 16a, 16b have slightly higher scores than Item 13; focus group interview, 2019). The student teachers wanted to ensure they were capable of explaining most fundamental concepts of ES, so the feeling of "lacking solid science knowledge" could have resulted in a lack of confidence in teaching ES. This indicates that EDU452 needs to consolidate understanding on ES knowledge through thorough explanation and explicit clarification on ES facts, not necessarily increase the depth of ES.

EDU452 significantly improved student's background knowledge in ES and corrected misconceptions. Both cohorts of PDP and PLP teachers demonstrated low levels of pre-existing ES knowledge with widespread misconceptions (Pre-course MESEES 2018 & 2019). This indicated that ES in the formal education for environmental educators may not have received enough attention. The most common source of learning ES is through personal experience (Field reflections Module 1, 2018), often outside of classrooms without guidance, potentially leading to misconceptions. This emphasizes the necessity for instructors to draw out students' pre-existing knowledge to identify misconceptions at the start of modules. The instructors during their interviews also reiterated the importance of providing clear explanations on ES facts, and detailed scaffolding during the activities to mitigate the problem of developing misconceptions during learning. The 2019 pilot effectively reduced misconceptions during teaching (30.8% to 22.6%), while the 2018 pilot did not (23% to 27.8%)). This may reflect differences in the student groups between the cohorts, and also the updates and development of the course informed by the first pilot. The updates for the 2019 pilot also evoked deeper connections to ES, shown in the student portfolios, which demonstrated more quantity, and personal and professional linkages to ES topics covered e.g. incorporation of ES into lesson plans, (Final portfolios of 2018 vs 2019) as well as the recommendation for full-scale incorporation of ES into every module of EDU452. This implies that the action research for improvement was successful and beneficial.

7.1.2 Overall Effectiveness and Activities of EDU452

MESEES illustrated a mostly positive result for overall effectiveness and activities of EDU452 (Item 25-29 & 37-41). Learning ES through hands-on activities presented a new image of how ES could be taught contrasting with most courses associated with passive learning. Many students believed that the activities made ES learner-friendly, and they were willing to adopt them in their own teaching (Focus group interviews 2018 & 2019; final portfolios 2019). Many activities demonstrated the practical use and relevance of ES, (Field reflections & informal interviews), and offered impactful images of particular places (e.g. landslides at Lynn Valley, liquefaction at Iona Beach). Ensuring activities are practical and well connected to specific localities (Informal interviews Module 1, 2 & 4, 2018 & 2019) is a good way to reflect why knowledge gained matters and how student teachers may teach these contents in their own classes. Debriefs and the researcher's info-session helped to support activities. This was shown when the lecture on the geological time scale and geological history of Vancouver (presented during Module 3) created a positive influence on the subsequent modules (Focus group interview, 2019). Concise in-field debriefs such as during the Resource Product Pairing activity and after the Earthquake Simulation Activity helped consolidate understanding (Focus group interview, 2019). In all, well-organized, guided, information-supported activities that establish firm ties to localities created a positive image of ES in EDU452.

7.2 Research Question 2: What is the process or the model of incorporating Earth science into Environmental Education, and how effective is it from a teacher-centered, student-supported perspective?

7.2.1 Inquiry Learning

Based on students' responses during interviews, inquiry learning was shown to be an effective pedagogy to introduce ES. This was probably due to its advantage in quickly engaging learners in experiencing, drawing attention to key features and facilitating discussions (Informal interview & field reflections Module 1, 2018 & 2019). Just as reflected in MESEES, most students preferred to learn ES by "doing" activities rather than by "reading" textbooks (Item 32).

The triangulation between MESEES and student interviews showed a variation in preference for intensity of information that should be offered to support inquiries (the scattered distribution for item 30 & 31, 2018 & 2019; informal interviews). Inquiry learning was said to initiate the learning cycle in a way opposite to lectures, but for ES, which is a very knowledge-based subject, the questions asked during inquiries rely on pre-existing knowledge (Informal interview & instructor interviews, 2018 & 2019). An increase in the depth and abstraction of ES concepts amplifies the tension in inquiry learning between advocates for extensive supporting information and those who prefer to maximize experiencing. This was evident as opinions became increasingly diverse from the introductory module to the most abstract Land Use module (Informal interview Module 1, 2 & 4, 2018 & 2019). Offering a balanced amount of information in a group with diverse backgrounds is challenging. A "happy medium" could be limited information on the context and key skills, while avoiding too much detail (Post-course instructors' interviews, 2018).

Where in the inquiry process information should be introduced was also discussed. There was a clear difference between students who sought in-depth information in advance and those who asserted for post-course resources only (Informal interview Module 1, 2019). A similar tension was also reflected in the instructors' interviews when Mr. Cameron and Dr. Zandvliet had contrasting preference on when and how much information should be offered. The depth of inquiries depends on knowledge, but over-frontloading may impede field experience. Students with no ES background had a higher tendency to ask for guidance during the field activities, but not necessarily frontloading (Informal interview Module 4, 2018). In EDU452, most students would like to know the context beforehand, and then commence their learning in the field through inquiries (e.g. suggested by means of Item 30 & 31 which are >3, 2018 & 2019). Pre-readings could be optional, so that peer teaching in the field would be promoted by those who read them before the class. Learners could maintain the freedom to read more or less, depending on the difficulty of the content or whether the readings took away from their experience. EDU452 sought to refrain from frontloading while providing enough insights to optimize the field experience. In all, activities and overarching questions need to be carefully designed (Field reflections Module 1, 2018 & 2019).

7.2.2 Constructivism

Constructivism underpins inquiry learning. The constructivist process can be facilitated by inquiries, and itself may produce deeper inquiries, giving a positive feedback (Informal interview Module 1, 2018). In informal interviews following the introductory module, students expressed some difficulties inquiring about ES (Informal interview Module 1, 2019). As contents became more challenging in later modules, different students' reactions and approaches became apparent, and could be separated into 3 general categories: 1) "self-directed workers" who actively strive to construct their knowledge in response to inquiries, 2) "cooperative group workers" who develop thoughtful group discussions based on hints from instructors and 3) "knowledge-based workers" who are eager for detailed, pre-constructed information. Self-directed workers usually oppose frontloading and zealously challenge themselves. Cooperative group workers prefer to construct their knowledge framework with some pre-readings. Knowledge-based workers prefer more extensive information prior to the experience. Most students supported and appreciated the "ownership" of knowledge from constructivism despite experiencing frustration to different degrees (Informal interview Module 2 & 4; focus groups 2018 & 2019).

A recent study at Harvard University (Deslauriers et al., 2019) discovered a negative correlation between learners' self-reported perception of learning with active learning (e.g. constructivist learning) and their actual learning. A lower recognition of learning in active learning compared to passive learning (e.g. lecturing) was suggested as in part a result of increased cognitive effort required during the process (Deslauriers et al., 2019). This indicated that learners unfamiliar with active learning could initially assume poor learning due this cognitive struggle, and therefore potentially have their motivation and engagement impaired during the constructivist process. Fortunately, the study also showed that such negative attitude could be changed through clarifications on the purpose of active learning (Deslauriers et al., 2019). Although the students demonstrated different reactions to the constructivist process (Informal interview Module 4, 2018), the purpose and advantage of constructivism in EDU452 was widely understood and accepted (Item 33, MESEES). This is largely attributed to the instructors coaching students in becoming active learners during the activities and discussions. It is crucial for learners to appreciate the process of struggling in constructivist learning. Therefore, it is recommended that explanations on the benefit of constructivism in earlier stages of and during learning be continually carried out in future to ensure a positive motivation and engagement.

