

**Constructivism in Action: The Lingering Effects of The Education Lab Section of EOS 120
on Participants' Pedagogy**

By

Sarah Elizabeth Alpert

B.A., Wesleyan University, 2007

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

MASTER OF ARTS

In the Department of Curriculum and Instruction

© Sarah Elizabeth Alpert, 2012

University of Victoria

All rights reserved. This thesis may not be reproduced in whole or in part, by photocopy or other means, without the permission of the author.

**Constructivism in Action: The Lingering Effects of The Education Lab Section of EOS 120
on Participants' Pedagogy**

By

Sarah Elizabeth Alpert

B.A., Wesleyan University, 2007

Supervisory Committee

Dr. David W. Blades, Supervisor

(Department of Curriculum and Instruction)

Dr. Mijung Kim, Department Member

(Department of Curriculum and Instruction)

Dr. Eileen Van der Flier-Keller, Outside Member

(School of Earth and Ocean Sciences)

Abstract

The Education Lab is a specialized lab section of an Earth and Ocean Sciences introductory geology lab that is geared towards teacher education candidates and uses a constructivist approach through the model of E-D-U (Explore, Discuss, Understand). The EOS120 Education Lab was started in 2005 by David Blades and Eileen Van der Flier-Keller and continues to the present. The goal of this study was to assess the lingering effects, if any, of the Education Lab on the pedagogy of those participants that had continued through their teacher education. Qualitative analysis shows that the lab has had a lasting impact on the participants of this study, including the use of hands-on inquiry and constructivist principles in their pedagogy as well as an increase in participant interest and positive attitudes towards Earth Science and science in general.

Table of Contents

Supervisory Committee.....	ii
Abstract.....	iii
Table of Contents.....	iv
List of Figures.....	vi
Acknowledgements.....	vii
Frontispiece.....	viii
 Chapter One- Introduction	
• An Introduction.....	1
• The EOS120 Education Lab.....	4
• Immediate Results of the EOS120 Education Lab.....	7
• The Purpose of This Study.....	11
 Chapter Two- Constructivism and the EDU Model	
• A Definition of Constructivism.....	13
• A Brief History of Constructivism.....	13
• The Constructivism Debate.....	23
• The EDU Model.....	25
 Chapter Three- Methods of Research and Study Rationale	
• Selected Study Criteria.....	31
• Qualitative Analysis: the Case Study.....	32
• The Trials and Tribulations of Education Research.....	34
• Recruitment, Interviews, and Data Analysis.....	37
 Chapter Four- Major Data Trends	
• Evidence of Constructivism.....	41
• Hands-on Inquiry in Participants' Pedagogy.....	47
• Expressed Value of Education Lab Resources.....	50

Chapter Five- Minor Themes and Revelations

- Positive Experiences Remembered About the
Education Lab..... 52
- Positively Changed View of Science Education..... 55
- Lack of Experience with Science as
Teachers/Students..... 57

Chapter Six- The Final Chapter

- Conclusions..... 62
- Implications..... 64

References..... 68

Appendices

- Appendix A- Interview Questions..... 74
- Appendix B- Interview Questions (Non-practicing)..... 76
- Appendix C- Coding Sheet..... 77

List of Figures

Figure 1. Misconception Correction of Education Lab Participants versus Traditional Lab Participants, Questions 7 through 11, based on the data collected by Blades et al.	9
Figure 2. Lab, lecture and final grade in EOS 120 in 2005, 2006 and 2007.....	10
Figure 3. Comparison of the Constructivist View of Knowledge Retention (strong foundation) and the Traditional View of Knowledge Retention (no foundation).....	21
Figure 4. The Learning Cycle, based on a presentation at the WESTCast Conference in 2006 by Blades, Van der Flier-Keller, and Pryhitka.....	26
Figure 5. Interview Results.....	40

Acknowledgments

To my husband Max- thank you for being the best partner anyone could possibly ask for! Your love, humour, support, and editing skills have helped me keep my (relative) sanity over the course of this endeavor. I love you so much and look forward to the next hurdle in our life together.

A special thank you to my parents, my sister, and my grandfather for all of their support and for listening to me describe my work over and over and over again... You are all such amazing people, thank you for helping to make this paper a reality.

I would like to thank my friends for putting up with me for the past two years (particularly the latter half of my Masters spent researching and writing my thesis).

Lastly, I would like to thank my supervisor and mentor, Dr. David Blades, for his endless support, words of wisdom, and tireless assistance navigating this process from start to finish. I cannot thank you enough, David.

And to think that this all started with a brunch...

“Ah, there's nothing more exciting than science. You get all the fun of...
sitting still, being quiet, writing down numbers, paying attention... Science has it all.”

-Principal Skinner, *The Simpsons*

(Swartwelder & Anderson, 1995, Bart's Comet)

Chapter 1- Introduction

An Introduction

To teach at a public institution at either the elementary, middle, or secondary level in Canada, potential teachers need to complete a teaching certification program. In Canada, certification can be gained through several avenues: by completing an undergraduate degree in education commonly referred to as a Bachelor of Education (B.Ed.), or by completing a certification program after the completion of a bachelor's degree, which is typically called a "post-degree" program (or PDPP). At the University of Victoria in Victoria, British Columbia, certification programs are offered through the Faculty of Education, which offers both B.Ed. and PDPP routes (University of Victoria, 2012b, p. 1).

The Faculty of Education at the University of Victoria (UVic) is "one of the largest faculties at the University of Victoria" and recommends for provincial certification those persons that complete the PDPP or B.Ed. program within the province of British Columbia (University of Victoria, 2012a, p. 1). Potential candidates must complete a certain number of credits within fundamental subjects to meet the course requirements for entrance to either the B.Ed. or PDPP programs. The Bachelor of Education program at the University of Victoria requires candidates to complete one full year of courses at the university level that are deemed acceptable to the Faculty of Education prior to applying to the program. These courses include a wide variety of required courses in various subject areas in order to provide a solid knowledge of those topics taught in British Columbia (University of Victoria, 2012c, p. 1).

For candidates to be considered for teacher certification programs they must complete certain courses in preparation for the program prior to applying to the Education Program. This

includes 3.0 credits (two semester courses) each in Canadian studies, English, mathematics, and laboratory based science (University of Victoria, 2012d, p. 1). The Faculty of Education has a list of the preferred courses to meet the 3.0 credit requirement in each subject. For the laboratory science requirement, the suggested courses range from introductory Physics to introductory Earth and Ocean Science. Once these courses have been completed with satisfactory marks, those still interested in going into education can apply to the Education Program.

The certification program itself is geared towards preparing students to be teachers in the classroom by teaching them the basics such as curriculum expectations, lesson planning, and methods of student assessment. These courses, in addition to a practicum, allow students to learn the conventions and expectations of the school system in British Columbia.¹ Teacher candidates are taught by different professors who demonstrate a variety of pedagogical approaches. As a result, students are encouraged to develop their own pedagogical style through these instructional classes, which includes several practicum experiences under the guidance of a practicing teacher. The question then becomes: How does their approach to pedagogy form? Is it affected by their experiences, by the status quo, teacher education programs, teaching stereotypes, or all of the above?

As we now know from extensive educational studies, students are individual beings that absorb and construct knowledge (Matthews, 2003, p. 54). They are not “little vessels...ready to have imperial gallons [of facts] poured into them until they are full to the brim,” as Dickens once observed (Dickens, 1858, p. 203). Human beings learn information through their experiences and through a number of individually dependent factors that allow for individual understanding and

¹ In Canada, there is no national school system. Curriculum and school conventions are determined strictly by province.

interpretation (Driver, 1983; von Glasersfeld, 2005; Julyan & Duckworth, 2005). So, how exactly do we build our knowledge? In the case of the students in the education program, how do they develop their pedagogy? Constructivist theory suggests that we each have our own frameworks of understanding that are based on prior experiences and knowledge incorporated into our notions of the world: we all “construct” understanding. These frameworks help us to interpret, organize, and either accept, accommodate, or reject knowledge that we are introduced to. Once new knowledge becomes part of our world view, then our framework may change based on the new information that has now become a part of our framework of understanding. This new framework then dictates how we utilize new information and understand scientific concepts. Constructivism is explored in more detail in chapter two.

In science education, the constructivist approach uses various models and inquiry-based exploration to help students form a more comprehensive understanding of scientific concepts while simultaneously correcting misconceptions. This is accomplished by beginning with hands-on inquiry and exploration with the teacher functioning as a facilitator, followed by discussion of what was observed and thoughts of why this happened, and concluded with the application and re-iteration of the concept being investigated to complete students’ understanding. The traditional approach that is commonly used in science classrooms places the teacher at the head of the classroom and requires students to spend time taking notes, reading textbooks and doing formulaic labs. In contrast to that model, the constructivist approach to science education has the ability to move beyond memorization to a more detailed understanding through its use of hands-on exploration and various models of scientific phenomena. The concepts behind the constructivist teaching approach combined with serendipity brought about the creation of the Education Lab section of “The Dynamic Earth” course also known as EOS 120.

The EOS120 Education Lab

The EOS120 Education Lab section is the creation of two professors at the University of Victoria: Dr. David Blades of the Faculty of Education and Dr. Eileen Van der Flier-Keller of the School of Earth and Ocean Sciences. Dr. Van der Flier-Keller, an Associate Professor in the School of Earth and Ocean Sciences whose research focuses on sedimentary rocks and geology, began getting involved in the pedagogy of geology as the result of arranging workshops for practicing and new teachers sponsored by EdGeo geoscientists². She began to create hands-on activities that focused on curriculum content within geology for the classroom teachers attending the workshop. As a result of these workshops, Dr. Van der Flier-Keller began to wonder about the advantages of teaching her EOS120 lab sections using the same methods she was using in the workshops (Van der Flier-Keller, personal communication, May 6, 2011). After approaching well-known science educator Larry Orr, Dr. Van der Flier-Keller realized that she was using formalized constructivism within her workshops. It was at this point that she contacted Dr. David Blades.

At the time that Dr. Van der Flier-Keller contacted Dr. Blades he was the Associate Dean of Education. As the Associate Dean his responsibilities included the admission of students to the Education Program. Due to his role within the Education Department and as a member of the Faculty of Education, Dr. Blades was already interested in the quality and involvement of the Faculty of Education in the recommended laboratory science labs taken by Education program candidates. He had long wondered if the two faculties could collaborate their efforts towards preparing these students using the same forms of pedagogy that they would be learning about in the teacher certification program (Blades, personal communication, May12, 2011).

² EdGEO is a Canadian organization that supports education devoted to Earth Science.

Prior to his work in academia, Dr. Blades had been a science teacher at the secondary school level and as a direct result had found his passion and commitment to constructivism. It was this passion and interest that had led him to creating the EDU, or “Explore-Discuss-Understand” model of constructivist education. When Dr. Van der Flier-Keller approached him about the pedagogy of her workshops, he had already been musing about the creation of a constructivist lab using the EDU Model for education candidates looking to complete their laboratory science pre-requisites. Dr. Blades introduced Dr. Van der Flier-Keller to the EDU Model by inviting her to observe a class that he was teaching on electricity and demonstrated the potential of the EDU Model to Dr. Van der Flier-Keller.

At the time, all five sections of the Earth and Ocean Science Introductory Geology lab, or EOS120 lab, were being taught using a traditional approach: the lecture portion of the class covered content prior to the lab, which reinforced the topics covered in the lecture and corresponding textbook section. These labs embraced the scientific method and were very formulaic, using mostly workbook-like approaches. As a result of their discussions about the state of the EOS120 lab, Dr. Blades and Dr. Van der Flier Keller decided to create an experimental lab section specifically designed for education candidates that would use a purely constructivist approach through the use of the EDU model.

After receiving funding for the lab from the University of Victoria Teaching and Learning Centre and getting approval from their respective departments, Dr. Van der Flier-Keller and Dr. Blades created the Education Lab section of EOS120 in 2005. All materials for the lab had to be re-written to comply with the EDU Model and a new course manual and new course materials were created for the new constructivist lab. Over the course of the EOS120 Education Lab, participants received numerous resources for their future classrooms including rock kits,

fossil kits, and posters that were made available by EdGEO and Pacific CRYSTAL Project grants (Van der Flier-Keller, Clinton, & Haidl, 2009, pp. 136-137).³ Additionally, one of Dr. Van der Flier-Keller's graduate students that had been present at her workshops using hands-on techniques with classroom teachers was chosen as the lab instructor for the new, constructivist lab section. As a way of studying the effects of this new lab, the other four sections of the EOS120 lab continued to use the traditional approach, effectively serving as control groups. Each section of the EOS120 lab has a maximum capacity of 20 students per lab section and depending on the number of education candidates that enroll in the class, not all of them are able to take the Education Lab section. Significantly, those students who intended on applying to the Education Program, but who were unable to be in the EOS120 Education Lab section, did not show any differences from their traditional lab section peers. This offers more validity to the results of the EOS120 Education lab study by contrasting these pre-education students in addition to those students already in the sciences with those students in the EOS120 Education Lab (Van der Flier-Keller, Blades, & Milford, 2011).

The EOS120 Education Lab undertook the considerable task of attempting to answer whether or not the constructivist approach had any direct effect on student performance, attitudes, and misconceptions within the science classroom. Dr. Van der Flier-Keller, Dr. Blades, and the lab instructor, Tanya, were present for every class and were able to watch the progress of the education lab participants on a weekly basis. Various assessments were designed and administered to gauge the effects of the EOS120 Education Lab on its participants including pre-course and post-course surveys looking at students' misconceptions, interviews addressing

³ The Pacific CRYSTAL (Centre for Research in Youth, Science Teaching, and Learning) Project originates from the Faculty of Education at the University of Victoria and is funded by the Natural Science and Engineering Research Council of Canada.

attitudes towards geology, and Likert scales to assess any change in participants' valuing of Earth Science (Van der Flier-Keller, Blades, & Demchuk, 2006, p. 98). The data was then compared between students enrolled in the Education Lab section and students enrolled in the four traditional sections of the EOS120 lab.

