Filmmaking: A new pedagogical method to explore students' view of nature of science.

by

Alena Kottova
M.A., Charles University of Prague, 1989

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Supervisory Committee

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Abstract

This dissertation examines the nature, scope, and significance of a new pedagogical approach to teaching of views on nature of science (VNOS) to high school students. Educational approaches based on teaching 'correct' VNOS continue to be dominated by the epistemology of logical empiricism and, as I will point out, these approaches are inadequate to address the issues of VNOS. I assert and the findings presented in this dissertation offer evidence that students' VNOS are dynamic and context-based.

In this research I used filmmaking to explore students' VNOS. High school students, supported by a professional filmmaking crew, completed a short film entitled, *The Shadows of Hope*; this film explores the use of scientific knowledge in understanding everyday life problems. The filmmaking environment introduced simultaneously a number of contexts in which students' VNOS were concurrently collected using mixed methods methodology.
The results show that contexts sway students' VNOS and generate a variety of the VNOS for each student. Evidence shows that there is a common, theme-based pattern to individual students' set of VNOS. The variety of expressed VNOS seemed natural to the students, with no registered discomfort. However, in this study a contrast between students' VNOS and their 'school-based' understanding of science also became apparent. This is evidence that cognitive dissonance is not sufficient to explain the full spectrum of ways in which students learn, deepen knowledge and arrive to conceptual change. I assert that including *cognitive contextual expansion* in our understanding of conceptual change is essential to provide a framework that

allows to integrate cognitive diversity into the theory of learning, reflecting a perhaps more natural way human mind works.

The project's findings offer evidence that students' VNOS deepened and expanded through filmmaking; students arrived to a more examined and mature VNOS while enjoying the activity of making a film. There is evidence that cooperation with a professional team provided students with a feeling of respect and pride. Filmmaking offers a robust way of learning, based on collaborative work that enlivens a large number of learning-enhancing activities. Additional resources and a *Brief Guide For Teachers* are added to this text to support teachers in adopting filmmaking as a unique pedagogical method.

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Acknowledgments

I would like to extend my sincere gratitude to the research participants, the group of high school students who devoted their precious free time to this inquiry. I am also grateful to Jennifer O'Ryan, a high school teacher who selflessly offered her help with informing students about this unique project.

I offer my sincere appreciation for the time and skills that the actors and filmmakers willingly shared with the research participants, helped to guide the students and manage the project to a successful completion of short film *The Shadows of Hope*.

The collaboration of the entire team and their commitment to this inquiry now allows a wide audience to better appreciate the challenges of understanding the nature of science and the intricate dynamic process through which are our views of science developed and changed. The final film serves as a lasting reminder that filmmaking (as opposed to film viewing) can be used as a powerful tool in education.

In addition, I am very thankful to my doctoral co-supervisors, Dr. David Blades and Dr. Mijung Kim, who shared their knowledge and offered their wisdom to guide me through the journey of my doctoral studies, and to my committee members, Dr. Warwick Dobson and Dr. Todd Milford for their invaluable support.

My academic journey has led me in directions I never expected it would take me, and indeed flung open the door to new insights and discoveries; here I stand and claim, as Leonardo DaVinci before me, that 'learning never exhausts the mind'.

Dedication

Filmmaking is a chance to live many lifetimes
Robert Altman

For Jaroslav, who is the reason this dissertation exists.

Your love and support,
your patience, tolerance and sacrifice
made this possible.

INTRODUCTION

Society - Current Societal Framing

It is common knowledge that science is important, as science permeates most aspects of modern life and society. It therefore matters how we act toward scientific knowledge and how we assess and use it in our everyday life as individuals but also how we use and understand science as members of a democratic society. Western democracies depend on having a large number of scientifically literate citizens, as today's political agendas incorporate debates over such science-related topics as global climate change, embryonic stem cells, future energy sources, and the possibility of a global viral pandemic; among others. As the twenty-first century progresses, issues requiring scientific literacy are only likely to become more prominent in the political sphere. That's why not only students interested in science, but also those who see themselves as 'art types', or even do not like science at all, need to sincerely consider and understand what science is and how scientists know what they know; in other words, they need to develop an understanding of nature of science.