To further ensure the efficacy of constructivism, the instructing team needs to be mindful about keeping the constructivist process gradual and well-framed. This learning process could be seen as immersing learners into their unknown regions to explore and experience. However, what is unknown cannot be too disfamiliar to the learners, which means the new concepts need to be somewhat related to the known knowledge of the learners. The region where learning occurs is described by Vygotsky (1987) as the Zone of Proximal Development (ZPD), within which the learners could carry out a task with guidance. If the students were moved too far away from their ZPD, they would be stranded and having difficulties learning. According to Dr. Zandvliet, "constructivism is assuming that we know something and we want to know more, and learn more based on what we know." Therefore, it is recommended to carefully control the depth of knowledge (Instructors' interviews). Similar to inquiry learning, constructivism became more challenging as the depth of knowledge increased, but the end result could be just as rewarding.

In EDU452, students' thoughts on fairness during instruction of different groups and consistently challenging themselves in agonizing (Informal interview Module 4, 2019), were good signs of autonomy being developed in EDU452. "Mutual consulting" and "mutual respect" (DeVries, 2002) were well demonstrated (e.g. Dr. Zandvliet's emphasis on peer and student-teacher communication). This mutual influence fostered cooperative relationships, resulting in students negotiating with instructors for information, as a sign of self-governance that is symbolic for active learners. In future, on-the-spot scaffolding should be enhanced to support students during their constructivist process, as well as establishing collaborative relationships (Informal interviews & focus group interview 2019).

7.2.3 Place-based learning and Learning Environment

Place-based learning proved to be critical to EDU452 because 1) the impact of ES depends very much on visuals, good geological exposures and localities, 2) the explanation ES offers to solve EE issues requires relevance to particular community situations and ecosystems, and 3) place is one of the commonalities of both subjects (Informal interviews & focus group interviews 2018 & 2019). ES by nature is place-based; therefore, locations with captivating geological features are natural assets to introduce ES content. Wise selections of typical localities not only readily attract interest but offer the best settings to aid inquiry and the constructivist process. This was realized when the experience on Deas Island was criticized, while activities were praised on Iona Beach (Informal interviews Module 4, 2018 & 2019). Deas Island was not a "good place" because it is disturbed by human activities, and lacked locations that present typical sediment layering examples of a delta system. This result could also be attributed to the reconnaissance trip to Iona, which greatly informed the instructors on ideal locations to demonstrate typical sedimentary sequences (Debrief interview Module 2, 2019). The instructors were careful to offer suggestions of similar locations, sending a message that learning could be transferred to other locations, making ES involved teaching adaptable.

The focus group interviews emphasized the importance of a good learning environment for adopting innovative pedagogies. None of the inquiry and constructivist learning could have worked in a place-based setting if the students weren't engaged, weren't willing to communicate, weren't cooperating with the instructors, and were restricted to closed-ended assignments and assessments. In EDU452, feedback from students showed that an encouraging learning environment was constructed through activities and leadership leading to positive group cohesiveness, student involvement (informal interview module 1), critical voice, student negotiation (informal interview & field reflection module 2), shared control and open-endedness (The final portfolios).

7.2.4 Difference in Pedagogies

The Pre-course and Post-course Instructors' Interviews indicated that the three instructors each had their own distinct pedagogy. This aided the students in noticing, experiencing and developing a variance in pedagogy, thus gaining the freedom of choosing their preferred pedagogies. During the collaboration, instructors changed their views towards each other's pedagogies (Instructors' interviews 2018 & 2019). Instructors saw that this incorporation of ES in EDU452, offering an opportunity to co-teach and experience different pedagogies, was an unusual experience that helped them gain new insights and appreciations for different ways of approaching learning (Post 2019 instructors' interviews). Co-teaching allowed each instructor in the team to have a critical role offering his or her own specialty and approach, and meanwhile the opportunity to modify teaching strategies to best achieve the learning goals. Collaboration also allowed instructors to support each other, model different ways of teaching, and add to others' comments, making content more enriching and engaging both for the students and the instructors. Thus, co-teaching positively contributed to the design and implementation of activities and course organization. The result of EDU452 indicated that pedagogies can evolve, and different teaching methods do not have to be mutually exclusive. The demonstration of innovative and integrated teaching is critical to foster changes in preparing future K-12 teachers, because many teachers learn how to teach through mimicking and reproducing the teaching strategies they experienced as students (Windschitl & Stroupe, 2017).

7.3 Conceptual and Experiential Learners

Based on student interviews, focus groups, the surveys, and supported by researcher observations, the EDU452 students showed different levels of engagement in activities and contrasting opinions on how the inquiry and constructivist processes could be supported (Field reflections & informal interviews 2018 & 2019). These differences were especially prominent in the 2019 cohort, probably contributing to the overall lower mean score in the Pedagogy measure than in 2018 (MESEES). This phenomenon raises a new question: what is the dominant reason for the difference in engagement and reactions to the pedagogies?

During instructor debriefs and interviews, it was suggested that the difference may be due to the sequencing of ES and EE learning activities during the modules. For some, ES is seen to provide fundamental understanding to help explain EE issues (Debrief meetings & instructors interviews). In this case, introducing ES before EE would contribute to understanding their connection, whereas done vice versa may impede this comprehension (Debrief meeting Module 1, 2019). However, for the students, there was no correlation between the understanding of the connection between the subjects (Informal interview, Module 1, 2019) and the order in which they were introduced. Some students advocated to first introduce EE for the relevance it provides for ES to society (Informal interview, Module 4, 2019). Therefore, the “ideal order” of introducing EE and ES depends on the learners themselves and the purpose of the activity.

Having students with a background in ES in a group was discovered to be beneficial (Informal interview Module 2, 2019) for promoting engagement; however, engagement does not necessarily entirely depend on learners’ pre-existing knowledge in a subject. A variety of backgrounds may help facilitate peer teaching, raising the interest of students in different fields, and providing opportunities to connect knowledge in their own fields to the classroom. For example, nonconforming results were observed between instructors’ speculations on students’ disengagement in debrief meetings and the informal interviews (Module 1, 2019). The second group’s disengagement in the introductory module of 2019 was probably due to tiredness and disorganization. It is proposed here that the main influence on engagement and student reactions depends primarily on the way knowledge is presented and the type of learner.

Table 7.3.1 Key traits of conceptual and experiential learners in EDU452. Information is from the triangulation between field reflections, informal, focus group, and instructor interviews.

Characteristics of Conceptual Learners vs Experiential Learners in EDU452			
Type of Learners/ Traits	**Conceptual Learners**	**Experiential Learners**	**Commonality**
Learning is centered around…	Overt scientific explanations	Connections and relevance of knowledge	Curiosity
Frontloading vs Backloading	Advocate for reasonable amount of frontloading independent of format	Advocate for mostly backloading; only minimal frontloading with place-based discussions (not generic information)	Frontloading could be optional to support inquiries and debrief, but must not impair experience
Prefer…	Knowing before experiencing	Experiencing before knowing	Experience should be supported with hints
Sees the relationship of ES and EE as…	ES is the scientific foundation of EE; EE is the application of ES	EE provides relevance for ES; ES deepens learning in EE	Both subjects are inseparable from each other
Pay more attention to…	Depth and amount of information	How and when the information is offered	Solid information that supports learning
Prefer to be exposed to…	ES before EE	EE before ES	N/A
Regarding Constructivism…	Prefer more on-the-spot explanation and information, and dislike the frustrating process	Enjoy even while experiencing frustration, and prefer full immersion in experience	Understand the point of constructivism, and advocate for it.
Typical Quotes	"I want to know this, just tell me!" "I love how ES explains what happens underground."	"I want to experience this" "I want to figure out myself" "If I didn't see the connection with ES, I would probably not be interested in it"	Understand the significance of an interdisciplinary course "You can't really teach one without the other."