Immediate Results of the EOS120 Education Lab

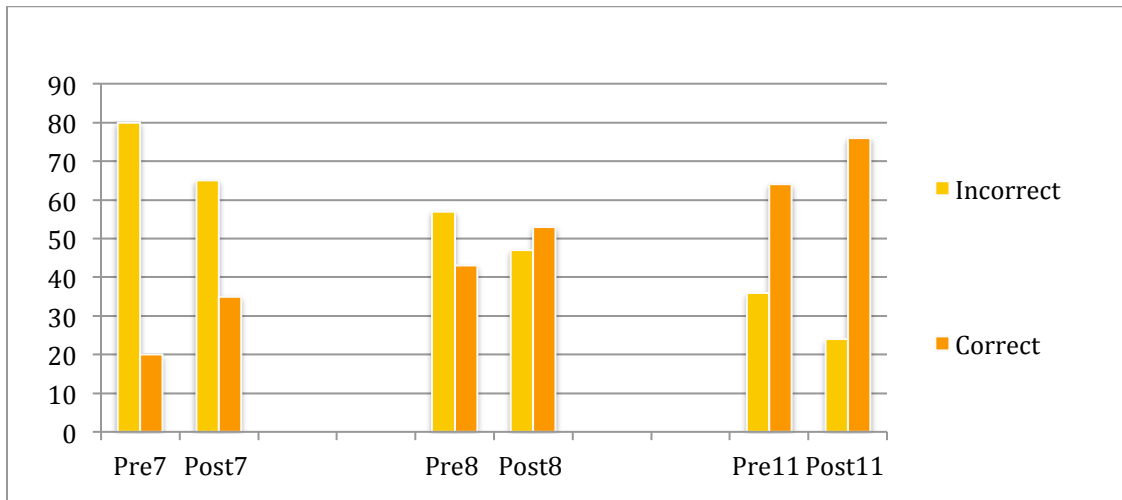
For the first year of the study, indications in the data suggested that the students in the education lab section performed academically better than their peers in the traditional lab sections in addition to correcting their misconceptions about various topics in earth science at a higher rate. Based on the interviews and data collected, participants in the education lab section also showed that their initial attitudes towards geology and science in general gave way to more positive attitudes following the lab than their peers, however the difference between groups was not statistically significant. The success of their first education lab section encouraged Dr. Blades and Dr. Van der Flier-Keller to continue the EOS120 education lab section.

In the second year of the study, Dr. Blades and Dr. Van der Flier-Keller did not attend the EOS120 Education Lab classes. Like the previous EOS120 Education Lab, data was collected regarding student attitudes, achievement, and misconceptions. The data from the second year of the project did not produce similar trends to the data collected from the first lab section. Unlike the previous year, lab sections did not show dramatic differences in either grade improvement or misconception correction. As a result it was decided that the project should continue for a third year to try and explain the discrepancy between the two sections' data trends.

The third year of the education lab was structured identically to the previous two years of the study. Tanya left her position as lab instructor and was replaced by a senior lab instructor named Duncan, but the materials and forms of data collection stayed the same. Additionally, Dr. Todd Milford became the chief statistician of the project. Using the data collected from the third group of participants, analysis was conducted that indicated once more that the structure of the lab and its pedagogical approaches did have an effect on student attitudes towards science, the correction of misconceptions, and overall achievement.

The data from lab years 2005 through 2007 indicate the following overall trends. To begin, there was very little difference between pre and post analysis of students in terms of whether they viewed earth science as a relevant topic (Blades, Van der Flier-Keller, Milford, & Alpert, 2011, p. 3). There was significant improvement of misconception correction for the Education Lab groups in comparison to their peers (see Figure 1). Lastly, the overall performance of the those students in the Education Lab in comparison to their peers in the traditional lab section were better for years 2005 and 2007, with only a slight improvement in 2006 (Figure 2). As a result of this initial data it is apparent that students in the Education Lab section, “made significantly stronger gains in knowledge and tended to correct more frequently their prior Earth Science-related misconceptions.” (p. 6)

Education Lab Section



Traditional Lab Sections

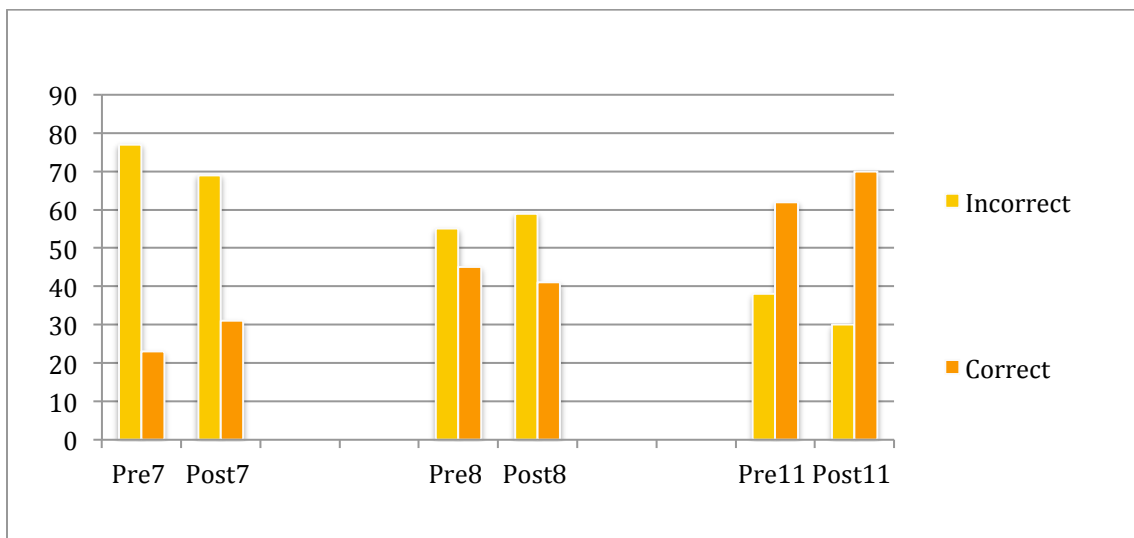


Figure 1. Misconception Correction of Education Lab Participants versus Traditional Lab Participants, Questions 7 through 11, based on the data collected by Blades et al. (Blades, Van der Flier-Keller, Milford, & Alpert, 2011, p. 3)

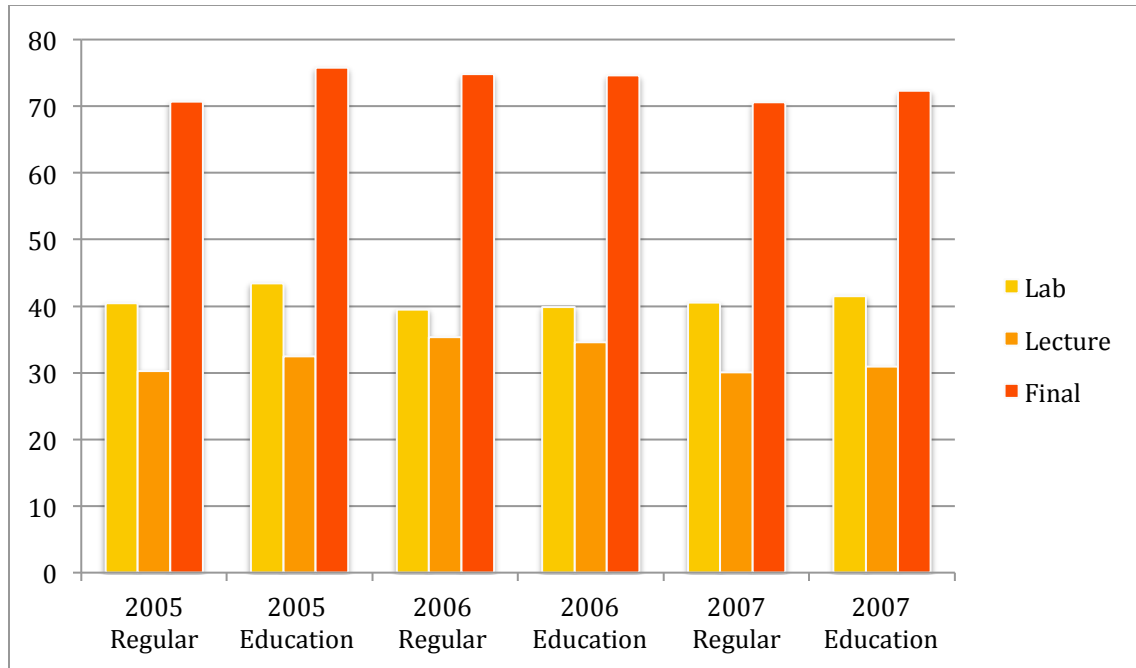


Figure 2. Lab, lecture and final grade in EOS 120 in 2005, 2006 and 2007 (Blades, Van der Flier-Keller, Milford, & Alpert, 2011, p. 4)

The education lab project began in the fall of 2005 and is still being run to this day. Research by Dr. Van der Flier-Keller and Dr. David Blades is on going and after five years of data analysis, overall data trends indicate similar trends to those found in the first three years of the project. These data trends suggest that the constructivist approach and EDU model are effective in enabling concept acquisition in the EOS120 Education Lab and correcting students' misconceptions about Earth Science (Blades et al., 2011; Van der Flier-Keller, Blades, Milford, 2010; Van der Flier-Keller, Blades, Milford, 2011).

The Purpose of This Study

While I found many papers in which authors either argue for or against constructivism as a theory, very few studies have attempted to analyze the direct effects of using the constructivist approach in a University level science classroom geared towards future teachers. Until this study, the EOS120 Education Lab study had been limited to researching how the constructivist approach affects students while they are involved in EOS120, but had not researched the effects of such an experience on participants after completing the EOS120 class and the Education Program. Additionally, in the field of educational research, much research has been dedicated to looking at constructivist theory, but very little research has been done examining specifically the long term effects of teaching pre-service teachers using a constructivist approach and any consequences this might have and on their career paths and pedagogy. Whether or not the constructivist approach can contribute to lasting changes of common misconceptions and attitudes towards science has yet to be studied in depth with teachers that were taught using the constructivist approach during their pre-service training.

By tracking down those that participated in the EOS120 Education Lab, graduated from the Education Program and interviewing these participants, I was able to ascertain how their experience in EOS120 affected their pedagogy and whether their experiences might give insight into how to better prepare pre-service teachers to teach hands-on inquiry and constructivist science lessons. Research questions guiding this study were:

- What were the long-term effects of the EOS120 Education Lab on participants' pedagogy?

- Are those participants that participated in the EOS120 Education Lab and graduated with a degree in Education using constructivist principles in their pedagogy? If so, which ones?
- Is the EDU Model present within participants' pedagogical approaches to science education?
- Is the lab section simply a gateway, or does it need to be reinforced by courses within the education program to effectively contribute to changing participant's views of science and science education?

Chapter Two- Constructivism and the EDU Model

A Definition of Constructivism

The term “constructivism” is difficult to define as it has found its way into use in numerous disciplines. While the definition of “constructivism” varies between academic fields, *constructivism* in education focuses on how students build knowledge through existing cognitive frameworks of understanding that are socially and experientially based. In science education, the constructivist approach focuses on learners’ awareness of their existing cognition and then actively constructing their knowledge using models and hands-on activities to build a higher level of understanding of scientific concepts while simultaneously correcting misconceptions.

In order to look at the constructivist approach to science education, the history of constructivism and its tumultuous past within the education community need to be discussed and examined. While the concept of *constructivism* was first elucidated by the French philosopher of education Jean Piaget in his 1959 article *Logique et Connaissance Scientifique* (Piaget, 1967, p. 53), constructivism is a difficult theory to examine in its entirety as no definition is commonly agreed upon in all branches of academia that employ the term ‘constructivism’. Adding to the confusion are the different permutations of constructivism that have joined the academic lexicon (e.g. deconstructivism, radical constructivism, and social constructivism) (Matthews, 2003, p. 52).

A Brief History of Constructivism

As stated above, Piaget was the first to use the term *constructivism*, but the currently accepted definition of constructivism within education is a product of the interpretation and application of Piaget’s work, and the introduction of cognitive psychology to the field of

educational research (Driver & Easley, 1978; Driver, 1983; Novak, 1988; von Glasersfeld, 2005). Piaget's "numerous studies detailed examples of the construction of knowledge by children...[and] his ideas provide an important foundation for all the research in this area" (Julyan & Duckworth, 2005, pp. 62-63). Despite the prominent support of constructivism being rooted in Piaget's work and the theories of cognitive psychology, many educators disagree with the conclusions made by Piaget and his followers.

Opposing those who support Piaget is a faction of educational theorists that suggest *constructivism* has been a part of general intellectual discourse since "Greek and Roman times," and has been present in educational discourse specifically since the 18th century, seeing it as "the underlying tenet of Rousseau's *Émile*" (Novak, 1988, p. 80). However, this account of constructivism's origin neglects the fact that while humans have indeed been constructing meaning for many centuries, constructivism as it pertains to educational research and understanding is strictly a product of educational theories and practices that emerged in the 20th century. During the 20th century there was a movement away from behavioral psychology, which examines how we teach to illicit certain responses, and towards cognitive psychology, which studies how students actually acquire knowledge and use "cognitive foundations" to build understanding (Lord, 1997, p. 198). Constructivist theory suggests that students themselves build their own knowledge, rather than knowledge being dispensed by teachers to their students in a strictly hierarchical form. The constructivist model allows for learners to develop their own understanding of the world around them through direct, hands-on experiences (von Glasersfeld, 2005, pp. 6-7). This is achieved by requiring the teacher to act as a facilitator rather than a lecturer, seemingly pouring knowledge into empty minds (Lord, 1997, pp. 198-200). While

there are other educational theories that do not use lecturing as the primary means of sharing knowledge, these theories have other shortcomings. One such theory is developmentalism.

The theory of developmentalism was first articulated by Jean-Jacques Rousseau and later championed by the American philosopher and educational reform advocate John Dewey (Matthews, 2003, p. 53). Unlike constructivism, developmentalism is a philosophical position holding that the development of an individual is rooted in “natural tendencies, which have occurred as a result of natural selection and evolution” (p. 53). This philosophical stance works from the assumption that the desire to learn is a biological imperative for humans, and that learning experiences should occur as they evolve through natural information acquisition. Developmentalism is a positivist model of learning, and as I will argue later, scientific discovery can no longer be said to be a wholly positivist pursuit. As a result of this philosophical stance, developmentalism is an inappropriate approach for modern science education. While Dewey also “stressed the importance of having a student’s knowledge grow from experience” (Julyan & Duckworth, 2005, p. 63), a position that is similar to constructivism, it must be stressed that there is a great difference between developmentalism simply providing students with the opportunities to experience phenomena and “supporting students’ developing understanding” through the use of exploration and discussion, which is a key constructivist principle (Julyan & Duckworth, 2005, p. 63). If a teacher does not support their “student’s emerging understanding” by *facilitating* the students’ construction of ideas through exploration then, in the words of Elstgeest quoted by Julyan and Duckworth, even a teacher that *believes* in exploration can teach “a marvelous lesson virtually to ruins” (pp. 63-64). Ending a lesson without facilitating discussion about the students’ experience in the classroom, or applying this knowledge to demonstrate the students’ degree of understanding prevents teachers from addressing student experiences and

allows misconceptions to be potentially ignored that might have resulted from the students' exploration. Teaching without facilitation neglects the cognitive processes of the learner and assumes that students will automatically develop an understanding devoid of misconception.