The expression "nature of science" (NOS) refers to matters regarding the epistemological and ontological understanding of science that are informed by contributions from several disciplines including, but not limited to, the history, philosophy, and sociology of science. Consequently, there are discussions and disagreements among the experts making it difficult to find a definition of NOS that would be widely accepted. However, questions such as what science is, how it works, how scientists operate as a social group and how society itself both influences and reacts to scientific endeavours need to be addressed. There is an ongoing conversation among educators regarding to what level of understanding of NOS students should experience so that they can become both intelligent consumers of scientific information and

effective local and global citizens. Educators and researchers look at students' understanding of NOS by attempting to capture and evaluate students' views on particular topic within the area of NOS. Students' 'view on nature of science' (VNOS) are evaluated, categorised and can serve as an indicator of students' comprehension of NOS.

Research into comprehension of NOS has a history several decades long. Educational researchers and institutions worldwide recognize the importance of the issue of students' understanding of NOS (Bybee & McCrae, 2011; National Research Council, 2009; Osborne, Simon, & Collins, 2003; Papanastasiou, 2003; Yore, Bisanz, & Hand, 2003). In Chapter One I'll discuss the attempts that have been made to bring the topic into the classroom, currently with little or no improvement in students' understanding of the NOS. Research shows that generally students do not have a good grasp of NOS (Deng, Chen, Tsai, & Chai, 2011; Osborne et al., 2003; Pedretti & Nazir, 2011) and tend to default to naïve realism (Deng et al., 2011), which views science and scientific knowledge as a faithful representation of an objective 'real world' (Chalmers, 1976). Students generally see scientific knowledge as objective and universal, something that can be harvested for the answers to the issues facing the society (Abd-El-Khalick et al., 2008; Buffler, Lubben, & Ibrahim, 2009; Buffler et al., 2009; Dagher, Brickhouse, Shipman, & Letts, 2004; Moss, 2001; Niaz, Klassen, McMillan, & Metz, 2010; Sandoval, 2003). The problem we are facing is that without understanding NOS students cannot distinguish between science and pseudo-science, or recognize features of pseudo-sciences like astrology or water dowsing (Afonso & Gilbert, 2010; Turgut, 2011; Urhahne, Kremer, & Mayer, 2011). A sophisticated understanding of NOS is needed because it counteracts students inclination towards uncritical acceptance of scientific knowledge, which results in misunderstanding of what science

can and cannot do, and may misplace the responsibility for decisions in personal as well as community life.

In Chapter One I discuss in detail the current approaches to NOS. I review the research on teaching and learning NOS, and I show that these approaches are insufficient and aggravating the problems by focusing on teaching and testing strict definitions of NOS that end up in pressing forward positivistic views (Blades, 2008). The idea of a 'correct' understanding of NOS introduces the possibility of students' 'misconception' into the discourse, and with it the attempt for curricular solutions to address (remove, change etc.) these misconceptions (Abd-El-Khalick, Bell, & Lederman, 1998; Abd-El-Khalick & Lederman, 2000; Bell, Abd-El-Khalick, Lederman, McComas, & Matthews, 2001; Bell & Lederman, 2003; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Some education theorists question the idea of NOS 'tenets', i.e., principles that we can all generally agree on, and argue for a more sophisticated approach to NOS (Eflin, Glennan, & Reisch, 1999; Smith & Scharmann, 1999). Research into teaching and learning NOS shows a broad tendency toward using constructivist approach (Deng et al., 2011), but this approach is not without problems (Hyslop-Margison & Strobel, 2007; Matthews, 1993; Perkins, 1999; Peter, 2006; Phillips, 1995;). Considering that teachers themselves have difficulties with the concept of NOS (Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick & Lederman, 2000; Liang et al., 2009; Tsai, 2006; Turgut, Akcay, & Irez, 2010; Wong, Hodson, Kwan, & Yung, 2008), we are facing a difficult situation where teachers are supposed to teach an approach to topics they generally may not understand.

Society, powered by science and technology, requires a scientifically-educated population that is able to wisely use and manage the implementation of new scientific knowledge and technological advances within the society. It is no longer possible for each member of

society to reach a deep level of understanding of every scientific subject area, therefore a general understanding of what science is and what it can do becomes the guiding principle in addressing problems that are out of the knowledge scope of each individual.

Researcher – A Personal grounding of the project.

Learning science and learning about science is an ongoing process. My journey through the landscape of scientific knowledge and philosophy is deeply influenced by my personal life. I have experienced turbulences that turned 'my world' upside down, destroying certainty and clarity yet at the same time allowing me to shake out and discover shifting patterns of my own thoughts and my understanding of the world.