In Kolb's (1984) Experiential Learning Theories, learning occurs in four stages: 1) concrete experience (CE) 2) reflective observation (RO), 3) abstract conceptualization (AC) and 4) active experimentation (AE). These stages depict an experiential learning cycle where a learner immerses (CE) into, and reflects (RO) on, a new experience, then theorizes reflections into concepts (AC), and finally applies problem solving (AE). The

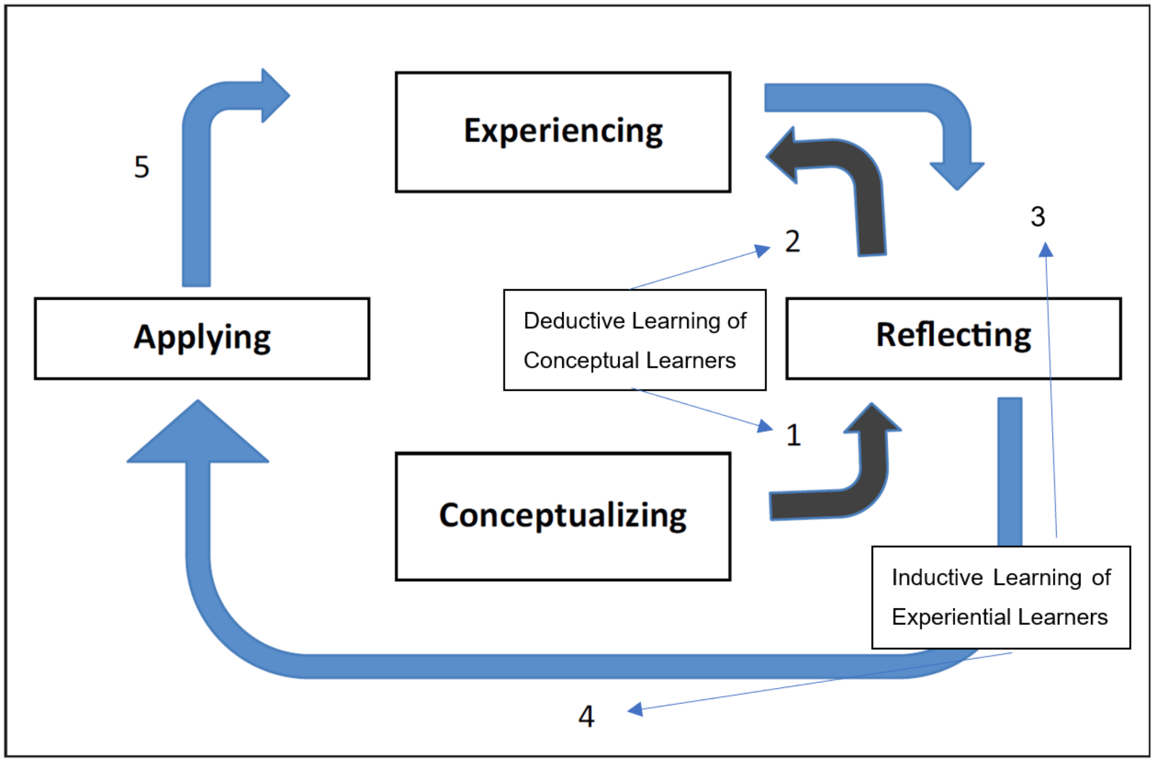


Figure 7.3.1 A combined model of conceptual and experiential learning cycles, modified from Rodgers et al., 2016. Conceptual and experiential learners would begin their learning at different points in the cycle (conceptualizing and experiencing respectively).

conceptual learning cycle reverses how knowledge is acquired in Kolb's experiential learning cycle by reflecting on concepts before in-field experiencing (Rodgers et al., 2016; Coleman, 1976). According to Rodgers (2006) experience could influence perception of learning and vice versa. Experiential learners rely on inductive learning (from real-world examples to concepts) and conceptual learners rely on deductive learning (from concepts to real-world examples) (Rodgers et al., 2016). In EDU452, the conceptual learning cycle could be seen as embedded within the experiential learning cycle but with the addition of two extra steps before experiencing. That is, "frontloading" described by many students and the instructors, essentially representing conceptual support and reflections before the actual field experience (Fig. 7.3.1).

Individuals’ different cognitive learning styles lead to preferences for various modes of presentation of knowledge, or learning models (Norman, 1983; Van der Veer & Felt, 1983; Wu et al., 1998). Kolb (1984) believed that a person’s learning style is determined by a combination of how information is perceived and processed. The “concrete abstract continuum” describes how learners either perceive information through CE (sensing) or AC (thinking), and the “active-reflective continuum” describes how perceived information can be processed through either AE (hands-on activities) or RO (mental reflection) (Wu et al., 1998; Lu et al., 2007). Therefore, these standards are polar opposite (AC vs CE; AE vs RO), which means a learner would have to develop a preference for a set of learning skills (Kolb, 1984; Kolb & Kolb, 2005). Preferences cause students to respond differently to distinctive pedagogies (e.g. different response to inquiry and constructivist learning shown in informal interviews 2018 & 2019), and therefore teaching strategies should aim to understand and be aware of preferred learning styles (e.g. Wu et al., 1998). According to these two dimensions, learners could be categorized into: 1) Diverging (CE+RO), 2) Assimilating (AC+RO), 3) Converging (AC+AE) and 4) Accommodating (CE+AE) (Kolb, 1984; Kolb & Kolb, 2005).

EDU452 expects students to both act and reflect during critical thinking and hands-on activities, and no intense debates regarding the transformation of knowledge (how knowledge was processed) were encountered during the research. Thus, the “active-reflective continuum” dimension is predicted to have had little impact on opinions around frontloading, preferences for constructivism and views towards the relationship between ES and EE, and therefore is not discussed further in this research. For EDU452, Converging and Assimilating Learners were grouped into “conceptual learners” and Diverging and Accommodating Learners into “experiential learners.” Each type of learner has a preferred way of learning. In an interdisciplinary course for a group of students with diverse backgrounds, maintaining a balance between their preferences while implementing the pedagogies is vital.

Conceptual learners begin their learning process by perceiving scientific explanations of concept and expanding their understanding using real-world examples. They strive for well-structured frameworks that help introduce fundamental knowledge before the inquiry process or hands-on activities. In EDU452, these conceptual learners consider ES content to be the fundamental mechanism to understand environmental issues, and would like to acquire ES knowledge before exposure to environmental content. Conceptual learners prefer to have some degree of information, i.e., one page of vocabularies, overarching themes or even some frontloading, to set up for inquires. Such demand was well pronounced in the informal interviews (2018 & 2019). These students believe that obtaining the framework/scope of the discussion beforehand is more helpful than stepping into the field blindly. Most of the conceptual learners would also prefer additional readings (i.e. backloading) after their experience. Their learning in EDU452 was described as “bottom-up comprehension” since the core of their learning roots in the foundational theories of the planet (Informal interview Module 2, 2019).

Experiential learners pursue autonomy in their learning. They feel the necessity of starting the learning process with inquiries, and prefer to maintain the freedom of choosing their questions. Frontloading is usually opposed since it was believed to impair learning interest by impeding field experience. Yet, “smart frontloading” with place-based discussions or info-sessions (e.g. lecture before Module 4, 2019) rather than generic information were considered acceptable. These students commonly feel that abstract ideas are disjunctive from reality or personal lives. Without developing enough connections with inquiry and hands-on activities, it is difficult to keep them engaged in the discussion. They insist on more involvement in hands-on activities and further post-course readings. To them, it is the experience and activities that make scientific explanations stick in their minds. In EDU452, they prefer that EE be introduced before ES, because this establishes relevance and makes the connection with ES matter. Experiential learners prefer to engage with theories after their significance has been clarified through more relevant topics. This explains why some students disapproved of a coherent, natural relationship between ES and EE. To experiential learners EE discusses a place on the “surface,” and ES helps us to discover what is underneath. Their learning in EDU452 was described as “top-down comprehension” since the core of their learning initiates from the issues of surficial environment (e.g. Informal interview Module 4, 2019).