There are those that also suggest, in the words of Driver, that Ausubel's "theory of meaningful learning offers science educators a more useful and valid model of learning than the Piagetian stage model" (Driver, 1983, p. 58). This is not necessarily the case. While there are shortcomings in Piaget's work, namely Piaget's lack of a uniform instructional method for all students regardless of age, the concept of "stage" as a limitation, and priorities in curriculum, Driver rightly suggests that in the "debate about the validity of the stage theory it is not the results of Piaget's investigations which are being questioned, it is the interpretation being placed on them which is under review" (p. 57). In his book, "The Language and Thought of the Child," (1959) Piaget outlines three stages of development that are governed by three dramatic concepts: a decline in precausality, the development of logic, and the act of conscious realization (Piaget, 1959, pp. 226-286). While Ausubel's theory focuses on the "structuring of content," Piaget's theory "focuses on logical operations a pupil can perform" (Driver, 1983, p. 58). These foci are not mutually exclusive and familiarity with certain concepts within these theories can help to promote a better understanding of students' general understanding of concepts in the curriculum. As Driver explains,

[m]any substantive concepts in the sciences take their meanings not simply through the network of the other substantive concepts to which they relate, but through the nature or structure of the relationship between them. Content and structure should be complementary considerations in curriculum design. (p. 58)

Ausubel's theory of meaningful learning does not look at the cognitive process of creating frameworks of scientific concepts. While his theory aids teachers in the design of a better

pathway through the prescribed curriculum, it neglects to consider the structure, or nature, of the scientific concepts (Driver, 1983, p. 58). Consequently Ausubel's work alone cannot be used as the primary basis for constructivism in science education.

A key principle of constructivism that can be traced back to the work of Piaget is the concept of alternative frameworks. Research has shown that children and adults have “beliefs about how the world works [that] are formed around the meanings we construe from the data of our experiences” (Julyan & Duckworth, 2005, p. 63). Constructivism suggests that learners build information into individual “frameworks” through which they accept, assimilate, or reject information using what Piaget referred to as “knowledge based on physical experience and...logico-mathematical or operational knowledge” (Driver, 1983, p. 61). Formal operational knowledge is defined by Piaget as, “hypothetico-deductive reasoning, the ability to raise and test hypotheses, to see the need to control variables in making inferences from data and to impose quantitative models on observations, specifically that of proportionality” (p. 61). Piaget's notion of logical thought is strikingly similar to the desired effect of learning the scientific method in its objective, formulaic approach to scientific discovery. What prevents thought from being purely objective and “operational” is Driver's observation that learners bring their own “conceptual schemes” formed during prior experiences to every subsequent experience (p. 61). Educational researchers, including Driver, have stated that these two “modes of thinking are inter-related” (p. 61) and that students' reliance on causal thinking and their conceptual schemes when accepting new ideas can lead to the formation of both alternative frameworks and misconceptions (pp. 61-72). So how do we as educators define “misconception” in constructivist terms?

According to Driver and Easley, there are two ways to read the work of Jean Piaget that dictate how theorists view misconceptions in student frameworks (1978, p. 63). Piaget's

Genevan work embodies two different kinds of study: nomothetic and ideographic approaches (Driver & Easley, 1978, p. 62). *Nomothetic* studies look at student learning in terms of stages of learning, what order material should be introduced to students based on their conceptual stage, and the common misconceptions that “occur during the learning process” (p. 63). As Driver and Easley suggest, this kind of study neglects looking at students’ misconceptions “on their own terms” (Driver & Easley, 1978, p. 63). Driver and Easley define studies that analyze learners “without assessment against an externally defined system” as *ideographic* studies, which give integrity to all student responses. For example, an ideographic study would focus on “illuminat[ing] the way pupils understand phenomena,” by asking pupils to describe phenomena in their own words (pp. 68-69), something which Piaget’s later work illustrates.

While the early work of Piaget can be said to fall within a nomothetic approach, his later work is ideographic and focused on the mechanisms of learning (Fosnot & Perry, 2005, p. 12). It is this dichotomy present in Piaget’s work that has caused much confusion of the work of Piaget. The ideographic component, not the nomothetic, allows for the acceptance of *alternative frameworks*, which is paramount to the idea of misconceptions and misconception correction within the constructivist approach (Driver & Easley, 1978, p. 68). The concept of personal frameworks suggest that students build different understandings of phenomena, despite traditional instruction, and that these can lead to misconceptions about scientific phenomena (p. 76). As Driver and Easley reiterate about Piaget’s work:

What *is* important about this large body of work is that it shows the extent to which pupils have been able to structure and make sense of their experiences of natural events and indicates common trends in the developmental sequence in ideas...it is in the details of pupils’ responses that the main educational value of the work lies. (Driver & Easley, 1978, p. 76)

The work of Piaget is fundamental to constructivism, but it is only the starting platform. Further ideographic studies of student exploration suggest that not only are the conceptually-framed phenomena that students are being introduced to through the traditional approach leading to student misconceptions of scientific phenomena, but they are doing so at a far higher rate than anticipated even by educational theorist who oppose the traditional approach. These misconceptions are ignored by the traditional approach (Driver & Erickson, 1983, p. 46; Driver, 1983, p. 76). There is also a social component necessary to developing understanding and uncovering misconceptions amongst students. This social component is lacking not only in the approach suggested by Dewey, but in the traditional approach as well, which isolates learners from their peers, especially through the use of textbooks, note taking, worksheets, and individually-based assessment (Brooks & Brooks, 1995, pp. 3-4). The work of both Jean Piaget and the Russian philosopher Lev Vygotsky looks at discussion and social interactions among learners. Piaget focused on the development of the individual based on their social interactions with others, while Vygotsky was concerned with the development of understanding through social and cultural interactions, which are then internalized.

Piaget and Vygotsky made profound contributions to the understanding of the social component present within constructivism. Vygotsky was influential in the development of *social constructivism* and “believed that children learn while interacting with peers and adults” (Vygotsky, cited in Taveira, 2007, p. 20). His work focused on the role of social interactions and language in building student understanding. Vygotsky noted that, “aspects of external speech or communicative speech as well as egocentric speech turn ‘inward’ to become the basis of inner speech,” suggesting that students internalize and adapt what they hear to their own preexisting picture of reality (Vygotsky, 1978, p. 57; see also Solomon, 1993, p. 90). In addition to

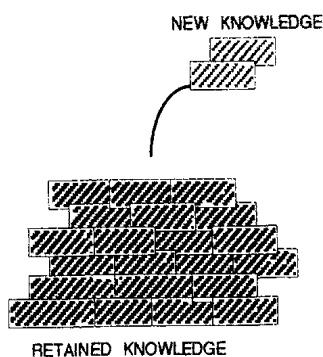
internalization, Vygotsky suggested that there are two classes of concepts: those that spontaneously “emerge from the child’s own reflections on everyday experience and those that he [or she] labels as scientific [and] academic” which is introduced through formal instruction (Taber, 2006, p. 166). This suggests that formal scientific concepts can “evolve connections to real life”, as concrete experiences acquire a “more formal structure” (p. 166). However, learners do not necessarily experience a convergence of the abstract and concrete when building frameworks. Learners instead develop a conceptual framework within which they accept, assimilate, or reject information based on their own schema. The cognitive repercussions of social interaction and social agreement among students are present in pupils’ understanding of scientific concepts, but are not necessarily the sole foundation of an individual’s understanding.

Many of the changes in how educators view science education have occurred as the result of the “significant advances [that] have occurred in two fields” (Novak, 1988, p.77). A shift in learning psychology away from behavioral psychology towards cognitive psychology and a movement of epistemology away from empiricist and positivist views of science has contributed to a change in how philosophers of science view science itself (Novak, 1988, p. 77). Many philosophers of science no longer view science as a means of discovering “truths” about “reality,” but argue that science is “the construction of explanatory models that encompass increasingly wider ranges of phenomena” (p. 77). Scientism, a term for the fundamental belief that the “scientific method is universally powerful and applicable”, furthers positivistic views of science by presenting a distorted image of scientists and scientific endeavor as “objective” or “infallible” (Hodson, 1985, p. 27). This view is propagated through the traditional “teacher model [which] transmits science-as-knowledge that is crystalline and crystal clear, contained and containable, trustworthy and indisputable” (McWilliam, Poronnik, & Taylor, 2008, p. 229). The

positivist pedagogy introduced into schools during the 1950s and 1960s is still being taught in classrooms despite the end of positivism in the philosophy of science (Novak, 1988, pp. 78-80). This view of science has resulted in students viewing scientific information, and consequently their own misconceptions of that information, as objective “truths...highly resistant to change with instruction” (p. 78).

Constructivist theory dictates that “it is the learner alone who makes connections in any meaningful way,” not the teacher (Julyan & Duckworth, 2005, p. 62). Since our understanding of scientific terms is based on our own personal experiences with science and many concepts in science cannot be communicated through the strict memorization of scientific words (p. 62), science cannot access the underlying truth that positivism suggests it does. Constructivism is fundamentally non-positivist (von Glasersfeld, 2005, pp. 3-4). The traditional approach, which expects students to absorb knowledge, understand scientific terms verbatim, and not form misconceptions, allows gaps to form within student knowledge. In contrast, the constructivist view allows students to build a more solid understanding of scientific concepts through their own explorations of scientific concepts (as seen in Figure 3).

CONSTRUCTIVIST VIEW



TRADITIONAL VIEW

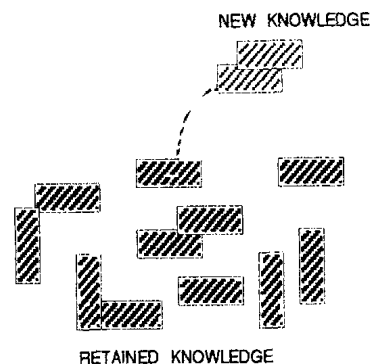


Figure 3. Comparison of the Constructivist View of Knowledge Retention (strong foundation) and the Traditional View of Knowledge Retention (no foundation) (Lord, 1997, p. 199)

Misconceptions occur in all subjects, but in the case of science education, the constructivist principle of misconception correction through experience has shown clear evidence that the constructivist approach can address alternative frameworks of understanding and correct misconceptions (Driver, 1983). The use of hands-on inquiry and exploration coupled with teacher facilitation and discussion is essential in building a “firm experiential foundation” which is not as “readily displaced” by students (Driver and Erickson, 1983, p. 49). While evidence suggests that students’ benefit from experiencing constructivist principles in the classroom, there has been contentious debate within the science education community regarding constructivist theory and its potential as the next teaching paradigm.

The Constructivism Debate

As indicated by the majority of works referenced here, the constructivist debate began in the early 1980s, was carried on into the 1990s, and continues to resurface intermittently down to the present. Two major factions developed within the constructivist debate in the 1990s: those that focus on how students learn and those that focus on the external variables of social and cultural interaction (Taber, 2006, p. 125). In the words of Fosnot and Perry (2005): “widespread interest in constructivism over the last decade led to a debate between those that place more emphasis on the individual cognitive structuring process and those that emphasize the social and cultural effects on learning” (p. 28). As a result, much of the debate has focused on constructivist

theory, rather than the constructivist *approach* and the practical application of constructivist principles in the classroom.

When doing research on the topic of the long-term effects of constructivism it became clear that this subject was little investigated within science education research. There are extensive arguments for or against the theoretical applications of constructivism in the classroom and some studies have even looked at the benefits of constructivism over the course of a single class or full year course. Research into the practical applications of constructivist principles at the elementary and secondary level, however, and the effects of constructivism in science education is minimal. Those studies that are published tend to be short-term examinations of educational experiences and not longitudinal, or long-term, studies. No study queried the effects of introducing pre-service teachers to the constructivist approach in a constructivist science class and subsequently analyzing any lingering effects of being taught science in a constructivist classroom.

Despite the small number of studies that apply constructivist theory in actual classrooms, those that have been carried out help address the continuously debated question of whether constructivism is a useful theoretical paradigm within the science education community. There are, however, a variety of reasons why the question of constructivism and its long-term benefits as a pedagogical approach has yet to be settled. First, there is no commonly agreed upon definition of constructivism. Second, a fierce debate surrounding constructivism has been ongoing since the 1980's, focusing primarily on the merits of constructivism as a perspective within the science education community, and not necessarily on long-term data showing the utility of the constructivist approach within classrooms. There is an additional lack of consensus regarding which form of constructivist theory based on which theorist should form the basis for

the pedagogical approach used within studies, particularly in light of newly emerged learning theories that are similar to constructivism, but campaign under different banners.

As a result of this lack of consensus, the science education community has had trouble moving away from the traditional approach, an approach that has consistently been shown to fail our students' needs (Taber, 2006, pp. 125-126), and other approaches to science education. The reality is that no cookbook-style application of constructivism, or any other educational theory, will "solve" every issue and shortcoming that has become apparent within the traditional approach to the satisfaction of every educator or theorist (Fosnot & Perry, 2005, p. 33). As stated by Osborne, Simon, and Collins (2003), evidence suggests there has been "a decline in the interest of young people in pursuing scientific careers" (p. 1049). Despite this decline, there has yet to be a massive pedagogical change away from the traditional approach in the classroom (McWilliam, Poronnik, & Taylor, 2008, p. 226; Osborne, Simon, & Collins, 2003, pp. 1049-1050). Evidence presented by studies looking at the potential of constructivism, such as a study analyzing the effect of a constructivist approach in secondary Biology classes carried out by Lord (1997), have shown that teaching science using a constructivist approach improves student attitudes and achievement in science (pp. 208-215). Despite this evidence, new teaching models proposed by various science organizations still embrace elements of the traditional approach while advocating for hands-on inquiry and constructivist principles (Minner, Levy, and Century, 2010, pp. 474-476).

Many of these teaching models, such as the Engage, Explore, Explain, Extend/Elaborate, and Evaluate (or 5E) Model that was created by the Biological Science Curriculum Study (BSCS), or the 6E and 7E Model, are expanded versions of the learning cycle (Bybee, Taylor, Gardner, Scotter, Powel, Westbrook, & Landes, 2006, p. 1; NASA, 2012, 5Es Overview).

Despite the constructivist principles present within these models, those versions of the 5E model that are supported by science organizations, such as NASA, still ascribe to the scientific method during periods of exploration. For example, the 5E Model as described by NASA specifies that during the “Explore” phase of the model, “students make hypotheses, test their own predictions, and draw their own conclusions” (NASA, 2012, 5Es Overview). This is no different from the scientific method used in many classrooms. By asking students to develop a “hypothesis”, test their hypothesis, and then make “conclusions” based on their hypothesis, this model is encouraging the same formulaic process of thinking as the scientific method despite advocating for hands-on inquiry and experiential learning. What is needed is a model that employs constructivist principles, while simultaneously being easy for teachers to remember, to help address the shortcomings of the traditional approach (Fosnot & Perry, 2005, p. 33). We have such a model in the Explore-Discuss-Understand (EDU) Model.