I was brought up in an environment where science was considered a privileged source of knowledge, truth and rationality. Born and raised in communist Czechoslovakia, I was educated in the style best described as 'totalitarian Marxism.' Even though early on I rejected Marxism from a philosophical, social and political perspective, deciding to put my family and myself in the uncertainty and the danger of illegal escape rather than live under its tenets, I didn't realize how deep the roots of Marxism reached in my own understanding of science. I studied physics at a faculty of Mathematics and Physics, and philosophy at the faculty of Philosophy at Charles University in Prague and within the ideological straightjacket of communist existence it was my study of scientific subjects that protected my 'not-so-appropriate' ideas within the system. As long as I could mask or obscure my anti-Marxist thinking with a scientific theory of physics, I managed to navigate 'unharmed' the ideological landscape of a totalitarian society. This society was a political environment where scientific discussions were 'allowed,' but the results and conclusions of these discussions were prescribed. Paraphrasing R. W. Emerson (Wilson, 1981), people say that it is the journey, not the destination that matters, and I found that these

discussions and the journey to finding an answer was truly a liberating experience. It was this experience that moulded my inner belief in the essential role that science, scientific thinking and argumentation plays in supporting ongoing discussion of citizens and as such becomes the 'protector' of democracy.

The view that all sciences in principle reduce to physics, i.e. reductionism (Fieser & Dowden, 2015), was generally accepted within the communist society (and its ideological elite), and the scientific worldview was seen as the only rational one. This was the view I adopted as well. Under the philosophy of Marxism-Leninism, positivism was denounced and 'science wars' discussions never happened in the Communist block. Only later I could understand the roots of Lenin's harsh criticism of Ernst Mach and anybody influenced by him in *Materialism and Empirio-Criticism* (Lenin, 1972)*;* Mach's anti-realist and anti-materialist stance denied that the object of scientific knowledge was reality (Pojman, 2011). Lenin *had to* defend the 'traditional' conception of scientific knowledge, because otherwise Marxism itself, along with the idea of Scientific Communism and the historic necessity of a Communist revolution, would become a mere convention!

Children were the main focus of Communist propaganda and control; therefore, the education system was considered to be essential for promoting Scientific Communism. The tradition of humanist philosopher Comenius is deeply entrenched in Czech education and the slogan, 'school as play' was translated into a large number of hands-on educational activities, particularly in science. Vygotsky's ideas of scaffolding (Chaiklin, 2003) were readily implemented in the approach to science education as well. This was the environment I came from, expecting to find a better life and a better education in a free Western country.

In Canada, facing the completely new cultural, technological, scientific and historic environment of my new homeland, I realized I needed a deep reflection to identify what 'colours' of knowledge I actually have from my previous studies and life and how that influences my understanding of science today. Even though my personal path to such realization was turbulent, complex, and in a way 'forced' by the dramatic change in my social context, including status, knowledge and language, I imagine that many people have to walk a similar path as they encounter the fast and dramatic changes in our science and technology-driven society. Everyone is influenced by their education; education that, within the assumptions of the times, might present knowledge as 'fixed,' 'rigid,' 'completed,' 'solved,' 'permanent,' never revealing its uncertainty and its intrinsically changing character.

Through my reflection, I found it striking that there was a modality to my perception of science and scientific knowledge, depending on the role (or assumption) from which I approached a particular problem. Was I addressing the problem from the position of a scientist, teacher, philosopher, consumer, mother, citizen, etc.? Each role seemed to require a different set of arguments, a different level and type of complexity to be included or excluded, a different level of uncertainty 'admitted' or 'rejected'. My view also seemed to be influenced by the perceived 'use' or 'need'; similar to an attitude one would adopt when choosing, for example, a camera. An 'inner voice' says: for what you will need it, this camera model is the best one for you.

This experience led me to think about our everyday, practical approach and use of scientific knowledge; can I capture the dynamics of views about NOS in research? Can I find a new way to teach, explore or address issues of NOS?