Both types of learners enjoy real-world examples either with or without additional information from text readings. In general, conceptual learners prefer their experience to be enriched by in-depth information, while experiential learners seek for more emotionally triggering, personally related, place-specific, activity-based experiences. Note that these types are the end members of a learning spectrum, and a learner may fall anywhere in the middle, possessing a combination of traits. Preference of learners is also not static. Mr. Cameron and Dr. Zandvliet used their changes through the two-year journey to demonstrate how both types of learning could co-exist and be supportive of each other. There is always common ground where we may reach a balance (e.g. having articles and images in advance, followed by interwoven activities and explanations (Informal interview Module 1, 2019). Cooperation, such as was examined in this study of EDU452, is an active research process.

Finally, there seems to be a tendency for students to shift towards conceptual learning when content becomes difficult (Informal interviews 1, 2 & 4, 2018 & 2019). More conceptual learning tends to promote intense learning of facts rather than extensive discussion based on experience. The liquefaction activity at Iona Beach was a good example of explaining complex abstract knowledge in a descriptive way. Implementing such well-designed hands-on activities and eyes-on features to simplify difficult content may potentially facilitate critical thinking, promote learning interest in each subject, and also preserve the “interface” between them.

Chapter 8 Conclusion

Overview of EDU452

The Earth science content incorporated in the three modules of EDU452 functioned well as a "spotlight" for introducing ES. Students gained basic knowledge of plate tectonics, bedding, superposition, slope stability (Module 1), erosional features, carrying capacity, glaciation (Module 2), characteristics of a delta system, geological history of Vancouver, geological resources and hazards (Module 4). The EDU452 students gained an appreciation for the value of ES in EE education, as a foundation for EE decision-making, and also as a way of understanding place more deeply.

The redesigned EDU452 seemed to effectively improve learning attitude and learning interest towards ES. Students gained recognition of 1) Earth Science's fundamental role in explaining environmental issues, 2) its relevance to daily life and 3) the excitement of seeing EE through the lens of ES. The reciprocal roles of ES and EE to each other perfectly manifested the significance of interdisciplinary knowledge, and this was well acknowledged in both pilots.

Linking ES to artistic, social or historical facets greatly contributed to the increase in learning interest towards ES, conveying a message that learners do not need to be experts to discuss ES. Making activities and discussions "informal" and "casual" promoted engagement and aided related conversations to students' own background. The students not only had their own learning interest increased, but also pondered about how to empower others to do so. The students further proved their excitement towards interdisciplinary teaching by suggesting a formal incorporation of ES into all modules of EDU452.

EDU452 has a more limited influence on confidence in teaching ES. Introduction of some fundamental ES concepts stimulated willingness to involve ES activities in their own teaching and allowed students to become more comfortable and feel qualified to answer relevant questions related to these topics; however, not to an extent where the students felt they were well-prepared to teach the breadth of ES subjects. The sense of relevance and curiosity around ES topics in EDU452 should be considered a breakthrough for learners outside of the field, encouraging them to pursue further education in ES.

Incorporation of Earth Science

The way ES was incorporated into EDU452 contrasted with students' prior experiences with ES instruction in schools and universities, and positively contributed to the influence on students. Passive and teacher-centered pedagogies seemed to have already formed a stereotype that ES is difficult, memorization-based and irrelevant. In EDU452, students were satisfied with the way ES was introduced in experiential, practical, student and teacher-friendly, hands-on activities. It was valuable for the instructors to "hold-back" information and allow students to take the initiative on deciding what they want to know. Succinct, student-driven and place-based debriefs enriched by plenty of visuals outperformed long, descriptive ones as a better way to engage learners.

The carefully managed depth of ES knowledge also played an important role. EDU452 focuses on the "interface" between the two subjects, and sought to maximize "horizontal expansion" of their overlapping while minimizing "vertical extension" of ES knowledge. This avoided overwhelming learners with excessive information, but instead effectively captured their interest.

More recognition of the integration of content and pedagogies in 2019 was also reflected in the final portfolios, which included greater ES involvement in diverse, creative and more personal-related formats. The way ES modules were implemented ignited passion in ES, as the first step in developing teachers who are aware of, enthusiastic about and interested in teaching Earth science.

Inquiry Learning

Inquiry learning was effective at initiating a learning cycle in a learner-friendly way that mimics the real-world scientific research process. Learners in EDU452 preferred inquiries guided by overarching questions over pre-readings, and could easily adapt to the observational stage.

Open-ended self-leading discoveries were considered favourable, yet the results suggest that this could also be a double-edged sword. As more abstract concepts were introduced, students without a strong background in ES struggled to produce quality inquiries, and voices advocating for front loading began to be heard. Therefore, careful design of overarching questions together with pre-class and in-field support are required to optimize the student experience. The degree of guidance for inquiry learning must be adjusted according to the background understanding of individuals and the conceptual difficulty.

Clarification of the purpose and definition of inquiry learning up front should help enhance the inquiry process. Analogies, hands-on activities and connections to relevant contemporary topics may also aid explanations. Inquiry learning was found to be effective in promoting active learners and thinkers.

Constructivism

Constructivism, as the “cornerstone for pedagogy,” helped build understanding and develop autonomy. The capability of managing one’s own learning is critical for anyone that is considering becoming a teacher, and this is highlighted by “ownership” of knowledge. The constructivist process helped expand the ZPD of learners and produce more inquiries for a positive feedback. Since cognitive dissonance is the first step of constructivism, exposing and unlearning misconceptions is a disruptive process. Therefore, it is expected that learners may experience various degree of frustration and may react differently to constructivism.

The process requires an appropriate amount of time for students to absorb information and critically think. Over-rushed or too-slow paced activities with unguided discussions impair the experience and eventually demotivate learners. Providing equal information to all students and carefully planning for on-the-spot guidance that gradually expands learners’ ZPD are critical for a positive experience. The instructors also should explicitly explain the value of increased cognitive efforts early during the constructivist process to persuade students that active instruction is beneficial. The development of autonomy as a sign of self-regulation was revealed when some students in EDU452 urged for fairness of instruction and in-field cooperation with the instructors. Similar to inquiry learning, the success of constructivism depends on the design and organization of activities.

Place-based Learning and Learning Environment

Place-based learning provided a linkage between knowledge and places, which immediately made activities relevant and meaningful in the day-to-day lived experience. Leading the class to specific familiar localities humbled the students with a “sense of not knowing.” With full immersion into the local environment using all five senses, knowledge gained leaves strong impressions and establishes learning at a personal level.

In choosing effective locations, reconnaissance trips were critical, providing opportunities for instructors to test a variety of locations, try out activities and search for effective spots for activities and other course components. Place-based learning does not contradict lectures or readings, and instead could be supported by them, as recommended by the students. In EDU452, both classes enjoyed the opportunity to learn in-place, and were willing to adopt this approach in their own teaching. The supportive learning environment ensured the successful implementation of all pedagogies.

Difference in Pedagogies and Integrated Teaching Strategies

The collaborative teaching exhibited by the EDU452 instructors demonstrated a wide spectrum of adoptable pedagogical approaches for students, and also showed the potential for integration of teaching strategies between teachers with various preferences. The instructors of EDU452 demonstrated differences in their teaching strategies at the beginning of the collaboration. This allowed some freedom for pre-service teachers to discover their preference, from descriptive lecturing to constructivist discussion. In the second pilot, as the instructors became more comfortable both within the course and also with each other’s teaching styles, a happy median was reached as all instructors developed a student-centered, inquiry-oriented teaching strategy. This highlighted the potential for integrated teaching even between different teaching models, which is believed to enhance the congruency of the two subjects.