The EDU Model

Canadian professor and educational researcher David Blades, whose work includes seeking to improve pre-service teacher education in science, designed the EDU Model. Unlike the 5E Model and other teaching models that include constructivist principles in linear learning model structures, the EDU Model combines constructivist principles with Learning Cycle Theory.

Originally developed by Karplus (1927-1990), learning cycle theory argues that learning is not linear, but cyclical, and as such, learning by rote memorization is not sufficient (Taveira,

2007, p. 24). Students learn through an introduction to information by directly interacting with phenomena through hands-on inquiry or the use of models representing the phenomena (Carin & Bass, 2001, p. 117). The Exploration phase, “in which children *discover* new knowledge” leads to the Conception Invention Phase, “in which students *acquire* knowledge from teachers” (p.117). The Conception Invention Phase leads to the Concept Application Phase, “in which students *construct* new understandings from their discovered and acquired knowledge,” and in which students can apply the concepts they have discovered and test their newly acquired knowledge (Carin & Bass, 2001, p. 117). This leads to a more powerful and meaningful understanding of phenomena (p.118).

Similar to the three phases suggested by Carin and Bass, the EDU Model uses three phases that are interconnected: an exploration phase, a concept invention phase, and a concept application phase feeding into the next phase of exploration (see Figure 4).

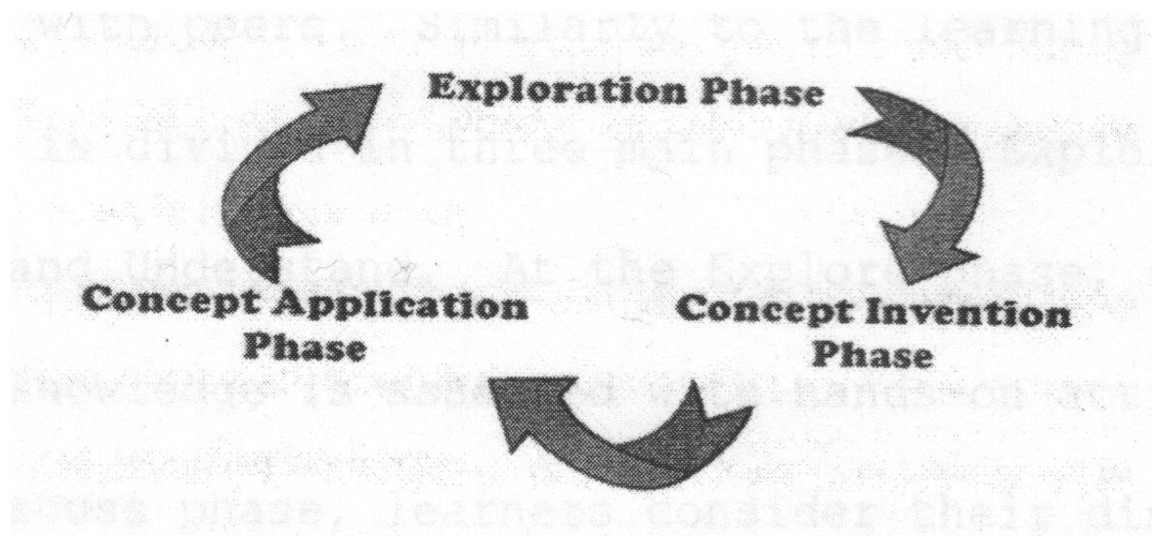


Figure 4. The Learning Cycle based on a presentation at the WESTCast Conference in 2006 by Blades, Van der Flier-Keller, and Pryhitka (Taveira, 2007, p.26)

However, the stages of the EDU Model are different from the Learning Cycle outlined by Carin and Bass. In the Explore phase, “students’ previous knowledge is assessed with hands-on activities,” indicating if they have any misconceptions that already exist about the phenomena which need to be addressed through further exploration and discussion (Taveira, 2007, p. 27). This phase prevents teachers from over-teaching and wasting time or alternatively under-teaching and so preventing students from having the time and experience necessary to understand the concept being introduced. In this model, teachers can more effectively plan, adapt, or design classes. Unlike the second phase of the Learning Cycle outlined by Carin and Bass, in which students acquire knowledge from teachers, the second phase of the EDU Model is a Discuss phase, in which “learners consider their discoveries in class and/or group discussions” (Taveira, 2007, p. 27). During the Understand phase, students are “invited to apply their knowledge” in a new scenario which tests their knowledge and indicates whether the scientific phenomena being discussed has been incorporated into learners’ frameworks, or if they have contributed to alternative frameworks which need to be addressed before the cycle begins once again (p. 29).

In this way, the EDU Model is more akin to the Play-Debrief-Replay instructional strategy outlined in Wassermann and Ivany’s book *Teaching Elementary Science* (1988). In the Play-Debrief-Replay model, learners investigate phenomena using “investigative play” providing students with “direct, hands-on experience in manipulating scientific variables” while teachers observe and help to facilitate play (p. 90; p. 91). This is followed by a Debrief phase in which students are able to make meaning from their play experience through teachers asking questions that “elevate pupils’ deeper consideration of data and promote concepts and principles based on experiential play” (p.91). Instead of presenting answers from the beginning, or lecturing to

introduce students to scientific concepts, it is the job of the teacher to question, but not answer. Teachers work to slowly elicit scientific content, requiring students to use “higher-order mental processing”, while building critical thinking skills (Wasserman & Ivany, 1988, pp. 91-92). The Replay phase allows students to test their new knowledge and functions as an indication to the teacher if the scientific concept introduced during the Play phase has been understood or if more play is needed in order to clarify the concept. The EDU Model is similar in structure, but there are some key elements that Blades, Van der Flier-Keller, and Pryhitka discuss in their WESTCast Conference presentation from 2006 that are strongly emphasized in the EDU Model: 1) alternative approaches to examination, 2) teacher-stimulated discussion, which should be present within all phases of learning, and 3) a more rigorous Understand phase to ensure understanding has been achieved (Blades, Van der Flier-Keller & Pryhitka as cited in Taveira, 2007).

The concept of misconception correction in the constructivist approach is a key factor in constructivist learning models. There is a consequential need to detect misconceptions in student knowledge. Depending on the model, however, there are many possible forms of such assessment. Unlike the model proposed by Wasserman and George Ivany emphasizing the teacher overhearing discussion and asking questions during the Debrief phase to detect misconceptions, the EDU Model incorporates multiple ways to analyze student knowledge for misconceptions. Instead of traditional assessments such as tests or quizzes to test acquired knowledge, Blades, Van der Flier-Keller, and Pryhitka suggest that teachers should use different modalities of assessment including, but not limited to, concept maps, plays depicting a scientific process, creating models of the phenomena explored, and a variety of other assessment tools (Taveira, 2007, p.33). These alternative means of assessment allow for student discussion to

occur continuously throughout the learning process. These assessment tools can be excellent ways to not only assess students' acquired knowledge, but can also help foster peer and group discussion.

The Play-Debrief-Replay Model discussed by Wasserman and Ivany (1998, pp. 89-104) emphasizes the teacher's role during the Debrief phase to tease information, but it does not emphasize constant discussion or the teachers' role in fostering such interactions amongst students through out the learning experience. In contrast, Blades et al. suggest that peer and group discussion should not only be present, but should also be stimulated by the teacher if needed (Blades et al., cited in Taveira, 2007, p. 31). By discussing their ideas with one another, students, "can state their preconceptions and check them against others' ideas and against experimental observations. Students then can clarify their thinking by further discussion, and build new ideas by assessing and incorporating the views of their classmates" (pp. 31-32). By achieving a social consensus that empowers students and their interests, teachers can "[build] on students' existing interests" expressed in discussion and make "learning a motivating and relevant process" (p. 32). By "inviting students to do most of the talk[ing]", students are essentially required to learn from one another and create a learning community while simultaneously developing critical thinking skills due to the knowledge put forth by their peers, which they must now evaluate (p. 32).

Endeavoring to create a learning community and test the use of a constructivist approach to a University level science course, the EDU Model was used as the basis for the curriculum written for the EOS120 Education Lab. Data on the Education Lab section from 2005 through 2007 suggests that the EDU Model does have an impact on student learning. This is indicated by their rate of misconception correction and overall achievement in comparison to their peers in the

traditional lab sections (Blades, Van der Flier-Keller, Demchuk, & Pryhitka, 2007, p. 1). The question, however, remained whether those who participated in the Education Lab, and continued on to become teachers adopted the EDU Model and constructivist principles within their pedagogical approach to science education? One of the greatest strengths of the EDU Model is that it is easy to remember and teacher-friendly. According to Blades, Van der Flier-Keller, and Pryhitka, “this model is easy to remember since the first letters, EDU, are also the first three letters of the word ‘**education**’” and that this was deliberately done to “emphasize that, by using this constructivist approach to teaching, teachers can be sure the students learn concepts more effectively and accurately” (Blades et al., as cited in Taveira, 2007, p. 27). Despite the EDU Model being “easy to remember” in comparison to other learning models, there are a multitude of other models currently employed in science education. There is also a tendency for teachers to revert to traditional approaches of instruction despite their introduction to constructivist principles during their teacher training (Uzuntiryaki, Boz, Kirbulut, & Bektas, 2010, p. 404). This question of pre-service teacher training and the reversion of teachers to the traditional approach warranted a continuation in the EOS120 Education Lab study to see if participants had followed the trend back towards traditional teaching approaches. In the next chapter I outline my methods of research in assessing the lingering effects of the EOS120 Education lab, the frustrations of educational research, and initial findings.

Chapter Three- Methods of Research and Study Rationale

Selected Study Criteria

In order to look at the effects of constructivism on participants of the EOS120 Education Lab, I had to first define the population of study. My initial criterion was that potential participants had to have completed the EOS120 Education Lab. This was an obvious criterion because of the purpose of my research. The second criterion I decided upon was that all potential participants should be graduates from the B.Ed. or PDPP program through the Teacher Education Program at the University of Victoria. This was a necessary criterion because my questions about the long-term effects of the Education Lab look at the current pedagogy of the EOS120 participants, thus making the participants' completion of the education program and the consequent evolution of their teaching skills a required experience. While their experiences within the Teacher Education Program (TEP) wouldn't be identical, having had exposure to different pedagogical approaches within the same program would provide potential participants with the information needed for them to develop their own pedagogy.

Since all potential participants had completed the education lab, spent time studying education in the education program, and consequently completed at least two practicums, I decided that I would allow participants that were not currently teaching but had met these criteria to participate. Additionally I decided that the location of participants would not be a criterion. It is exceedingly hard to get a job in education in British Columbia: the number of full-time teachers in British Columbia has decreased while the number of part-time teachers has increased (BC Ministry of Education, 2011, p. 3). Although curriculum is written and prescribed by each province, I saw this as having only a marginal effect on my research data because my research

questions focus on the pedagogical views of the participants, not the listed topics in the curriculum or their execution.

Qualitative Analysis: the Case Study

Quantitative and qualitative researches have their respective pros and cons, but in the realm of educational research both forms of research have become common practice. Surveys of students, multiple choice tests, Likert scales, and open question interviews can be used as forms of data collection depending on the structure and questions asked by research. What divides qualitative and quantitative studies is not always the use of numbers and graphs, but the degrees of control on the environment of the participants and the whether the event that is being researched happened recently (Flick, 2002, pp. 4-5). Qualitative research offers the inclusion of the “perspectives of the participants and their diversity” and allows for “reflexivity of the researcher and the research” in a way that makes the presence of the researcher an asset (pp. 5-6). Unlike quantitative research, qualitative research approaches and methods include interviews, which allow participants’ perspectives and “methods so open that they do justice to the complexity of the object under study” (p. 5).

When deciding what kind of qualitative study would best address questions about the long-term effects of the EOS120 Education Lab, a case study became the obvious choice. Case studies “are the preferred strategy when ‘how’ and ‘why’ questions are being posed, when the investigator has little control over events” and as a result have become extremely popular in the social sciences (Yin, 1984, p.13). A case study is, “an empirical inquiry that: investigates a contemporary phenomenon within its real-life context; when the boundaries between

phenomenon and context and not clearly evident; and in which multiple sources of evidence are used” (p. 23). Case studies are not confined to, nor should they be confused as the only method of qualitative research, but they have a distinct place within evaluative research (p. 25). To look at the long-term effects of the Education Lab, my research had to be explanatory in nature to answer how and why participants were affected (p. 18). Since the experiences and career choices of the participants were completely out of my control, doing a case study focused on evidence collected through individual interviews was the best and most time effective way to gather data.

Among traditional prejudices against case studies, the assumption tends to be that case studies “provide very little basis for scientific generalization” (p.21). The point of a case study is not to “represent a sample” and provide statistical generalization, but to give some indication of trends that an investigator can use to expand and explore theories resulting in analytic generalization (p. 21). Since my questions about the EOS120 Education Lab and its long-term effects all focus around trends in participants’ views and pedagogy, to explain any possible causal links required a case study approach (p. 25).

As my form of data collection, I chose to do one-on-one interviews with participants. My hope was that interviews with each individual would allow participants the opportunity to talk freely without interruption from their peers. Additionally, I didn’t want participants to feel that there was a right or wrong answer to my questions and interviews allowed them to freely give their opinion without feeling socially constrained to give a certain answer. My goal was to maintain an unbiased approach and equal power dynamic for the participants. This decision to do interviews one-on-one also resulted in a space where participants could create a more

personal narrative regarding their beliefs, their experiences in the Education Lab, and their experiences following the lab to date.

The Trials and Tribulations of Educational Research

Having decided upon the basic criteria of my potential participants and the structure of my research, I then began the process of getting ethics certification from the Human Research Ethics Committee (HREC) at the University of Victoria. This included a brief outline and rationale of my research, a recruitment script, future interview questions, participant consent forms, and a plan of how to have the recruitment scripts disseminated on my behalf to potential participants. The University of Victoria Alumni Relations department has contact information for all alumni, so after contacting a member of the Alumni Department staff that agreed to send my recruitment script and meeting all other criteria of the board that my research would be done ethically, I was given approval from the HREC. Ironically it wasn't the ethics process and review that was time consuming, but the months following my ethics approval in which I began my research.

Initially I had to collect the names of those that had completed the education lab section of EOS120. This resulted in a list of 110 potential participants that had completed the project and agreed at the start of their EOS120 classes to have their names associated with the project. This information was gathered from achieved participant consent forms from the education lab research. Then these names were crosschecked with a list of those that had graduated from the Education program beginning in 2006.