Even though my studies and my professional life have been in philosophy, science and technology, since childhood I was deeply immersed in arts. I attended a music school, learned to play several musical instruments, and studied classical voice. This background allowed me to direct a theatre group for two years, providing experience with theatre. I was and continue to be an avid photographer, making my own prints, which eventually lead to digital photography today. Oil painting and pencil drawing are among the activities where I practise visual arts, as is an exploration of historical and traditional methods in art. I became interested in film and studied Film Production and Management at the Toronto Film and Technology Institute. I became involved in a number of film and video projects, cooperating with established companies and independent filmmakers alike. I also became a member of a production team on several documentaries, music videos, films and short films in a variety of positions and experienced first hand the successes, failures, and hard work of filmmakers, as well as the excitement, fun and the lasting impact filmmaking has on people. Through these experiences I realized that there might be a potential for filmmaking in learning and education worth exploring in a research project.

Will Durant's words, "every science begins as a philosophy and becomes an art" (Durant, 1953, p. 62) is my favourite motto; I learned how each may seem to demand different skills, thinking or approach but I found that experiencing how philosophy, art and science works as an amalgamation leaves one with understanding and awe. Exploring these connecting influences made me wonder how the excitement of creating something wonderful and beautiful might lead the mind to wonder about the understanding others might have of your work. To travel this 'wondering path' seems to demand finding out much more in depth meaning of every little aspect of a work; these meanings start to re-combine as one discovers the influence of the past (finding the reasons why one attached particular meaning to a particular aspect) to current

understanding. Trying to extrapolate to the future and musing about how others will react to your work leads further still, deepening and widening the understanding of the meaning of a piece of work. I experienced this deepening myself and I have seen the impact on others. I wondered why did people get so excited and invest time and energy to learn, sometimes about fringe and awkward topics, to satisfy either the story, behaviour of character or simply to be able to recreate action in a section of the film accurately for the viewer. I wanted to better understand the impact of the interplay of science, art and philosophy on our learning. That's why bringing together science education and filmmaking, and exploring the effect on students became the focus of my research.

Theoretical Framework Overview

A new conception of NOS. In Chapter One, I review the current approaches to implementation and research of NOS and identify the areas that I believe to be problematic. Further I show that the 'static' approach to NOS that uses pre-determined tenets may be insufficiently reflecting the complexity of the NOS topic. I offer a new conception of understanding of NOS as stochastic, dynamic and dependent on context. I explain the reasons for adopting the currently accepted, consensus-based tenets of NOS while I ground the meaning of the tenets within a pluralistic and praxis-oriented framework based in neo-pragmatism. I offer the possibility of exploring a new, unorthodox and unique way of engaging students in a deep reflection on NOS by way of filmmaking.

Narrative and filmmaking in science education. Storytelling is a widely recognized approach to learning. Our 'storied nature' searches for stories because they logically organize, describe and explain the world around us (Fisher, 1985; Shanahan, Susanna, & Priest, 2010). Science is no stranger to storying but it is challenging to bring storying into science classroom,

as many do not accept storying as an activity essential to science education (Booth, Barton, & Barton, 2000; Clough, 2011; Miller & Saxton, 2004; Piliouras, Siakas, & Seroglou, 2011). In Chapter Two I examine the features of the narrative environment within which the exploration of NOS could happen, revealing potential connections between storytelling, learning in general and learning science in particular. I highlight the function of storying and re-storying in our adaptation to changing conditions, and show how the multiplicity of re-storying activities could create a stochastic base for the development of NOS understandings during filmmaking. I also explain that when students get immersed in a filming environment where the elements of game 'rule-setting' take place (Vygotsky, 1966), the students' understanding of NOS may potentially become deeper.

Overview of the research project

Research project outline. This research project consisted of a 4-day intensive film production, where high school students, paired with an experienced film crew, produced a short film, '*The Shadows of Hope'*. During the project students learned basics of filmmaking and rotated in various roles within the production crew. The research project unfolded in several stages including participant selection process, pre-production meetings, filming during production stage and finally completing the film and evaluation data. I provide a detailed description of all stages of the project in Chapter Three. I show the practical challenges to implementing such project as an addition to classroom education and highlight the benefits and possible changes to the project for a school-wide cooperative endeavour.

Mixed method research. The conception of understanding of students' VNOS as stochastic, dynamic and dependent on context demands that the research method is able to

capture the complexity of the phenomena. This challenge is addressed in detail in Chapter Three, where I describe the philosophical and methodological framework of the research project.