The instructors themselves gained insights into different methods of supporting learning, the importance of constructivist teaching strategies and learning environment, and there was a renewed interest in ES developed through the experience. Clarifying the instructional models and maintaining a good coordination between each instructor to define distinctive roles in the course may positively contribute to co-teaching.

Learning Styles

Individuals' different cognitive learning styles lead to preferences for learning models (Norman, 1983; Van der Veer & Felt, 1983; Wu et al., 1998). Kolb's (1984) Experimental Learning Theories described how knowledge can be perceived through either conceptualization or concrete experience. In EDU452, this is foregrounded by a contrasting description of the "ideal structure of constructivism," which separated the students into conceptual learners and experiential learners.

Conceptual learners are knowledge-based learners who seek well-structured frameworks of scientific explanations. They advocate frontloading of information, and seek depth of knowledge. Their learning in EDU452 is symbolized by "bottom-up comprehension;" viewing ES as the foundation for EE. Experiential learners are inquiry-based learners who pursue autonomy and relevance of knowledge. Only minimal frontloading that is place-specific was acceptable to them. They sought strong ties to localities, and paid more attention to the format in which knowledge is presented. Their learning in EDU452 can be considered as "top-down comprehension;" where they view EE as providing the relevance for ES. Therefore, ES and EE both could be seen as the foundation to the other, depending on the students.

Preference of learning models does not have to be static. Both learning styles could co-exist and be supportive of each other. Engagement truly depends on the synchrony between the pedagogy that influences the ways knowledge is presented and the type of learner.

Suggestions for the Future

Based on the EDU452 experiences described here, it is recommended that ES be broadly incorporated across all modules of EDU452, and formalized as an integral part of all aspects of the course. The continuing presence of an ES instructor for scaffolding and as a resource person would support this full integration. The course design could be enhanced by the offering of clear, optional pre-readings, "hooks" or leading questions for better engaging students, field booklets and identification charts, and additional post-course resources for further studies. In-field experience may be improved through further on-spot guidance, reduction in group numbers, and optimization of time management.

Learning should be as specialized to individuals as possible, especially at the professional development level. Instructors who are capable of developing a positive learning community are required. It is also recommended that, if possible, teachers have the opportunity to collaborate and co-teach in order to experience a variety of teaching approaches, receive feedback on their own teaching and learn that different pedagogies are not mutually exclusive. Either a “happy median” needs to be set for different styles of learners, or the instructors should support learners to personalize their learning. It is important to find the “interface” between subjects, learning styles and pedagogies for all interdisciplinary courses.

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Appendix A

MESEES & Results

Description:

The attachments include the pre-course and post-course questionnaires of MESEES, and the frequency response table of both pilot's result.

Filename:

Appendix A Pre-course MESEES.pdf

Appendix A Post-course MESEES.pdf

Appendix A 2018 MESEES Frequency Response Table.xlsx

Appendix A 2019 MESEES Frequency Response Table.xlsx

Appendix B

EDU452 Course Curriculum & CARE Framework

Description:

The attachments include the most updated course curriculum of EDU452 (2019).

Filename:

Appendix B EDU452 Course Curriculum 2019.doc

Appendix C

Students' Informal & Focus Group Interview Questions

Informal Interview Questions 2018 & 2019

1. What have you learned from the Earth science activities in this module?

2. Do you think the Earth science activities were enjoyable and well-designed?

3. Do you think the Earth science content was well-merged and useful to environmental education? If no, why not? If yes, how did it help?

4. How did you like the pedagogical approaches of your instructors?

5. What is your comment on learning through inquiries / asking questions? What did you find the advantage and disadvantage was?

6. Did you enjoy the process of building your own knowledge or would you rather have the instructors to be more informative upfront?

7. Did you like the place-based real-world examples? How do you feel about it compare to a lecture setting with more readings?

8. Comment on something you believe the instructors did / did not do well, and provide suggestions for future activities.

Focus Group Interview Questions 2018 & 2019

1. Comment on the overall learning environment of this course (educational approach/ social context/ physical setting etc.) and how it influenced Earth science contents in the course.

2. Describe the change of your appreciation and understanding on the importance of Earth science before and after taking this course (change in learning attitude). How do you see places differently in your life now that you have some Earth science knowledge and experience?

3. Do you like Earth science now (change in learning interest)? What do you like or dislike about it?

4. What do you think about how Earth science was merged into environmental education and the overall performance of the course (Earth science incorporation)?

5. Do you feel more confident and comfortable about teaching Earth science contents with environmental education or your own subject in your teaching career (confidence in teaching ES)? Why?

6. How do you think Earth science supports environmental education or the other way around? What do you think the role of Earth science is for mitigating environmental issues (EDU452 Effectiveness)?

7. Thinking about Earth science, which modules, where and which parts did you learn the most? What activities, inquiries or discussions did you like the most and which do you think require more improvement?

8. Would you like more beforehand resources and information prior to field experience or would you like learning through inquiries (Inquiry Learning)? Explain.

9. Would you like the freedom of constructing your own understanding based on hints and clues or would you rather have your instructors present complete information? Explain the purpose or reasons to your preference (constructivism).

10. What are your comments on learning in-place (place-based learning)?

11. What would you like us to do differently if you were to take the course again? Are there any other subjects or Earth science topics or approaches for teaching Earth science you would like us to include?

Appendix D

Instructors' Interview Questions

2018 Pre-course Interview Questions

Section A - Basic Information of the Course

1. Which modules were you directly or indirectly involved with?
2. What background readings did you provide to your students or recommended them to read? What is your stance on pre-readings?
3. What are the themes and the purpose of the course?
4. Describe the activities. How were they carried out? What did you do with your students?
5. What materials were involved/used during the field trip?
6. What was the size of the group?
7. What are some assessments on the effectiveness of the field trip?

Section B - Outcomes and Feedback

8. What is your comment on the learning outcome and course performance?
9. What do you think the impression of your student was?
10. Please comment on the significance of Earth science activities to the course.
11. How and when did you ask students for the feedback/reflections?

Section C - Suggestions and Improvement

12. What would you change if you were to design the project once more? What were the difficulties you have encountered during the 2017 field trips?

13. What would you suggest for readings, demonstrations, overviews before the field trip?

14. Possible locations for new field trips in the upcoming semesters include the Vancouver Aquarium, the Bowen Island, and the Whyte Cliff. Do you have any specific suggestions/ideas that you wish to note here?

2018 Post-course Interview and 2019 Pre-course Interview Questions

Section A - 2018 Course Performance and Earth science Incorporation

1. Comment on the performance of the 2018 pilot.

2. Do you think Earth science was necessary for this environmental education course? What's its influence on students? What is your current stance for this incorporation?

3. Do you like how Earth science was incorporated with environmental education? Why or why not?

4. How do you think the 2018 pilot improved from the previous run?

5. What do you think the largest remaining problem is?

Section B - Activities

6. Comment on the activities that worked well and not well. What do you believe was the reason they worked well or not well?

7. Comment on the connections between Earth science and environmental education activities.

8. Comment on how the activities adopted pedagogies.

Section C - Pedagogies

9. Comment on inquiry learning and its influence on the course.

10. Comment on constructivist learning and its influence on the course.

11. Why do you think place-based learning was critical to this course?

Section D - Contents of the 2019 Pilot

12. Would you like more or less Earth science content to be in EDU452? What are some adjustments in contents / topics you would like to make?

13. Would you like to change the format of how Earth science was incorporated into EDU452? If yes, what changes would you like to make?

14. What changes would you make for activities in 2019?

Section E - Pedagogies of the 2019 Pilot

15. Which of the learning models do you think requires more attention next year? What suggestions do you have to improve it?