Finding the list of participants of the education lab was easy and people were very helpful. The first hurdle came in the form of getting the list of Education program graduates. Since the lists are technically part of the public domain, I had intended to contact the Department of Education for their convocation lists and had assumed that they would be available. The names are printed and available within convocation booklets printed every year and kept within the university's archive library. Perhaps it was because it was the middle of summer; perhaps it was because so many people were in and out of the office due to vacation, but over the first six weeks of my research I was shuffled from one secretary to another secretary to another secretary in search of convocation lists. After much aggravation and shuffling, my supervisor stepped in and emailed the department on my behalf. He received convocation lists within twenty-four hours.

While I was delighted to finally have the lists, I was deeply saddened to discover that the hierarchy present within academia was also present within academic research. No one was willing to take the time to assist me, but they were more than obliging to my supervisor, a well-known professor and senior member of the Faculty of Education. I couldn't help but take this turn of bad luck personally. Was this about me? Had I done something wrong? Was my status in my department a factor? Nonetheless, this list was then crosschecked with those that had participated in the Education Lab section of EOS120 and resulted in 25 potential participants that had both participated in the lab and graduated from the education program.

The process of doing scientific research is very different from research in the social sciences. In my experience, the head of the lab is generally the primary source of grant money and is in charge of the ethics application, research focus, and the researchers in the lab. While it is possible to get an individual grant, there are tiers and layers of ethics approval that researchers

can attach themselves to that already exist in the laboratory, so researchers can bypass needing ethics approval as long as their work falls within the guidelines of the lab's research niche. As a result, once you've decided what your focus is going to be and what question you are aiming to answer, the next step is to see if the supplies you will need are already stocked in the lab and order the remaining materials. Most background information on your topic of inquiry can be found in previous studies and, ideally, you generate all of the information that you will use in your research. Thus the only hierarchy you have to deal with is within the lab itself. In the case of social science, you are relying on the many people that are needed for lists, information, and assistance for ethical research to be done. This was my first hurdle, the second was not the result of academic hierarchy, but the result of human error.

Building up to this point I had been in constant contact with my liaison in the Alumni Relations Department. We had talked about them assisting with my research when I had first contacted about whether the Alumni Relations department would be willing to mail out materials on my behalf. They suggested that if I supplied the names and the recruitment script, they would then forward my recruitment letter. According to my contact, they believed that they had the authority to contact alumni and related that in previous studies the alumni relations department had assisted other researchers. After my ethics approval, I received an email from this individual saying that they would still be willing to assist me in my research, but that certain wording in my recruitment script would need to be changed in order for them to feel comfortable about me sending it. Since this individual had approved the wording of the first version of the letter, it was a bit surprising, but I complied so I could get my research moving forward. The second draft was approved by the ethics committee and I was given the go ahead. No sooner had I compiled my list of potential participants did this person email me again to inform me that they talked with

their manager and, even though they had sent such letters on behalf of researchers before, their boss had decided that they could not send any of my recruitment letters!

This was a huge blow both to me personally and to my research. I had worked very hard to accommodate the wishes of this person. Thankfully, Dr. Blades had the clearance to ask his staff to act as a go between. He gave the names to his staff and I was able to have my recruitment script sent by email through a secondary email address and by mail through the Department of Curriculum and Instruction. Had it not been for the help of others, namely my supervisor, I might have given up. Thanks to their support and wisdom, I am now a veteran of social science research and, hopefully, will be able to better navigate my future endeavors in educational research.

Recruitment, Interviews, and Data Analysis

Once letters and emails were sent, I immediately began to hear back from participants of the Education lab. Of the 25 potential participants, I heard from five participants within the first seventy-two hours after contact via email. The week following contact, two more participants agreed to participate. Finally after several weeks of waiting for more participants, my final participant contacted me. One potential participant contacted me saying that while they would like to participate in the study, they were unable to do so due to a lack of internet and phone access in their new home in New Zealand. In all, eight people agreed to participate resulting in a 32% rate of participation in my study. The 68% of potential participants that did not respond were either no longer at that address and their letters were returned or their email addresses were no longer active. Everyone that was contacted, with the exception of the potential participant in

New Zealand who could not participate for technical and not personal reasons, agreed to participate. After initial contact, all participants were sent the participant consent form first by email and then by mail depending on whether participants could sign, scan, and then email me their consent form. For those interviews that were conducted in person, I brought copies to be signed to each interview. All eight participants read and signed a participant consent form prior to us beginning our interview. This insured that they knew their rights regarding the recording of the interviews and their ability to leave the program at anytime. It also assured them of their confidentiality and anonymity through out the process of my research and consequent uses of their interview content.

Of the eight interviews, two were via Skype, two were by phone, three were in person, and one intended to be done via Skype but had to be done by phone due to technical issues. The average interview time was thirty-two minutes with the longest interview lasting forty-seven minutes while the shortest interview lasted twenty-one minutes. Participants were all asked the same questions with a slight modification for the participant that was non-practicing (see Appendix A for questions used in the interviews of practicing teachers and Appendix B for questions for non-practicing teachers) with as little interruption as possible. Anytime a participant went too far off on a tangent, I would try to steer them back to the question, however since most of the questions were aimed to be relatively open ended participants were allowed to develop the question based on their experiences and current beliefs.

Following each interview, the audio recordings were saved in password-protected files and then transcribed using a consistent system of marking emphasis, pausing, and additional noises and gestures made by both the interviewee and myself. These transcripts were then analyzed for any major differences in experience such as whether or not the participant was a

practicing teacher, and then for subsequent trends of topics such as participants views on misconceptions, the presence of the EDU model within their pedagogy, etcetera (see Appendix C for coding matrix). This data analysis was done using a similar matrix system to the matrix structure that has been outlined in the classic work by Miles and Huberman (1984, pp. 211-214). Having studied the constructivist approach to science education, I chose categories that I felt exemplified the constructivist approach and indicated a lingering presence of the EOS120 Education Lab in participants' approaches to teaching. These categories included "Hands-on Inquiry Essential to Science Education", "EDU Model (constructivist approach)", "Teacher as Facilitator", "Helpfulness of Resources", "Positively Changed Views of Science Education Post Lab", "Reinforcement of Constructivist Approach in Science Methods Course", and "Misconception Correction Through Experience". In addition to these categories, I created categories to analyze the impact of participant experiences in the EOS120 Education Lab such as having a positive memory of the EOS120 Education Lab and a positively changed view of science education. Each participant was assigned a coding sheet to accompany the transcript of his or her interview. If a participant directly mentioned any of these categories, the page number was placed in that column for that category. Similarly, if a participant described a category theme, but did not directly mention it, the page number was placed in the corresponding column of the corresponding category. If there was no mention of a category, all cells in the row corresponding to that category were left empty. Of the data generated within the coding matrix, seven of the eight categories were either directly mentioned or described but not mentioned directly by participants (see Figure 5 below for interview results).

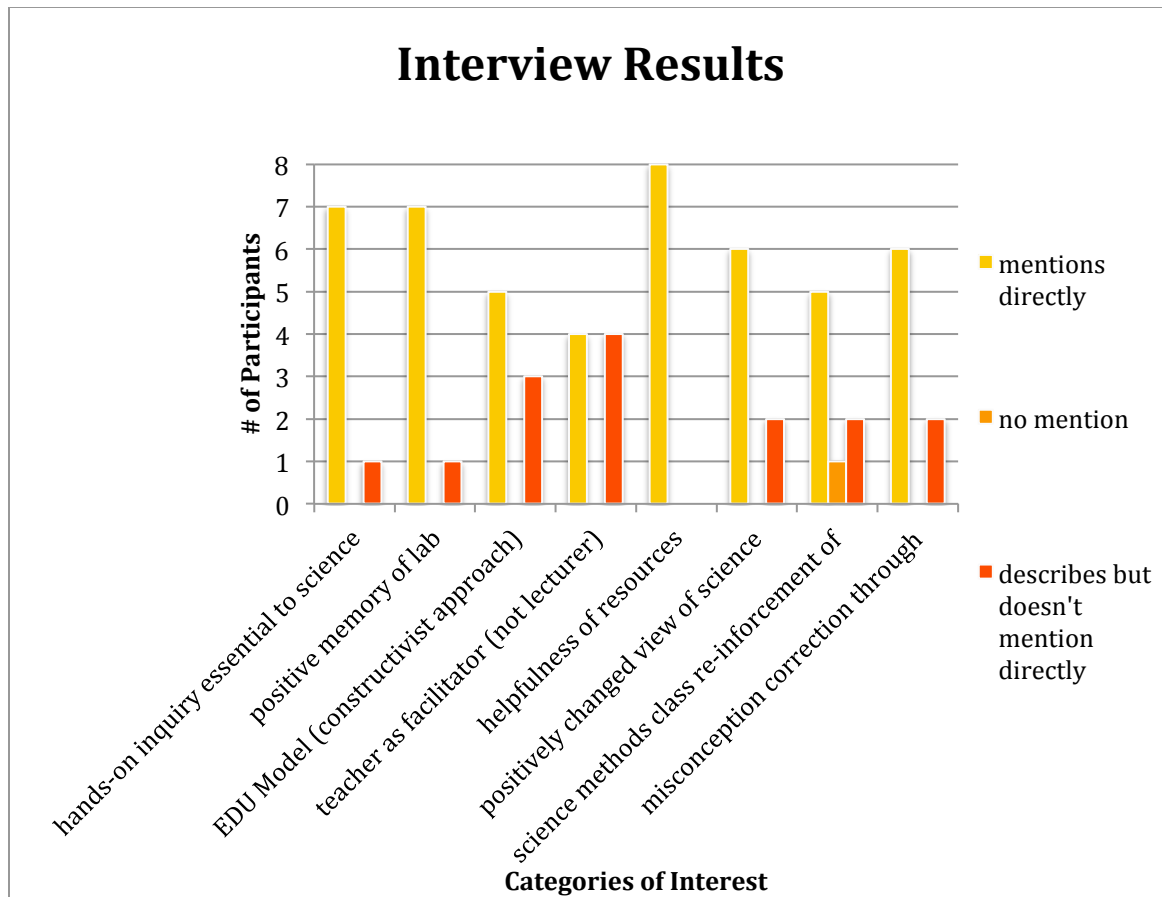


Figure 5. Interview Results— participant responses to coding matrix categories

The presences of these categories are indicative of any lingering effects of the Education Lab and the constructivist approach within participant pedagogy. Those trends that were largely expressed across participant interviews are labeled Major Trends where as those that were not blatantly expressed within all participant interviews either through direct mention or description, but still present within the majority of participant interviews, are referred to as Minor Trends. As a result, three major trends and three minor trends became apparent within the expressed views of participants. Conclusions drawn from those matrixes in addition to remarks supporting those conclusions have resulted in the next two chapters.

Chapter Four- Major Data Trends

Evidence of Constructivism

In order to assess the lingering impact of the constructivist approach used in the EOS120 Education Lab, five data categories were selected that reflected the presence of a constructivist approach within participants' pedagogy. Evidence of the EDU Model, the role of teacher as a facilitator, misconception correction through experience, and reinforcement of the constructivist approach within the science methods course that all participants took as a part of the Education Program function as indications of constructivist principles within the pedagogy of participants. The presence of hands-on inquiry being expressed within participant pedagogy, which is outlined in the section below, also indicates an integral part of the constructivist approach as outlined in the EDU Model, however because it was so pronounced in participant's pedagogy, it constitutes a separate major trend.

Evidence of the EDU Model.

While participants did not necessarily mention every category indicative of the presence of constructivism directly, *all* participants described if not directly mentioned each category within their pedagogical approach. Five participants mentioned the EDU Model directly while the remaining three described the model when remembering the lab or describing how they would design a science lesson. In support of the EDU Model and its use in their classroom, one participant remarked the following:

Often I find, you know, that often there aren't a lot of students that do hands-on experiments so you know they might have read something and forgot it or you know [students] didn't understand what they read, but having the hands-on experiments, they are experiencing it all and it sticks with them a little bit better,

and it makes sense to them on their own terms. You get some sense of process I guess, sense of reasoning. (Laura, personal communication, November 9, 2011)⁴

Similarly, another participant that is a fulltime teacher remarked that the EDU Model was the best way to get students interested in science: “So presenting concepts to the kids, letting them explore it, kind of like there is no wrong answer we’re observing...Science is not a hard on to sell to kids K-7, they’re excited to do it.” (Marie, personal communication, November 14, 2011)

Another participant expressed the same enthusiasm amongst her students when using the EDU Model to introduce scientific concepts related to weather:

[We] did do air pressure in the classroom with, and I can’t remember exactly how it was, but we made something that measured the, like a home made barometer like a balloon on top of something...and the kids were super excited and they would come into the class the next day and go” OH MY GOD HOW HIGH IS IT! THE PRESURE, WRITE IT DOWN!!!!” (both laugh) And it was, you know, much more effective than reading it in a book and then just trying to memorize it. (Barbara, personal communication, December 14, 2011)

Of the eight participants, all participants said that by using an approach identical to the EDU Model they were able to get their students more interested and excited about science.

In addition to their students, most participants said that their own experiences in the EOS120 Education Lab made them more interested and excited about the concepts in the lab, earth science, and even science in general. When asked about the lab, one participant said that by using the EDU Model they, “found it really effective for my learning and it just seemed like the perfect way to present it for kids” (Sally, personal communication, November 16, 2011).

Another participant remarked:

When I took the Ed lab, the way that they taught the earth science class was, I don’t know, out of all of my university classes and all of my education classes, that’s the one that I actually remember being in and remember the lesson from. I

⁴ To ensure complete anonymity of participants, pseudonyms have been substituted in for the actual names of participants.

still have all of the materials from it, so I probably would try the same approach that they had in that lab. (Elizabeth, personal communication, January 4, 2012)

When discussing the use of the EDU Model in the Education lab, one participant, pseudonym Maria, said, “[Dr. David Blades’] approach and his philosophy is stated so strongly, simply, and compellingly that you just realize, ‘yeah this is what we need to be doing’” (personal communication, November 21, 2011). Either in their own classrooms or in their experiences, all participants either directly mentioned or referred to the stages of the EDU Model. In addition to the EDU Model and its use of constructivist principles, two other categories were intended to examine any lingering effects of the constructivist pedagogy taught in the Education lab: how the participants view their role as teacher and how they approach correcting misconceptions.

Role of Teacher as a Facilitator.