Exploring the impact of context on the dynamics of students' VNOS is reflected in the activities of filmmaking. Film production is a collaborative work effort that enlivens a large number of learning-enhancing activities. The goal of film production is to create believable characters in a variety of situations and contexts within the film story. That makes it particularly relevant to explore subjects that examine deeply the issues that relate to NOS. In order to understand individual characters of the film story, personal views might require expansion and shifting. There are different levels of communicating these personal views not only among the production team but also (visually) to the viewer and it is this communication that maintains the deep immersion in the subject, with subsequent potential influence on personal views.

The approach of resolving the complexity and uncertainty of scientific knowledge by emphasizing pluralism within practical context is rooted in the pragmatist philosophy of John Dewey (Dewey, 1986, 2003a, 2003b; Garrison, 1994; Kruckeberg, 2006; Moore, 1961; Prawat, 2000), and influenced by the re-interpretation of pragmatism by Rorty, Putman and others (Curren, 2009; Goodman, 1995; Madzia, 2012; Prawat, 2000; Putnam, 1995; Rorty 1991).

Chapter Three describes the details and rationale for choosing the mixed method research methodology. In particular, Creswell's convergent parallel design (Creswell, 2008, 2009; Creswell & Clark, 2011; Meissner, Creswell, & Klassen, 2011), which is based on collecting both data types (quantitative and qualitative) in parallel, analyzing them separately and then converging and comparing the results, made such a mixed method approach well suited to the purposes of this research project.

Research Goal and Questions

The research project is concerned with exploring a new conception of understanding of student's VNOS. This research used film production as a medium to highlight and capture the dynamic nature of views about NOS, and explored the possibilities of film production for enhancing learning of the issues of the nature science.

Considering the difficulties of teaching NOS at school (Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick & Lederman, 2000; Liang et al., 2009; Tsai, 2006; Turgut et al., 2010; Wong et al., 2008) an original approach to addressing this topic is needed. Guided by the psychological research in the area of learning theory (Baars, 1986; Goldstein, 2008; Pasupathi, 2012), I focused on the possibilities of film production for enhancing and deepening student's reflections and understanding of NOS. In the work that follows, I reveal how filmmaking offers a robust way of learning and can be used as a viable pedagogical method. The Canadian Council on Learning highlights that Canada is "slipping down the learning curve" (Canadian Council on Learning, 2011, p. 6), and particularly for high school students, the issues of active participation, motivation and ownership of learning play crucial role. I will demonstrate in this dissertation how filmmaking offers an exciting and unique way of engaging students in exploring complex issues of science.

The research questions of the project are therefore layered; not only does it focus on the modality of students' VNOS but it also attempts to evaluate the benefits of using film production as a pedagogical method. The following questions guided this inquiry:

1. What is the pattern in students' understanding VNOS?
2. Is their VNOS changed within different contexts and situations?
3. How do different life situations (as simulated by the film) affect students' VNOS?

4. What is the range of VNOS each student demonstrates?
5. How do the qualitative results support or contradict the quantitative results?
6. In what ways did the film project influence the sophistication of student's VNOS?
7. How did the students respond to the experience of filmmaking?

Following this brief overview of the project's background, theoretical framework, approach and questions, I will delve into the detailed discussion of the knowledge areas that define or influence this research project.

In Chapter One I will discuss the importance of NOS in science education and the history of the NOS subject in education system. This chapter examines the varied dimensions and interpretations of NOS and outline the difficulties with current approaches to teaching the NOS. The chapter concludes with a discussion of the pluralistic framework used in this project and proposes filmmaking as a multi-contextual environment for learning NOS.

Chapter Two discusses filmmaking as a way of learning, including the role of narrative in learning, particularly learning science through self-explanations. This chapter demonstrates how storying and re-storying underlie adaptation to a new environment and therefore learning about the world. Narrative can be presented in a variety of mediums and I will show how each medium influence the way storying happens, however I will focus on film and filmmaking. I will explain the role of filmmaking in this research project and look at filmmaking as pedagogical method by exploring all sections of the film creating process.

Chapter three focuses on the research project's methodology, describing in detail the project's progress, selection of participants and explain the methods used in data collection and analysis. Chapter four reports on the outcomes of the research project and addresses the project research questions. Chapter five focuses on the implications of the findings, a summary of the

project and a brief document to support teachers interested in implementing filmmaking inquiry in their classroom entitled, *Brief Guide For Teachers*.