16. Would you change your own pedagogy for the next pilot?

17. Would you like more opportunities for integrated teaching or have students experience different pedagogies?

2019 Post-course Interview Questions

Section A - 2019 Course Performance and Earth science Incorporation

1. Comment on the performance of the 2019 pilot.

2. Do you think Earth science was necessary for this environmental education course? What's its influence on students? What is your current stance for this incorporation?

3. Do you like how Earth science was incorporated with environmental education? Why or why not?

4. How do you think the 2018 pilot improved from the previous run?

5. What do you think the largest remaining problem is?

Section B - Activities

6. Comment on the activities that worked well and not well. What do you believe was the reason they worked well or not well?

7. Comment on the connections between Earth science and environmental education activities.

8. Comment on how the activities adopted pedagogies.

Section C - Pedagogies

9. Comment on inquiry learning and its influence on the course.

10. Comment on constructivist learning and its influence on the course.

11. Why do you think place-based learning was critical to this course?

12. How do you think these pedagogies will influence the students in their teaching? What are your expectations?

Section D – Future and About Yourself

13. What is your current stance / expectations on the prospect of EDU452 and Earth science involved interdisciplinary courses in future?

14. Comment on the largest change (pedagogical, attitude, interest towards Earth science etc.) of yourself through this 2-year research.

15. Comment on the other two instructors. What have you learned from this experience? Describe your largest take-away.

Appendix E

Researcher's Field Reflections

Table E.1 The Summary of Researcher's Field Reflections on Module 1 "Education In, For and About the Environment"

Aspect	**Observer's Observation/ Comments**	**Behaviors/ Activities/ Evidences**	**Quotes/ Comments/ Feedback**
Earth Science Knowledge	The principal of plate tectonics and the geological location of Vancouver were introduced.	E.g. using your hands to mimic possible movements of plates; debate on thickness of tectonic plates; where is Vancouver?	Most students were engaged to mimic plate motion with hands (2019). Majority of the class joined the debate of whether continental or oceanic plates were thicker (2019).
	Beddings on northern face of Burnaby mountains were discovered.	Most people were amazed when they first observed bedding in an outcrop	
	Terrestrial, underwater and glacial depositional features were used to infer local paleoenvironment.	E.g. both groups loved the water-sand bucket experiment (pouring sand in air vs in water); erratic; cross-bedding etc.	"This is actually pretty cool (referring to the bucket experiment). They actually have very different degrees in water and air (student, 2019)."
	Students learned slope stability and local landslides	E.g. resulting pistol bottomed trees; infrastructures location	
Connection Between Earth Science and Environmental Education	Students realized Earth science and environmental education are complementary to each other.	To explain why "pistol bottomed trees" form, knowledge on slope stability and soil creep was required. E.g. landslides gave rise to red alders and ferns; similarities between mineral and plant species identification (using 5 senses).	A student planned to create an ancient feather pen (2018). His ingredients were a perfect combination of environmental and geological resources: local coal discovered in beds + alcohol + lamp smoke + Arabic gum = traditional ink; blackberry + vinegar + halite (salt) = kid-friendly ink

Complexity	Many students came to their first realization of nature was much more complicated than they thought.	E.g. “nurse trees” formed because they desired a “jump start” in their growth; cross-bedded Eocene gravels could only form in a river system; till indicated glaciers; heat tolerant plants survived forest fires; logging marks imply human intervention	The entire class started off fast as though many students were impatient (or fast hikers), and gradually slowed down as more complex stories been discovered.
	Interweaving Earth science concepts through inquiries and shocking facts was a good idea.	E.g. many students were amazed when small features such as local topography was impacted by global tectonic events; the entire Strait of Georgia was under glacier 25,000 years ago.	“You guys gotta slow down! When you tell me the ice above Burnaby Mountain was over 1km thick, give me 2 minutes (A student with biology background, 2019).” Most students could infer the erratic was moved by ice, but hardly imagined from northern valleys across the Burrard Inlet (2018).
	Visualization helps explain the complexity of nature.	“It would take you over 100 years to even just count 4.6 billion loonies (Cameron, 2019).”	“Billions of years is an expression that’s off the scale of what I could imagine. It’s just a number when I can’t visualize it. My grandfather lived about 90 years, so his heart beat more than 3 billion times (Student, 2019)!”
Aesthetics	Fascinating features that impressed students led to the amazement and appreciation to nature and the planet.	Diverse lifeforms (Douglas firs, cedar, wine maple, big leaf maple, ferns etc.) and characteristics of differential weathering frequently amazed the class; images worked better than numbers.	“I never thought real coal seams could be so perfectly layered and accessible just off campus (Student, 2019).” “Humans were the only intelligent species that genuinely pursue aesthetics in nature. Think about this: we can’t even tolerate the smell of our own feces (Zandvliet, 2018)!”
Responsibility	Students realized their responsibility of preserving environment after shown how human civilization extracted resource from nature.	E.g. logging marks, coal seams, the salmon hatchery in the afternoon rose lots of discussion on social responsibilities and education	“I think its our responsibility to educate our future generations to appreciate what we have, to be thoughtful and also responsible for the environment (Student, 2019).”

Ethics	Students admitted the motivation of solving environmental issues should by driven by ethics.	Some students were critically thinking about the purpose of the salmon hatchery and its long term influence on the ecosystem.	“When you have ethics, you are doing it for your moral beliefs, not to avoid punishment (Zandvliet, 2018).” “The hatchery is not like a fish farm, as the whole purpose of raising the salmon is to help them through the most dangerous period of their lifecycle, not to harvest them (Rod MacVicar, the director of the hatchery, 2019)”
Inquiry Learning	It was important to create suspense by not directly answering questions during an inquiry process. This allowed students to take initiatives.	The instructors often guided with questions like “what may I ask when I see something unknown to me?”	“I have been around here for 11 years, but never explored these trails. I really appreciate this opportunity to explore (Student, 2018).” “I don’t like him to tell us;” “I think she wants us to figure it out (Student, 2018).”
	Clarifying the definition and the purpose of inquiry learning beforehand and leaving more freedom strengthened its influence.	Students were more willing to ask in general; the inquiry process was more fluent in 2019 than 2018.	Many students demonstrated more understanding on the inquiry process along the hike and during informal interviews.
	Having a few students with strong backgrounds in a group helped facilitate inquiry process.	Quality questions allowed the introduction of tiling, folding, cross-beds, mass wasting etc.	the 2nd group of 2019 mostly had no background in Earth science and was not as engaging as the first group.
Constructivist Learning	The constructivism process was done through a “notice, ask, discuss and answer” manner.	Questions were expanded with supporting evidences, pictures, hand-samples etc.; discussions were organized in a train of thoughts for conclusions to be made.	A few students who were guessing could not support a hypothesis with evidences or logics, and had to re-think through the process. “why,” “what if,” “what else will happen” were often asked to facilitate inference. E.g. “what if the rocks were transported by ice? What traits do you expect (2019)?”

	Relating geological events to popular topics helps explain concepts.	E.g. the last glacial maximum was related to the movie "Ice Age;" superposition was compared to a "layered cake;" cracked egg shells for plate tectonics	Sounds of people understanding the concepts were commonly heard after analogies were made. "So the coals are dark because black means organic rich? Just like why the soil in my garden is dark in color (Student, 2019)?"
	Hands-on activities added to the experience.	E.g. the water-sand bucket experiment for testing depositional media	*See the quote in in "Earth science knowledge"
Place-based learning	Personal learning for Earth science and environmental education was only possible in a place-based setting.	All examples and discussions linked to actual image or sample of the locality.	Most of the class were engaged and active as the learning connected to the locality.
	Disassembling the formal classroom into outdoor small groups promoted teamwork and closer ties to real life.	The class was divided into 3 groups for 2018 and 2 for 2019, both created an overall positive atmosphere.	Students were relaxed and casual in an informal setting. "Education around a place is an investigation, a negotiation, a meeting (Zandvliet, 2019)"
Learning Environment	Sharing personal experience and life examples helps develop a positive learning environment.	E.g. when the class began with an open-ended discussion personal experience, most of the class were surprised at how much personal relations they had to Earth science	Mr. Cameron was surprised when a student asked about ArcGIS after seeing local aerial maps on a tough pad, a commonly used contemporary technology in professional geology fields.
	Allowing enough time to develop a good learning community is vital to a class.	Zandvliet left much time for personal communication during the hike and the overnight retreat.	Student interactions indicated a success with this plan.