The traditional approach to science education places the teacher at the head of the class as a source of knowledge, providing information and managing student behavior. The constructivist approach suggests that in addition to designing opportunities for students to construct their knowledge, teachers should facilitate student learning and help to correct their students’ misconceptions through active exploration of the phenomena in question. Both of these constructivist precepts were present within the responses of all participants. Half of participants directly mentioned being a facilitator and the remaining four described this concept. Laura, Elizabeth, Barbara, and Sally all described themselves as “facilitators”. In support of being a facilitator, Elizabeth said, “I like trying to find kids an opportunity to discover stuff and...I would like to try and herd them into an direction of ‘here’s what’s considered right, right now’” (Elizabeth, personal communication, January 4, 2012). Similarly, Barbara suggested that her role as teacher was not to give lots of information and answers, but to get them asking

questions and facilitate their learning: “[Y]ou want to keep that question asking alive because the root of genius is keeping curiosity and passion alive...it’s better to not give the answers and step back and allow the questions” (Personal communication, December 14, 2012). In addition to assisting in her students’ inquiries, Laura commented that by using the EDU Model and being a facilitator, “[I]t’s not my investigation, it’s their investigation so they have some invested interest really in getting the answers” (Personal communication, November 9, 2011). By stepping back and allowing her students to explore with limited guidance, she believed that she was able to encourage enthusiasm and ownership of knowledge amongst her students.

Unlike the four participants above, Maria, Harriet, Rosalind, and Marie suggested that their role was as a facilitator through their descriptions of their ideal science lesson. When asked how she would design a science lesson, Harriet said that in addition to using hands-on inquiry the best way to engage her students was not to lecture, but to ask questions.

[T]he kids will be like ‘huh’ and then you say, well find something that really irks you about the world. What do you want to explore that relates to science? What’s something that you want to find out? What’s a question that you have when you look out at nature? What’s a question that you have when you look at a volcano? Right? It’s making it relevant to the students so that they will actually want to find out and looking at how to help them find out in real ways. (Harriet, personal communication, November 23, 2011)

Similarly, Marie indicated that she acts as a facilitator and not a lecturer:

Science, very interactive my lessons, very exploratory, not a lot of actual teaching, more showing them and then asking about their observations and exploring, that sort of thing, you know, the inquiry approach for sure. (Personal communication, November 14, 2011)

Misconception Correction Through Experience.

Another indicator of the constructivist approach in participant pedagogy, misconception correction through active exploration, was also present in the responses of all eight participants. Six participants directly said that they would correct student misconceptions through active exploration and the remaining participants described having their students use active exploration when they revealed misconceptions about scientific phenomena. When asked how she would deal with a misconception, Sally described how she would correct a misconception about seasons or the moon cycle:

Things like the orbit of the earth around the sun and showing how it's at an angle and using a flashlight to show how, why the moon appears like it does, things like that are very powerful and the students are going to retain that and they have a better chance of retaining that rather than if they get an explanation or they read a paragraph or they hear at student report, they might remember it, but they probably won't. They will probably daydream or something like that. (laugh) But you know, if they get a really interesting demonstration or something like that, they are much more likely to remember that because they will be more interested and it's just a much more powerful way to learn... (Personal communication, November 16, 2011).

Similarly another participant, Maria, said, "I can't remember exactly what it was, but I just remember not really needing to talk about you know not needing to beat it to death, but then allowing them to make that discovery and then at the end allowing them to understand an make that lasting point" (Personal communication, November 21, 2011). Further evidence for this was provided by Laura, "you just say well that's really neat or that's a great idea you know and try and get them interested in doing some research and trying to find out what the real answer is on their own terms" (Personal communication, November 9, 2011). In addition to advocating for hands-on misconception correction, Harriet suggested that, "misconceptions are one of the most powerful ways to start inquiry science...I really think that it can be utilized to the teacher's advantage and to a student's advantage too" (personal communication, November 23, 2011).

Reinforcement of the Constructivist Approach within Participants' Science Methods Course.

Lastly, participant interviews suggest that the constructivist approach was reinforced in the science methods course that all participants took during their Education degree. After bringing up the EDU Model, Rosalind said, “in our science methods course once I was actually in the education program, I feel like our instructor had a similar sort of take. And so that’s what I took away, that this was the sort of desirable way to teach science“ (Personal communication December 14, 2011). Another participant, Maria, had Dr. David Blades for her science methods class and had this to say about the course, “I was fortunate that it was David and so it just served to reinforce all of the principles and all of the practices, and you know it was kind of interesting because I was able then to see his influence on that lab (laugh) and realize, oh ya right, I get this part and I get that part. So he and that approach have definitely affected my approach to teaching “ (Personal communication, November 21, 2011). This experience was not isolated to Dr. Blades’ science methods class. Dr. Milford taught another section of the science methods course using the EDU Model and used Dr. Blades’ materials within his class. Harriet, who took Dr. Milford’s section had this to say about the class, “[W]e had science in fourth year and my professor, Todd, he’s amazing, and he pretty much demonstrated constructivism and hands-on inquiry...So it was like, ‘oh ya, I’ve seen that before’ but maybe it was in that EOS lab, maybe it wasn’t, I can’t remember for sure” (personal communication, November 23, 2011).

Regardless of their comments, all participants mentioned the EDU Model, the teacher’s role as facilitator, and misconception correction through experience during the course of their interview. As mentioned earlier, because hands-on inquiry was so strongly advocated for I chose

to view it as a separate major theme despite the fact that it is a principle of the constructivist approach.

Hands-on Inquiry in Participants' Pedagogy

The most striking major data trend within this study was the support for hands-on inquiry given by participants in regards to science education. While the traditional approach to science education strongly supports the use of lecturing, textbooks, and worksheets, all eight participants suggested that hands-on inquiry was an important component in having their students to enjoy science and retain information about scientific concepts either by directly mentioning or describing hands-on inquiry.

Of the participant interviews, 88% of participants directly mentioned the importance of hands-on inquiry in teaching science. One participant, Sally, commented to this effect, "I think hands-on is huge and is really key...I think that in my experience for years afterward, if they discovered something by actually doing it, it's just much more powerful..." (Personal communication, November 16, 2011). Maria also commented to this effect saying, "in terms of the lasting knowledge, that comes from the active, hands-on piece" (personal communication, November 21, 2011). Another participant, Elizabeth, suggested "if you can get them playing with it and actually seeing how stuff works then they are way more likely to remember it than just seeing images on pages...I mean really? Who cares about theories written on pages? But when you're actually launching a rocket, then you care about how it goes up in the air..." (Personal communication, January 4, 2012). When asked how she would design a science lesson, Elizabeth candidly remarked, "I think I would probably keep [using] the hands-on

approach in the classroom because I think that the idea of learning by just sitting there and taking notes is really dumb” (Personal communication, January 4, 2012). Similar to Elizabeth, Barbara suggested,

I think the more hands-on the better and I think about the students that are getting [into the] higher grades and are starting to go, ‘uh I don’t want to learn about this’, there should be more hands-on to make it more meaningful, you know, because when things are more hands-on it becomes more meaningful and more memorable...” (personal communication, December 14, 2011).

In the words of one participant when asked what is the most effective approach with their students when teaching science,

They get very excited by it and then they’re focused on what they want to get out of it, so it’s not my investigation it’s their investigation so they have so invested interest really in getting the answers” (Laura, personal communication, November 9, 2011).

In addition to advocating for hands-on inquiry, every participant advocated for doing hands-on inquiry first prior to discussion or establishing terms to concepts when detailing how they would design a science lesson. When describing how she would design a class, Laura said,

Well I would do something small to start, actually get them to do something hands on as a kind of a hook into the lesson to get them to do something, to get them going and then, bring in the questions and theories and put up charts of what do you know about this, what do you want to know about this, depending on how the classes were and how vocal they were I could get them easily to do the self directed sort of explorations and things like that.” (Personal communication, November 9, 2011)

Harriet echoed this in her interview:

I would definitely start off with hands-on, some kind of, not necessarily an experiment per se, because science is so (makes an “eek” noise) experimental, but something hands on. An inquiry topic, that’s probably how it would start” (Personal communication, November 23, 2011).

While this was astonishing to find so widespread throughout the testimony of participants, the most powerful example of the lingering effects of the hands-on aspects of the Education Lab was that of one participant, Rosalind.

When our interview began, I discovered that Rosalind did not feel comfortable or confident with science, let alone teaching it. She openly admitted that while she had been hired to teach all subjects with the exception of math to a 2/3 class, “I should just tell you, I’m not a super confident science teacher” and that as a result she taught using the textbook (personal communication, December 14, 2011). This created a very different, less active classroom in comparison to the hands-on inquiry based lessons that the other participants had advocated for. Because of her reliance on the textbook, Rosalind’s science lessons looked more like this:

[B]ecause the textbook was my guide, because I’m not confident enough to deviate too much from that, it can be an issue using that book because the students’ literary skills weren’t always that great. I mean it makes you realize how difficult non-fiction reading is for a lot of students and how much time has to be spent on scaffolding and supporting students in using and reading the textbook. So that literacy part of it was a much bigger part of science than I had expected it to be, and I’m unclear if it has to be like that, like a more skilled science teacher would be able to avoid that because they wouldn’t, hopefully, rely on the textbook as much as I needed to. (Personal communication, December 14, 2011)

Despite this, Rosalind expressed something that I was not expecting: a desire to use and learn how to incorporate hands-on inquiry into her teaching practice as her central pedagogical approach. After discussing her discomfort with teaching science, she said, “The struggle with science was, I mean what I would like it to look like would be lots of hands-on activities and lots of going outside.” (Personal communication, December 14, 2011) Later in the interview when she was talking about the how much her students loved the hands-on “touch tank” activities that they had done with the help of a company that maintained the aquarium at the school she were she was teaching she added, “so the hands-on aspect of it and just getting to see

these organisms and getting to write down their observations was for sure my students' favorite thing. They loved it. And so I wish that science could have been more like that..." (Personal communication, December 14, 2011) When talking about the lab, Rosalind remembered the EDU Model, described her desire to function as a facilitator, and said that misconceptions should be corrected by experience.

Expressed Value of Education Lab Resources

One result is particularly significant is the expressed value that all participants saw in the resources they received during the EOS120 Education Lab. These resources include a rock kit, fossil kit, activity booklets, posters and pamphlets designed for teachers. Every single participant mentioned directly that they thought that the resources were important. Harriet commented, "If there's anything that I can really see as being a lasting positive thing it was getting those resources. And having that made available to us. Absolutely." (Personal communication, November 23, 2011) Later in the interview she remarked,

The resources will be used forever and I still have the binder of all the labs, in fact it's the only binder that I really saved, you know because it's really got neat information in it, because it's my favorite type of science, and I think it's so relevant. (Personal communication, November 23, 2011)

Marie reiterated Harriet's sentiment in her comments about the resources:

I mean it stands out to me as a course, I don't know if it's being run the same way, but it had *amazing* resources. Like even though I wasn't in teaching yet, I knew that I needed to hold onto this stuff like the books, the pamphlet that [Dr. Eileen van der Flier-Keller] wrote on identifying pebbles and rocks and all of that stuff...I flip through those books to explain things to kids. All of those resources. I mean ya, the books, the rock kits and the posters... (Personal communication, November 23, 2011)

Sally said one of my favorite quotes about the resources when she happily declared, “I remember the goodies we got were amazing! It was like Christmas every time! It was like yay, we get posters and rock kits and that was great” (Personal communication, November 16, 2011). When talking about using the resources in class, those participants that had used them generally said that their students loved the hands-on activities and information present in all of the resources, particularly the rock kits. Sadly, many participants had yet to have the opportunity to use them in a classroom setting, but even these participants mentioned the usefulness of the rock kits and other resources. One participant even admitting to “geeking out” with the rock kit when her friends or kids of friends would come and visit by taking the rocks out of the rock kit and letting people just interact with them (Elizabeth, personal communication, January 4, 2012). This participant continued to say that when she does, “get hired to teach a core social that [has] a geography component, then I will be tying earth science into that and I will *definitely* be using those rocks based on the curriculum of course. Because yeah, I’ve still got them, they’re on my bookcase and I was having a look at them now so (both laugh).” (Elizabeth, personal communication, January 4, 2012)

While most had yet to use the resources in the classroom, many participants still had all of the resources, regardless of the number of years that have passed since they completed the lab or how many places they have moved to since then, some to other cities and provinces. For example, Maria said in her interview, “I’ve got my box of goodies that I got after the lab and I’ve got it stored in a way that I can access it because there are so many opportunities...to do some active exploration” (personal communication, November 21, 2011). Even Marie, Elizabeth, and Laura who have moved many times since leaving Vancouver Island still had their resources at the ready, waiting to be used.

Chapter Five- Minor Themes and Revelations

Positive Experiences Remembered About the Education Lab

One of the astonishing elements that emerged from participant interviews was the amazing number of detailed experiences that participants reflected upon positively when asked about the Education Lab. While two participants did not express a fervent appreciation for the lab (one sighting that she just wanted to get her prerequisites done for the education program and the other said that she wished she would have had a better understanding of education as a study prior to the lab) *all* participants had at least two very detailed memories about the lab that they were excited to retell. Since two of the eight participants did not express a direct enthusiasm when referencing their opinion of the lab, but nonetheless had positive memories associated with the lab activities, this functions as a minor trend.

While there were many different activities that were described by participants, there were some reoccurring activities that stood out: the earthquake lab, rock sorting, the river activity, and field trips to name just a few. All of the activities were remembered in a positive manner as demonstrated by the participant's excitement when talking about the activity in the lab or by their direct enthusiasm for the activity. When asked about modeling in the lab, one participant immediately went into a very excited description of the earthquake lab:

There was the earthquake [model] showing subduction zones and things like that using exercise mats and rollers and there was, oh gosh, there were numerous [activities], so many I can't even remember how many! There were just so many little things. I mean [Eileen] showed us how you could pretty much use anything, any shape or size, and it didn't need to be technical, as long as you got the concept right and you got the labels on there you could use anything you had to demonstrate something and you could use lots of people to participate and get them involved in the demonstration. It was just fabulous! (Laura, personal communication, November 9, 2011)

Similarly, Barbara also talked about the earthquake lab with great enthusiasm, “You know like, I’m always going to remember the earthquake or the tectonic plates with the foamy stuff because those kinds of things, you get the visual and you’re going to remember that. And if you have that it’s much easier” (Personal communication, December 14, 2011) When asked about the EOS120 Education Lab, Elizabeth directly cited the rock sorting activity saying, “You know I remember sitting there with the rocks and they had all of the lessons broken up into small little portions which is way easier to learn.” (Personal communication, January 4, 2012) In addition to describing activities in detail, some participants also alluded to their application in reconstructing or furthering their previous understanding of certain scientific concepts. For example, in addition to talking about the earthquake lab, Laura also commented on the river activity and how it had “made sense” to her:

Well, some things that you read about they become very abstract. You know it for a fact because you’ve memorized it, but you never really think much about it or want to find out why things happen in a certain way. For example, you know that the erosion of a river, well rivers never seem to be straight and all you know is that it starts to erode and they had one activity and they were showing the erosion of the river and they showed the flow of the river and how it slowed down and as soon as it started slowing down, the sediment started to zigzag and you could see how, you could start recognizing rivers and streams that were around that had different shapes in them and why that would happen. (Personal communication, November 9, 2011)

In addition to these more popular activities, sedimentary layers were also discussed by participants as positively remembered activities that helped them build a more detailed understanding of the scientific concept. One participant, Harriet, described learning about sedimentary layers by, “using granola bars and...other food items” (personal communication, November 23, 2011) while another participant recalled, “[Eileen] cracking a hard-boiled egg and talking about the layers of the earth” (Marie, personal communication, November 14, 2011).