CHAPTER ONE: THE NATURE OF SCIENCE

Science has a pervasive and persistent impact on nearly every aspect of modern life. As Western society deepens its dependence on technology and scientific discoveries, it is imperative that our students have the willingness, skills and confidence to critically evaluate and understand the ever-changing complexity of the scientific endeavour as they grow up to be full members of a democratic society and citizens with responsibility for the future of humanity.

Science has changed, and continues to change our life, and the questions of how it does so, and why it is able to do so are difficult to answer (Goldman, 2007). Philosophy of science continues to debate the very nature of what is meant as *science*. The echoes of ideas of Heidegger with his focus on the phenomenology of technology (Heidegger, 2001, 2010), Popper and his theory of falsification (Popper, 1959), Kuhn's historicism and the idea of 'paradigm shifts' (Kuhn, 1996), Feyerabend's refusal of a defined scientific method (Feyerabend, 1975), and the writings of many other philosophers create a complex symphony of ideas that escapes simplification.

The enormous influence that science and technology has on our life is why the issue of scientific literacy is so important in Western societies as well as globally. Scientific literacy is now an internationally well-recognized educational goal even though there are differences in meanings and interpretations (Bybee & McCrae, 2011; Kruckeberg, 2006; Papanastasiou, 2003); scientific literacy is a complex and diffused concept with an intricate history (Laugksch, 2000; Yore, Bisanz, & Hand, 2003).

Science education & nature of science (NOS)

The demand for science education has been traditionally driven by the society's and industry's demand for science and technology professionals (Blades, 1997), but a relatively small

proportion of students actually choose science as their profession (Driver, Leach, Millar, & Scott, 1996). Bell and Lederman (2003) point to the usual science classroom instruction, where:

> Typically, students experience a wide range of direct instruction and conformational, cookbook-style laboratory experiences in their science instruction. It is not surprising that in such an environment, students often develop the misconception that scientific knowledge is portrayed as the result of steady and unproblematic accumulation of confirmed hypotheses (p. 374)

Discussions around science literacy indicate that it is important to educate students to adopt a more realistic view of science (Oulton, Dillon, & Grace, 2004) and understand science in the everyday context of their lives from an early age (Kim, Yoon, Ji, & Song, 2012); to be critical of science and technology enables them to participate in socio-technical controversies, analyze arguments related to social application and implication of science, and negotiate with experts and specialists (Albe, 2007; KolstØ, 2001).

The advancement of a democratic society seems to be linked to a scientific way of thinking (Longbottom & Butler, 1999) through the understanding of the complex science-society relationship that has the potential to fuel responsible participation in decision making (DeBoer, 2000; Driver et al., 1996; Hodson, 2003; Hurd, 2002; Norris & Phillips, 2003; Yore et al., 2003). Research into adults use of NOS ideas in their decision making (Bell & Lederman, 2003) shows there may be limitations to the practical use of NOS views but understanding of NOS continues to be considered essential to grasp the complexities of the science-society relationship, and therefore it has become a fundamental part of teaching science literacy through science education.

Documents guiding educational reforms (McComas, 1998) show that the nature of science (NOS) has a significant role in improving science literacy (Deng, Chen, Tsai, & Chai, 2011; Pedretti & Nazir, 2011; Bell, Abd-El-Khalick, Lederman, McComas, & Matthews, 2001; Osborne, Simon, & Collins, 2003). This trend is reflected in the demand that science education adopts 'science for all' approach (e.g. National Research Council, 2009; Driver et al., 1996) with a focus on 'scientific literacy for citizenship' (Kolstø, 2007; Ryder, 2002; Schibeci & Lee, 2003; Wellington, 2002).

McComas, Clough and Almazroa (1998) describe the task of identification of dimensions and interpretations of NOS for education as:

> a hybrid arena blending aspects of various social studies of science including the history, sociology, and philosophy of science, combined with research in the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to the scientific endeavours. (p. 4)

The interplay of disciplines that inform science education about the character of science itself entails a dilemma for science education as each discipline continually evolves and changes. The experts in these disciplines continue to assert that we currently do not have a confirmed and agreed upon general picture of how science works (Abd-El-Khalick, 2012; Alters, 1997; Clough, 2007; McComas, 1998). This is reflected in claims that there is a "lack of belief in the existence of a singular NOS or general agreement on what the phrase specifically means" (Abd-El-Khalick & Lederman, 2000a, p. 666).