Table E.2 The Summary of Researcher's Field Reflections on Module 2 "Managing a Slippery Resource"			
Aspect	**Observer's Observation/ Comments**	**Behaviors/ Activities/ Evidences**	**Quotes/ Comments/ Feedback**
Earth Science Knowledge	Students learned about depositional agents and water management.	E.g. observations along the valley; local landscapes etc.	
	Students discovered the relationship between flow speed, river channel cross-sectional area, discharge and carrying capacity.	E.g. developing a formula for discharge; discussing on how flow speed of a river influenced the largest grains it could carry	Many students questioned about some factors that influence the appearance of rocks as they walked along the valley (e.g. size, rounding and sorting)
	The debrief helped review glaciation and tectonic events from module 1.	E.g. discussions extended to geological history & evidence for glaciers etc.	
Connection Between Earth Science and Environmental Education	Students acknowledged that Earth science and Environmental Education are inseparable after shown a local landslide example.	E.g. At the lounge landslide area, long, insightful discussions about the relevance between geological and environmental factors echoed among students; environmental researchers need to be able to tell what is underneath based on is seen on surface	"North Van is one of the wettest places on Earth. Logging and removing vegetation and heavy rainfall contribute to slope failure. (Zandvliet, 2019)" "As a forestry researcher, I need to know geology as well, for what you do to your land affects other fields (Student, 2019)"
Complexity	Students realized how much history there is embedded in a rock.	E.g. "Interview with a Rock" Activity	A poem from a rock's perspective: "People have spoken to me (the rock) in many languages; I know many languages, but very few know mine. (2019)"

	The complexity of nature was highlighted by its dynamic energy this module.	E.g. glaciers affected by procession and eccentricity leave traces as they pass; rivers deposit rocks and carves valleys as they travel etc.	I overheard at least 3/6 groups debating about superposition when they saw a tree trunk that was probably disturbed by a past flood stuck underneath some sandy beddings. (2018) “The mountains tell a more complex history than just its height or what grows on the surface. (2019)”
Aesthetics	Students were amazed at the strength and power of the river, and how this environment dramatically differed from what was seen on Burnaby Mountain.	Many beautiful factors created a magnificent image fast currents; e.g. V-shaped valley; resistant granodiorites; significant undercut riverbanks; large rock joints etc.	A few students screamed as they passed the suspension bridge. (2018) “This is the dopiest class I ever had…like…it blows my mind how pretty this canyon is, but hey…we are in school! (Student, 2019)”
Responsibility	Given how limited drinkable water resource there is on the planet, responsibilities on water management was emphasized.	E.g. “The Project Wet” Activity; deforestation and urbanization keeps depriving more underground aquifers	The whole class was stunned at the fact that only 0.003% of water in the world was available for drinking. “We are influencing the planet at a much faster speed than adapting to it, so our responsibility is not only to save the Earth, but also saving us (Zandvliet, 2019).”
	While minimizing human intervention to nature, we also have a great responsibility to protect it.	E.g. local dams at Lynn Headwater for flooding; ladder channels for salmons; restricted zones to protect water resources etc.	Majority of the class were very engaged during discussions on human responsibilities (2018 & 2019) A student removed a dog poop on top of a rock; she said she felt her responsibility to keep the locality clean (2019).

Ethics	Developing a good ethics is fundamental for people to carry out the 3 “R”s – “Recycling, Reducing, Reusing.”	Many students believed that living in Canada, one of the countries blessed with the luxury of rich water resources, it is important for our teachers to build appreciation and mindfulness to water usage.	“Not everybody is a geologist, but everybody should be aware of environment and their surroundings (Cameron, 2019).”
Inquiry Learning	Recalling knowledge addressed in previous module helped inquiry learning.	Many students in the beginning had difficulties to follow the overarching questions, but was overcome after some connections to module 1 was established.	
	Not having instructors assigned to groups facilitated critical thinking and debate among students.	Most students slowly acclimated to the observational process of scientific research.	Many students demonstrated their favor towards a more student-lead, teacher-supported inquiry process with a loose control. Some called this a “scavenger hunt” (2019).
	Open-ended self-leading discovery could be a double-edge sword, and a delicate design for overarching questions and background information was important for the experience.	Occasionally, students were stranded and confused about what to look at, but generally were able to observe, capture, hypothesize and conclude (2019). Some approached instructors for clarifications.	To enhance the class with some background knowledge while leaving enough freedom for inquiry learning, Mr. Cameron expanded the overarching questions for 2019. e.g. “What happened before?” “What is happening?” “What will happen?” “How do you think the mountains were formed here?” “What would this area look like during glaciation?” “What does the flow speed and valley shape tell you?”
Constructivist Learning	Five steps of constructivism in this module: 1. Individual observation 2. Group discussion 3. Reaching a consensus 4. Cross-group discussion 5. Final debrief	E.g. the walk along Lynn Valley; teamwork became natural and spontaneous during this process	“You construct your own knowledge framework, just like a worker building your own house, and your instructor corrects your misconceptions, just like your taskmasters who provides feedback on your structure” (Zandvliet, 2018).

	A good constructivist process helped produce more inquiries (positive feedback).	Change in water color means change in depth. A group created an experiment to test flow speed by throwing a branch to various parts of the river	Many additional inquiries such as “why does the river change direction?” “which part of the river has high flow speed?” “does water level change overtime” were asked.
	A debrief in a constructivist manner facilitated discussion and added to learning.	E.g. Mr. Cameron carried on with students’ observation on Red Alders to address how the river flashed the island overtime; linked the conclusion on flow speed to erosion and deposition by the river etc.	Students loved the conversation so much that it went from rivers to mountains, then to glaciation and Antarctica. “Constructivism is assuming we know something, but we are trying to fill the gaps of knowledge. Historically science education focused on content, not process, but actually it is about asking the ‘right questions’ not ‘answers’” (Zandvliet, 2019).
Place-based learning	Presenting real-world examples is the most straightforward method of interpreting Earth science concepts.	E.g. being at the valley, actually seeing the landslide impact, hearing the sound of currents and feel the height of the bridge all made Earth science relevant; indigenous cognition believed rocks were living organisms that provide a deep sense of witnessing together with native plants.	The overall engagement on discussing environmental issues and the motivation of understanding Earth science knowledge were persuasive evidences.
Learning Environment	Grasp the state of the group and create a safe place to speak were always important.	Zandvliet always started with a one-word check-in/check-out for debrief; he often stepped back to make students comfortable communicating among themselves and to train group managing skills; started a debate with the unpopular view; emotionally engaged the class by making matters personal	Zandvliet foregrounded “it is alright to be wrong; there is nothing to be ashamed of” to build a healthy learning environment. Voices of minority needed to be heard to avoid arguments becoming polarized. “Education is to get your students think, not to believe what you believe” (Zandvliet, 2019).