Regardless of the topic being referenced by the participant, the amount of detail in their recalling of an activity was truly astonishing.

In addition to their positive experiences, a majority of the participants were very enthusiastic about the lab itself and saw it as a valuable part of their education and transformation into teachers. In the words of one participant, “[The Education Lab] was one of the first education oriented experiences that I had...it really influenced the rest of my learning throughout the PDPP...” (Maria, personal communication, November 21, 2011) Later in her interview, Maria reiterated this when talking about how meaningful the lab was to her personally:

Activities were always multidimensional and there were always ways that you could do things that allowed for a difference in perspective...it was the active construction of meaning that would be the primary take away from that [for me]. Something that I had considered to be so boring and so useless (laugh) and it was because of the lab, it wasn't the lectures!” (Personal communication, November 21, 2011)

Another participant, Laura, echoed this notion of accessibility in the EOS120 Education Lab. “It was fabulous! It was absolutely fabulous! They gave you really hands-on things you could do with your students and things that really make sense, and it makes the ideas so accessible to everybody really” (Personal communication, November 9, 2011). Later in her interview, Laura also said about the lab, “I just think it's a fantastic program and I really hope that they keep that up because...it really gives a spark to science” (Personal communication, November 9, 2011). Similarly to Laura, Barbara expressed the value of her experience in the Education Lab: “I really enjoyed it...I found it a really valuable experience to take with me into the education program” (personal communication, December 14, 2011). Another participant, Elizabeth, was also very enthusiastic about the lab and applying it to her teaching when she said,

The lab had so many activities that were super educational, super, I don't know, impactful. They're easy to remember and they certainly made an impression on us. And [the activities are] fun! I think that I would probably be inclined to poach some of them to use in the classroom myself. (Personal communication, January 4, 2012)

Elizabeth also commented that the lab, "ended up being the best course I took that year", further supporting that the lab had a meaningful impact on Elizabeth (Personal communication, January 4, 2012).

Positively Changed View of Science Education

In order to further examine participants' pedagogical approaches to science education, one of the interview questions focused on whether they felt that their experience in the Education Lab had changed their view of science education. Seven of the eight participants commented on directly or described an effect in regards to their view of science education. One participant did not cite the lab as being responsible for a change *per se*, but she did advocate strongly for hands-on inquiry and the EDU Model as a result of the lab, which runs counter to the traditional approach to science education. This suggests that her view of science education was changed from a traditional view as a result of the lab. Of those seven participants that did directly mention or describe a positive change, some participants sighted an increased appreciation and interest in science as a result of the hands-on inquiry and EDU Model in the lab. For Maria, who is currently a "teacher on call,"⁵ the lab, "heightened my appreciation of science in general" and will act as cornerstone in her teaching should she get a fulltime classroom contract. Laura said

⁵ In British Columbia, being a substitute teacher and being on a substitute teacher list for a school district is referred to as being a "teacher on call," or TOC.

that the lab made her, “realize that science was an interesting subject and it’s not all memorization” and that it could be made accessible for everyone.

In addition to increasing interest, some participants commented on an increase of confidence when teaching science that they directly associated as a result of their experience in the lab. One participant in particular had a very significant response to this question based on her fear of science. As result of her experiences in previous science classes, Rosalind expressed that she was very uncomfortable with science. The anxiousness that she had experienced coupled with her lack of success in the science classroom prior to the Education Lab had led Rosalind to conclude that science was a “special subject” shrouded in “mystique” and that it was simply not available to her. Because of the science lab requirement in order to be considered for the Faculty of Education B.Ed. degree (see pages 2-3), she was forced to take a science class and chose to take the EOS120 Education Lab. “The [education] lab itself I found just really useful at alleviating some of those pretensions about, ‘oh my god I have to do this pre-rec course and I have to do a science methods course to get into the program! What’s that going to be like?’” (Personal communication, December 14, 2011). Later in the interview Rosalind added that, “[the education lab] probably made me feel more positive towards [science], like less intimidated for sure” and that Earth Science was something that she was now, “actually interested in and can see wanting to teach” once she feels more confident in doing hands-on inquiry based science lessons and can move away from using the textbook (Personal communication, December 14, 2011). For Marie, who had similar although not as pronounced anxieties about science as both a student and a potential teacher, the lab also helped to assuage her fears:

I think [the Education Lab] did that show that there are so many resources, so many ideas, and made it really accessible and science was not something that I was necessarily comfortable in. So knowing that that could be science was like

really comforting to me and I was thinking, 'Oh, I can do this' and get excited about it as well. So yeah, I would say that it did positively affect me. (Personal communication, November 14, 2011)

Elizabeth, echoing Marie's comment, said she was no longer scared of being hired to teach science (personal communication, January 4, 2012). All of these responses, particularly Rosalind's, suggests that the Education Lab with its use of hands-on inquiry and constructivist principles has the ability to empower teachers and overcome any previous, bad experiences that they as students suffered in the science classroom.

Lack of Experience with Science as Teachers/Students

This theme, although it is not central to looking at the effects of the EOS120 Education Lab on participant pedagogy, is something that needed to be included due to its prevalence among participants. While one participant is actively teaching science as a part of their fulltime teaching contract and another participant teaches science afterschool, the remaining six participants have had very limited experience teaching science. While they stated that they taught general education in the form of either a fulltime contract or part-time TOC position, they also stated that they have overwhelmingly not been asked to teach science. Additionally, some participants also expressed a lack of science in their own educational experience as students during elementary school as well during their secondary education.

Of those participants that were TOCing, it became clear that they were not being given the opportunity to teach earth science, let alone lessons pertaining to scientific concepts from other scientific fields. When asked if she had taught any science lessons, one TOC that teaches

mostly general education curriculum, Maria, responded, “teachers very rarely leave science lab type activities for TOCs. Those are usually things that they’re going to do. And no, I can’t think of an opportunity where I’ve gotten to do much science at all. So I have not, but I have hopes for the future. (laugh)” (Personal communication, November 21, 2011). Other participants such as Rosalind said, “I don’t feel like I’ve had a lot of chances to practice teaching science, you know?” (Personal communication, December 14, 2011). Harriet had a similar experience. When asked if she had taught any earth science topics she said that not only had not been asked to teach any earth science, but that she “actually [hadn’t] done any science in the last two months” when she has only started TOCing two months ago following her graduation from the Education Program (personal communication, November 23, 2011). As a result of their frustration, those participants that were not being given the opportunity to teach science had found several ways of coping with this situation: either through incorporating science into lessons or by using the resources given to them to teach their friends and their friends’ children. This is noteworthy because it suggests that those participants that are not getting the opportunity to teach science as TOCs not only want to teach science, but are willing to find a way to incorporate scientific concepts into their teaching.

Some participants actively added science topics to their lessons because they wanted to include science and were not asked to teach science topics, but they felt that they should be included in the lesson regardless. Sally, who was a TOC but is currently taking some time off, was asked to teach a social studies unit on recycling during her practicum that she turned into a science unit with the permission and support of her sponsor teacher. She has yet to teach another science lesson. Another participant found out at the last minute that the class she was substituting for was covering earth science topics, so she brought in her rock kit, but she was not

asked to teach a lesson on the earth science topics that the class was covering. As a Grade 5 teacher, she had done a unit on the human body, but that was the only science unit that she mentioned outside of her experience with the rock kit. Another participant loves her rock kit and lab resources so much that, “What I have done is kind of randomly sit down with friends or kids of friends and be like, ‘LOOK! LOOK AT THE THESE AWESOME ROCKS! CHECK IT OUT, THEY’RE ROCKS!’ So I occasionally geek out about rocks using the education kit (laugh)” (Elizabeth, personal communication, January 4, 2011).

Another aspect of this trend that is important and needs to be mentioned is that some participants also expressed that while TOCs are not getting the opportunity to teach science, some elementary school teachers are choosing to avoid teaching science as a core curricular subject and see it as an elective despite being legally required to teach science (BC Ministry of Education, 2011b, p. 1). One of the participants who teaches fulltime in Ontario noted that while she teaches science on a regular basis, there was not much science that she saw being taught by other teachers in her school. This is significant in that it suggests that even though there are teachers that are teaching science on a regular basis, this is not always the case depending on the teacher. One participant noted that in all of the TOCing that she had done over the past three years she had seen very little earth science being taught in classrooms, “I’ve been in a lot of classrooms but I don’t see a lot of it being taught out there. You know a lot of teachers are working their way through the textbook (laugh) and they’re working their way through the various resources that they have” (Maria, personal communication, November 21, 2011).

Another participant who teaches fulltime in Rosalind, who expressed a lack of confidence when teaching science as a result of her previous science class experiences, teaches a Grade 2/3 class fulltime. When asked if she had taught any topics related to earth science, she said “I’ve done

very little science with my students this term just because I've decided to alternate between social studies and science, so that's coming after Christmas." (Personal communication, December 14, 2011) Later in interview, it became clear that she not only taught science lessons when convenient, but that she had witnessed science not being taught with the same consideration as other subjects in elementary schools:

[E]lementary school science is so, well not downplayed because that's not fair to say, but it's almost like an afterthought, you know... Science is something that you do when you can squeeze it in. And that's unfortunate, I mean I'm sure some of that comes from lots of people not feeling comfortable about it or it's just not a priority and [their lack of comfort] would make it impossible to become a priority. (Personal communication, December 14, 2011)

The lack of opportunities that TOCs are being given to teach science and the lack of emphasis on science by those that are teaching fulltime could be reflexive of a lack of priority given to science in elementary schools.

Lastly, in many participant interviews, participants expressed a lack of experience with science and scientific concepts in their own education. As students, very few of them had chosen to focus on science. For some this was due to the amount of time that had passed from graduating high school to pursuing their undergrad and so they lacked confidence in science as a result. For others, it was simply an overall lack of experience with science education. In the case of Harriet, she had this to say about her experience in elementary education as a student and as a teacher: "I mean when I think about science and what was my science experience as a student, it really wasn't a strong presence in my education. And given that in the two months that I've been TOCing, that I haven't encountered any science I think really speaks for itself too, right?" (Personal communication, November 23, 2011) Another participant, Elizabeth, also expressed a lack of science in her education, particularly geology, because, "technically there

was a part of Socials 10 that had geology in it if your teacher was on the ball, but most of them focus on history, so I hadn't taken anything since then...I wish that I'd had time later in high school to do it, but I just had too many interests" (personal communication, January 4, 2012). Elizabeth admitted later in the interview, "I don't know how much science stuff I retained from school actually" (personal communication, January 4, 2012). For another participant, Barbara, she said that in fact she had learned more science outside of school with her parents than she learned in the science classroom. This indicates that participants are lacking familiarity with science and scientific phenomena in the classroom prior to entering University, perhaps adding to any anxieties that they might have had about completing their lab science prerequisites and their consequent choice to take the Education Lab in introductory geology.

Chapter Six- The Final Chapter

Conclusions

When examining participant interviews, it is evident that the EOS120 Education Lab had a profound effect on those who participated in this study. Every participant recalled an instance in which the lab had influenced him or her personally in positive ways, even after five to seven years. Their experiences in the lab not only changed their view of Earth Science in a positive way, but for most participants, it changed their conception of what science in the classroom should or could look like. This is echoed in their expressions of constructivism within their teaching approach to science.

Participants were overwhelmingly supportive of constructivist principles in their pedagogy. Participants were very vocal about the value of constructivist principles within their teaching approach to science in addition to other subjects: from the notion of being facilitators to advocating for correcting misconceptions through experience. *Every* participant advocated for hands-on inquiry and for exploration of some kind at the beginning of the lessons that they envision for science topics. This suggests that the EDU Model they were introduced to and experienced in the EOS120 Education Lab that was later reiterated in their Science Methods course remains a central aspect of their pedagogical approach.

While constructivist principles were reinforced in the Science Methods course that every participant took during their education degree and undeniably had an effect on the degree to which participants encountered constructivism and constructivist principles in education, being in the EOS120 Education Lab appears to have functioned as a means for participants to experience constructivist pedagogy *first* in a meaningful and powerful way. The majority of

participants cited the Education Lab as one of the best courses of their undergraduate and education degrees. Participants also commented on the lab as a truly mindful way to introduce how to teach science through meta-cognition not just as students, but also as future teachers. Additionally, while seven of the eight participants of this study connected the science methods course in terms of its reinforcement, the bulk of their descriptions of constructivist principles stemmed from the Education Lab itself, suggesting that the lab had prepared students to encounter constructivism later in the Education Program.

Another indication of the effect that the lab had on participants in terms of their lingering commitment to hands-on inquiry and the EDU Model of teaching is evident in participants' responses about the resources they were given during the lab. The fact that every participant kept their rock kits, posters, activity books, and other resources after years of moving, both locally and outside of the province, reflects the meaningful way that these resources were given and introduced to participants as useful tools to have in their classrooms.

In addition to the data provided within the coding matrix, the current career of participants and their exposure to teaching science was another point of interest. Of the eight participants, 38% are currently teaching full-time, 50% are teaching part-time as a TOC, tutor, or afterschool program teacher, and one participant had taken time off from TOCing due to a lack of available TOC positions to work on the campaign of a local MLA. Only four out of the eight participants had taught earth science in the classroom and six out of the eight had taught a science class. With the exception of those participants that have full-time contracts that include teaching science and another participant that teaches science afterschool, most participants had only been asked to teach science on a limited basis if at all.

It is clear that there is a lack of science being taught in elementary school classrooms. This conclusion was evident in the testimony of the majority of participants in that not only are those participants that are TOCs not being asked to teach science, but of those that had fulltime contracts, only one taught teach science on a regular basis. Science is regarded as a specialized afterthought when it comes to planning lessons, despite the fact that it is fully present within elementary school curriculum at all grade levels and teachers are legally required to teach it (see page 72).