Table E.3 The Summary of Researcher's Field Reflections on Module 4 "Land Use Issues"			
Aspect	**Observer's Observation/ Comments**	**Behaviors/ Activities/ Evidences**	**Quotes/ Comments/ Feedback**
Earth Science Knowledge	Knowledge on the products and their natural sources were gained	The Resource Product Pairing Activity: approximately 20 pairs	Compliments were frequently heard from the crowd during this activity
	Students learned the basic concept of coring and its relevance to the ES related fields.	E.g. Everyone in 2018 tried soil samplers; over 5 students participated in marking beddings & analyzing cores	The majority of the class demonstrated little to no knowledge in the petroleum industry
	Deas Island and Iona Beach are unstable and have been migrating in the past.	Inquiries and conversations on the history of Deas Island were often heard; 1 group from 2018 observed lamination	"What would the layers look like in the middle of the river?" (student, 2018) "Was the island always here?" (student, 2018)
	Alternating sandy to muddy sediment layers at the end of a delta system are vulnerable to liquefaction.	The Coring Activity; The Liquefaction activity; all the 3 groups of 2019 noticed the damage of liquefaction	"As I dig deeper, I see quite a mix of the two (sand and mud), but clay is dominant at the bottom" (student, 2019). "Wow, the blocks are actually sinking, so it is real! My kids (students) will love it" (student, 2019).
Connection Between Earth Science and Environmental Education	Some organisms commonly used for industrial and life purposes play important role in both Earth science, environmental education fields	E.g. Diatomaceous Earth for filtering swimming pools and grit in toothpaste are from diatoms, an important species for fossil record (ES); also a good source for silica intake for scouring rushes (EE, from module 1)	Positively commented by multiple students over 3 times. E.g. "Now I see the reasons for this incorporation. I really appreciate it" (student, 2019).

Complexity	Students advocated that the boundary between nature and human civilization should be blurred, because we depend the nature.	Everyone agreed that it is important to acknowledge our dependence on nature, and used Earth science examples and experience from this module to support their arguments.	Overwhelming number of students commented on the complexity of nature: "Since we connect to and rely on nature, it is arrogant to say that Vancouver is outside of the nature" (student, 2019). "It's hard to determine a definite answer to this debate, but we are all parts of a complex system" (student, 2019).
	Students recognized what they saw was a simplified picture of the complex nature, and admitted their lack of knowledge in Earth science.	All students appreciated the enlightenment of how Earth science was strongly tied into our daily life. E.g. The Resource Product Pairing activity: a brick is red because of the oxidized iron cement.	Extensive feedback on the pairing process. "We were using parts of the rocks or ores" (student, 2019). "We are using parts of nature yet not knowing where they were coming from" (student, 2019). "It was way harder than what I expected, but also at a perfect level. Some we could use knowledge in our majors, but some were just frustrating" (student, 2019).
	Demonstrating shocking images or facts helped boost learning interest.	E.g. The Resource Product Pairing activity: lava rock was used for barbeque; silver was used for mirrors	Exclamations during the activity were often heard.
Aesthetics	Students realized magnificent constructions were all sourced from nature, which was another evidence of humans cherishing, pursuing the beauty of nature.	E.g. The Resource Product Pairing activity: most facing stones (limestones and metamorphic rocks) and countertops (granite)	"You don't realize it until you take time looking at it" (Student, 2019).
Responsibility	Discussion on energy, material consumption and their relevant cost increased people's appreciation towards nature.	Everything we use comes from the Earth, whether biologically or geologically. E.g. fossil fuels provide 87-90% of energy nowadays, but accelerate global warming; Extracting aluminum from bauxite at high energy cost (95% more than recycling)	Complete silence when Mr. Cameron asked, "how many people know quartz was included in your soup as an anti-caking agent" (2019)? Many surprised faces when Mr. Cameron stated, "aluminum in food addictive was replaced as knowledge on Alzheimer was gained" (2019).

	Adding human intervention aspects to a locality promoted questions regarding social responsibilities.	Intense discussion on the landfill and the future of Delta area.	“What should we do after the landfill is full?” “Is what we are doing truly environmental friendly?” “how can we minimize our damage to nature” (Student, 2018)?
Ethics	The importance of protecting nature by taking only what we need was emphasized.	E.g. environmental awareness revealed by the understanding of processing the sewage and recycling.	“[We need to] appreciate what we have is all granted by nature” (Student, 2019).
Inquiry Learning	Students tend to let instructors take control when more abstract concepts in inquiry were touched on; therefore, the degree of guidance should be adjusted based on the difficulty of the topic and strength of individuals.	Most students were not used to being in the “drivers seat”; many couldn’t determine “where to core” and “how to analyze” (2018); e.g. the 2 relatively unguided groups were stranded, while the guided group was able to inquire on interbedded layers (2018).	Complaints in 2018 were heard occasionally during discussion: “I just don’t know; there is not enough knowledge to know what is going on in the sample”. (Student, 2018) “I wish all groups could get equal amount of information or introduction, so we are all on the same page” (Student, 2018).
	When not enough background information is provided for difficult, abstract concepts, the quality and motivation for inquiry were lowered.	Students with strong background knowledge demonstrated confidence discussing ES, while the rest was usually hesitant and evasive. (2018)	“I was comfortable talking about it (Earth science), only because I feel like knowing a bit more than others” (2018).
Constructivist Learning	Students used 5 senses to help build their conclusions.	E.g. The Resource Product Pairing activity: oxidized copper ore (yellow tints), peat (gasoline smell), sulfur (yellow color), obsidian (onyx-like luster), lead (weight), gypsum & garnet (hardness)	All conclusions were based on deductions. Nobody asked for answers

	Shaping understanding using stories related to other disciplines increased the broad-based connections in which knowledge can be transferred.	E.g. “salt” was evolved from “salary” for Roman soldiers; pencil tips were called “lead,” but were actually graphite that was mined since 1500s	Over about 1/3 of the class was observed to use personal stories and major-specific knowledge to explain pairs during the activity. E.g. “Oh I have heard about this in my history classes” (student, 2018).
	Additional guidance with clues during the deducing process helps students come to their conclusions.	E.g. “the natural water layering experiment,” which students were asked to imagine what happens when flowing tap water pours into a tank of salt water, helped to visualize the water layering in the Deas Island system.	Dr. Van der Flier-Keller often asked hinting questions to promote thinking, “what if I tell you that titanium, a non-allergic element in this mineral, does not corrode or react to any chemicals, what do you think it might be used for” (2018)?
Place-based learning	Developing a linkage between knowledge and places that appeal to personal memories consolidated understanding	The facing stones of Winnipeg’s parliament building were all limestones, typical for that place.	“So, the paleoenvironment in Manitoba was a carbonate reef environment rich in shallow water fossils, and that’s why we have so much of it [for facing stones]. I’m from Manitoba so that limestone example instantly left a strong impression in my mind” (student, 2019).
	Addressing indigenous stories added to the curriculum.	E.g. Earthquakes sounded like thunderbird; Tsunami was described as a result of a giant whale slapping its tail against water	
	Expanding discussion to contemporary issues is important to make Earth science explanations more relevant.	Delta, although not ideal for construction due to potential threat of liquefaction, is under the pressure of urbanization (Zandvliet, 2018); finite space for garbage disposal	“Why do you think the landfill is near Deas Island? The impermeable mud layer we saw in the core was a natural barrier to prevent toxics leak into the groundwater system” (Cameron, 2018).

Learning Environment	The positive learning environment created with the three pedagogies facilitates motivation.	Students remained engaged for the whole trip (2019).	"I talked to at least 5 people about what I learned from this module, and also taught my family about geological hazards around where I live" (Student, 2019).
	A short, visual, less abstract, student-driven and place-based debrief, a pre-module information session was favored.	Many students were unresponsive at the end of the long, descriptive debrief perhaps due to the overwhelming information (2018); all students were focused and kept adding inquiries during the debrief activity. (2019)	Visuals and presentation in module 3 was praised several times by the crowd. E.g. "we know this because we just saw it in last week's presentation;" "Thinking about the sewage outlet, it is the end of the "great journey" of water in Vancouver, but also a small part of the water cycle" (Zandvliet, 2019).