Based on the responses of participants, I conclude that the EOS120 Education Lab had a profound effect on the participants of this study and the constructivist principles that were experienced in the lab have lingered with participants, influencing their pedagogical approach to science education in the long-term. The conclusions of this study have only limited generalizability due to the small sample size that participated and hence cannot be generalized to the entire population of those that participated in the original Education lab study and have gone into education. Despite the limited generalizability of this study, the testimony of participants can be generalized among this group of subjects and suggests that by looking at introducing future teachers to constructivist principles prior to their entrance into the education program this could offer possibilities for future studies looking at how to encourage teachers to adopt a constructivist approach to teaching science.

Implications

These results are very significant in regards to teacher education. All of the participants in this study experienced a traditional approach in their school science classes, so it would make

sense that they would emulate the predominant pedagogy they experienced as science students. I had additionally anticipated that their pedagogy would be predominantly based on a more traditional approach due to the five to seven years between when they had taken the lab to the present as well as their subsequent exposure to other pedagogical approaches.

As a result of my initial assumptions, I had expected to see a spread of constructivist principles in participant pedagogy similar to the result found by Uzuntiryaki, Boz, Kirbulut, and Bektas, in which there was an almost even spread of participants' expressed views of constructivist principles ranging from weak to strong in influence (2010, p. 411). Unlike the participants that took part in this study, those interviewed by Uzuntiryaki et al. took chemistry classes prior to their teacher education, but did not experience constructivism as students prior to entering the teacher training portion of their degree.

There is one key difference in the structure of the study done by Uzuntiryaki et al. and my study: the Education Lab. While their study elected to look at individuals that had experienced a wide range of university classes in the field of chemistry, followed by a teacher training in which they were introduced to constructivist principles, the Education Lab not only provided study participants with the opportunity to experience the constructivist approach first hand as science students, but also to learn Earth Science concepts that, as a result of how they were experienced, have been retained by participants. This key difference between simply discussing constructivism in the classroom as was the case in the study done by Uzuntiryaki et al. and the active participation with constructivism experienced by participants in this study leads me to believe that the difference between creating teachers who understand constructivism and teachers who truly embrace constructivist principals is allowing pre-service teachers to actively explore different teaching styles as students. I believe that if one were to continue to study the

education lab, they would continue to see similar, high rates of constructivist pedagogy amongst those participants that continued into the Education Program. This suggests that the EOS120 Education Lab could be a key component to enabling pre-service teachers to adopt constructivist principles into their pedagogy.

One limit to this study that I feel should be addressed is the lack of experience participants had actually teaching science in classrooms. Those that stayed in Victoria, British Columbia following their graduation from the Education Program appeared to have faced a far more difficult hiring and TOC period than those participants that left Victoria to pursue their teaching careers. Of those that have been TOCing, they have not been offered many opportunities to teach science as is evident in their interview responses. As a result, their experience teaching science is very limited and there is a chance that their pedagogy will change when they are teaching science on a regular basis. However, due to the overwhelming support that they gave for hands-on inquiry and constructivist principles it is likely that the effects of the Education Lab will continue to linger with participants of this study. There is another issue that also needs to be discussed further that I alluded to above that I believe relates directly to participants' lack of experience teaching science: science is being left behind in Elementary school classrooms. With the exception of one participant that actively discussed teaching science in her classroom, the rest of the participants that were interviewed for this study were either teaching science when it was convenient, afterschool, or practically never as TOCs. This suggests that science is not being taught as a core subjects within elementary education. If science is to play an important role in students' critical thinking and university preparation, how can we expect students to know and correctly understand the scientific concepts that they are expected to have learned if we are not teaching science as a core subject?

This study reveals that for a select population that experienced constructivism as students in a science, a pedagogical change away from the traditional approach to science education is possible. Who knows what the future holds for the Education Lab? Recently students in the other traditional lab sections, having heard about the hands-on experiences in the EOS120 Education Lab by EOS120 Education Lab participants, have demanded the Education Lab's curriculum and as a result aspects of the handbook created for the Education Lab were incorporated into the traditional lab sections. A study comparing the Education Lab to the other lab sections is now impossible. However, having looked at the lingering effects of the lab on EOS120 Education Lab participants in this study, I would suggest that continuing to look at the lab for evidence of pedagogical change in participants would not only help researchers to better understand how teaching approaches can change through instruction, but is imperative if we hope to gain a full understanding of how pre-service teaching programs and faculty partnerships can shape future science teachers.

References

- BC Ministry of Education. (2011a). *Teacher statistics- 2010/2011*. Retrieved January 12, 2012, from <http://www.bced.gov.bc.ca/reporting/>
- BC Ministry of Education. (2011b). *Prescribed learning outcomes*. Retrieved May 22, 2012, from <http://www.bced.gov.bc.ca/irp/plo.php>
- Blades, D., Van der Flier-Keller, E., Demchuk, T., & Pryhitka, A. (2007). *Grounding Earth Science in Classrooms: A collaboration between science and education at the University of Victoria, Canada*. Poster session presented at NARST, New Orleans, USA.
- Blades, D., Van der Flier-Keller, E., Milford, T., & Alpert, S. (2011). *The EOS 120/Education Project: Improving science teacher education through faculty partnerships*. Poster session presented at AERA, Vancouver, Canada.
- Brooks, J.G. & Brooks, M.G. (1995). Introduction to constructivism. In D.R. Franks, H.G. Langford, & W.E. McEachern (Eds.), *Constructivism: its significance for education* (pp. 1-10). North Bay: Faculty of Education.
- Bybee, R., Taylor, J.A., Gardner, A., Van Scotter, P., Carlson, J., Westbrook, A., Landes, N. (2006). *The BSCS 5E Instructional Model: Origins and Effectiveness*. Colorado Springs, CO: BSCS.
- Carin, A. A. & Bass, J. E. (2001). *Methods for teaching science as inquiry (8th Ed)*. Upper Saddle River: Merrill Prentice Hall.
- Dickens, C. (1858). *Burnaby Rudge, a tale of the riots of 'eighty and hard times (Library Edition)*. Boston: Ticknor and Fields.

- Driver, R. (1983). *The pupil as scientist?* Philadelphia: Open University Press.
- Driver, R. & Easley, J. (1978). Pupils and paradigms: a review of literature related to concept development in adolescent science students. *Studies in Science Education*, 5, 61-84.
- Driver, R. & Erickson, G. (1983). Theories-in-Action: Some theoretical and empirical issues in the study of students' conceptual frameworks in science. *Studies in Science Education*, 10, 37-60.
- Flick, U. (2002). *An Introduction to qualitative research*. London: SAGE Publications Ltd.
- Fosnot, C.T. & Perry, R.S. (2005). Constructivism: a psychological theory of learning. In C.T. Fosnot (Ed.) *Constructivism: Theory, Perspectives, and Practice (2nd Ed.)* (pp. 8-38). New York: Teachers College Press.
- Hodson, D. (1985). Philosophy of science, science and science education. *Studies in Science Education*, 12, 25-57.
- Julyan, C. & Duckworth, E. (2005). A Constructivist Perspective on Teaching and Learning Science. In C.T. Fosnot (Ed.), *Constructivism: Theory, Perspectives, and Practice (2nd Ed.)*(pp. 61-79). New York: Teachers College Press.
- Lord, T.R. (1997). A comparison between traditional and constructivist teaching in college biology. *Innovative Higher Education*, 21(3), 197-216.
- Matthews, W. J. (2003). Constructivism in the classroom: epistemology, history, and empirical evidence. *Teacher Education Quarterly, Summer Edition*, 51-64.

- McWilliam, E., Poronnik, P. & Taylor, P.G. (2008). Re-designing science pedagogy: reversing the flight from science. *Journal of Science Education and Technology*, 17, 226-235.
- Miles, M. B. & Huberman, A. M. (1984). *Qualitative data analysis*. London: SAGE Publications Ltd.
- Minner, D.D., Levy, A.J., & Century, J. (2010). Inquiry-based science instruction –what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, 47(4), 474-496.
- NASA (n.d.)(2012). *5Es overview: “the 5E instructional model”*. Verstynen, S. (Ed.), retrieved March, 20, 2012, from <http://www.nasa.gov/audience/foreducators/nasaclips/5eteachingmodels/index.html>.
- Novak, J. (1988). Learning science and the science of learning. *Studies in Science Education*, 12, 77-101.
- Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: a review of the literature and its implications. *International Journal of Science Education*, 25(9), 1049-1079.
- Piaget, J. (1959). *The language and thought of the child*. New York: Routledge.
- Piaget, J. (1967). *Logique et connaissance scientifique* [Logic and scientific knowledge]. Paris: Gallimard.
- Solomon, J. (1993). The social construction of children’s scientific knowledge. In P.J. Black & A. M. Lucas (Eds.), *Children’s informal ideas in science* (pp. 85-101). New York: Routledge.

- Swartzwelder, J. (Writer) & Anderson, B. (Director). (1995). Bart's comet [Television series episode]. In J.L. Brooks, M. Groening, & M. Scully (Producers), *The Simpsons*. Los Angeles: Gracie Films & 20th Century FOX.
- Taber, K.S. (2006). Beyond constructivism: the progressive research programme into learning science. *Studies in Science Education*, 42, 125-184
- Taverira, M. (2007). *English as a foreign language curriculum adaptation: a constructivist model for enriching teacher class planning at a language institute in Brazil*. Unpublished master's thesis, University of Victoria, British Columbia.
- University of Victoria, Victoria, British Columbia (2012a). *About education*. Retrieved July 2, 2011, from the Faculty of Education Web site:
<http://www.educ.uvic.ca/about.php#section0-0>
- University of Victoria, Victoria, British Columbia (2012b). *Programs and Courses*. Retrieved January 1, 2012, from the Faculty of Education Web site:
<http://www.uvic.ca/education/home/home/programs/index.php#section0-0>
- University of Victoria, Victoria, British Columbia (2012c). *Teacher Education*. Retrieved July 2, 2011, from the Faculty of Education Web site:
<http://www.educ.uvic.ca/prospective/teacher/index.php>
- University of Victoria, Victoria, British Columbia (2012d). *Elementary BEd: application requirements*. Retrieved May 14, 2012, from Faculty of Education Web site:
<http://www.uvic.ca/education/prospective/teacher/programs/elmbed/index.php>.

- Uzuntiryaki, E., Boz, Y., Kirbulut, D., & Bektas, O. (2010). Do pre-service chemistry teachers reflect their beliefs about constructivism in their teaching practices? *Research in Science Education, 40(3)*, 403-424.
- Van der Flier-Keller, E., Blades, D., & Demchuk, T. (2006). *Empowering student teachers to teach Earth science; A collaboration between Science and Education at the University of Victoria, Canada*. GeoSciEd V International Geoscience Education Organization 'Geoscience Education: Understanding System Earth' Conference Proceedings, Bayreuth Germany, p.98. Referred by E. Van der Flier-Keller (June 15, 2012).
- Van der Flier-Keller, E., Clinton, L., & Haidl, F. (2009). EdGEO: Helping Teachers Teach Earth Earth Science. *Geoscience Canada, 36(3)*, 133-138.
- Van der Flier-Keller, E., Blades, D., & Milford, T. (2010). *The EOS 120/ education project: science and education connections for improving student achievement, attitudes and knowledge in university Earth Science*. FYCIC Series Notes. Referred by D. Blades (n.d.).
- Van der Flier-Keller, E., Blades, D., & Milford, T. (2011). Promoting earth science teaching and learning. In L. D. Yore et al (Eds.), *Pacific CRYSTAL centre for science, mathematics, and technology literacy: lessons learned* (pp. 165–183). Boston: Sense Publishers.
- von Glasersfeld, E. (2005). Introduction: aspects of constructivism. In C.T. Fosnot (Ed.), *Constructivism: Theory, perspectives, and practice (2nd Ed.)* (pp. 3-7). New York: Teachers College Press.

Vygotsky, L. (1978). *Mind in society: the development of higher psychological process.*

Cambridge: Harvard University Press.

Wasserman, S. and Ivany, J.W.G. (1988). *Teaching elementary science: who's afraid of spiders?*

New York: Haper & Row.

Yin, R. K. (1984). *Case study research, design and methods.* London: SAGE Publications Ltd.

Appendix A

Interview Questions

Are you currently teaching?

1. Please tell me a little bit about your teaching career.
 - a. When did you graduate from UVic?
 - b. How long have you been teaching?
 - c. What classes/grades have you taught?
2. Can you describe a typical science lesson?
 - a. Which approaches do you find to be the most effective with your students?
3. Have you taught topics related to Earth Science?
4. You were a participant in the Education Lab section of EOS 120.
 - a. When did you participate in the project?
 - b. Please describe your general impression of the EOS 120 Education Lab.
 - c. What methods of teaching did you experience participating in this Lab?
 - d. Do you use any of the methods of teaching you experienced in this lab in your teaching practice? If so, which ones were most useful/successful?
 - e. You were given some teaching resources (posters, rock kits, pamphlets, booklets) as part of the Education lab—have you used any of these resources in your teaching? How useful were these resources for your students?
5. Did your experience in the EOS 120 lab affect your view of science education?
 - a. Is there anything else you would like to comment on regarding the Education lab and/or its influence on your teaching?

6. Have you noticed that students have misconceptions about Earth Science topics or ideas?

How do you address these misconceptions in your teaching?

- a. Have you noticed that students have misconceptions in other science topics?

Appendix B

Interview Questions- Non-practicing

1. Please tell me a little bit about your teaching career.
 - a. When did you graduate from UVic?
 - b. What is your current job?
 - c. What classes/grades have you taught, during your practicum or after?
2. Can you describe a how you would envision a typical science lesson?
 - a. Which approaches do you think would be the most effective with your students?
3. Did you teach Earth Science during your practicum?
4. You were a participant in the Education Lab section of EOS 120.
 - a. When did you participate in the project?
 - b. Please describe your general impression of the EOS 120 Education Lab.
 - c. What methods of teaching did you experience participating in this Lab?
 - d. Do you use any of the methods of teaching you experienced in this lab in your teaching practice? If so, which ones were most useful/successful?
 - e. You were given some teaching resources (posters, rock kits, pamphlets, booklets) as part of the Education lab—have you used any of these resources in your teaching? How useful were these resources for your students?
5. Did your experience in the EOS 120 lab affect your view of science education?
6. Have you noticed that students have misconceptions about Earth Science topics or ideas?
How do you address these misconceptions in your teaching?
 - a. Have you noticed that students have misconceptions in other science topics?

Appendix C

Coding Sheet

	mentions directly	no mention	describes but doesn't mention directly
hands-on inquiry essential to science education			
positive memory of lab			
EDU Model (constructivist approach)			
teacher as facilitator (not lecturer)			
helpfulness of resources			
positively changed view of science education post lab			
science methods class reinforcement of constructivist approach			