Educational scholars take a practical approach and try to identify crucial aspects of NOS that students should learn about at school; finding and agreeing on those aspects, scholars can

then design curricula and educational approaches to effectively address the issue in the classroom. Some educators attempt to define 'tenets' of NOS that are to be introduced in the classroom (Clough & Olson, 2008; Flick & Lederman, 2006; Howe Eric M., 2007; Pedretti & Nazir, 2011; Smith & Scharmann, 1999), others call for a meaningful critical discussion instead of a defined set of parameters (Allchin, 2011; Clough, 2007; Eflin, Glennan, & Reisch, 1999; Taber, 2008). In addition there is a lack of consensus among educators about how exactly to characterize NOS (Eflin et al., 1999), as even philosophers of science can't answer the questions of 'whose nature of science' to present in the classroom (Alters, 1997; Smith, Lederman, Bell, McComas, & Clough, 1997). There are voices suggesting that the disagreements are exaggerated, and that there is a high level of consensus among educators on the issue, but the problem is not conclusively settled (Alters, 1997; Howe, 2009; Smith et al., 1997; Smith & Scharmann, 1999).

Dimensions and interpretations of NOS

In a recent attempt to 'benchmark NOS understanding' Abd-El-Khalick (2012) identifies three generic groups of approaches to identifying the dimensions and interpretations of NOS:

Group 1: Abandon the tenets of NOS.

First group argues that we should abandon the efforts to teach NOS all together, as there is no consensus among the philosophers, historians and sociologist of science and science educators (Alters, 1997); in addition research indicates that the efforts of several past decades to teach NOS based on the accepted tenets (Lederman, 2007; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) have had little impact on students' or teachers' VNOS (Deng et al., 2011; Osborne et al., 2003; Pedretti & Nazir, 2011). Students by far and large tend to believe in a naïve empiricist/realist/objectivist view of the world, assuming that there is an objective 'real world'

that is faithfully represented and understood in scientific knowledge (Deng et al., 2011). Students see scientific knowledge as objective and universal, knowledge that can be harvested for the answers to the issues facing the society (Abd-El-Khalick et al., 2008; Buffler, Lubben, & Ibrahim, 2009; Buffler et al., 2009; Dagher, Brickhouse, Shipman, & Letts, 2004; Moss, 2001; Niaz, Klassen, McMillan, & Metz, 2010; Sandoval, 2003), and they have difficulty differentiating science from pseudo-sciences like astrology or water dowsing (Afonso & Gilbert, 2010; Turgut, 2011; Urhahne, Kremer, & Mayer, 2011).

Taking into an account that teachers themselves have difficulties with the concept of NOS (Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick & Lederman, 2000; Liang et al., 2009; Tsai, 2006; Turgut, Akcay, & Irez, 2010; Wong, Hodson, Kwan, & Yung, 2008), there seems to be no solution on the horizon.

Despite the fact that all these studies used different instruments based on a variety of different dimensions and interpretations of NOS, research results and conclusions have been quite uniform. Lederman concludes that, "although various instruments suffer from specific weaknesses, if these were significant, it would seem improbable that the research conclusions would be so consistent" (Lederman, Wade, & Bell, 1998, p. 336). I suggest extending this statement, as each instrument defines its own target measurables (e.g. 'tenets'), it seems improbable that the disagreements or controversies around these definitions of NOS are in any way significant. The discussion fuelled by this group is fruitful, however, as it illuminates the hidden assumptions in our approach to NOS and thus can serve to expand the identification of additional influences on NOS (Smith et al., 1997). We will review some of these influences later in this chapter.

Group 2: Accept the tenets of NOS.

The second approach to NOS highlights consensus instead of disagreements among experts and focuses "on a level of generality that renders the target NOS understandings practically uncontroversial while keeping them relevant to school science" (Abd-El-Khalick, 2012, p. 355). As the issue of NOS is found important and not possible to simply skip because of controversies, this second approach is widely adopted by educators (Abd-El-Khalick, Bell, & Lederman, 1998; Bartholomew, Osborne, & Ratcliffe, 2004; Hodson, 1998; Lederman et al., 2002; McComas et al., 1998) as well as educational institutions and their guiding documents in the US (American Association for Advancement of Science, 1990), Canada (Council of Ministers of Education, 1997) and many other countries around the world (McComas, 1998). Reviews of explored and/or adopted NOS dimensions and its interpretations through NOS research show a large variability of breadth of focus in NOS instruments (Alters, 1997; Deng et al., 2011; Lederman et al., 1998). The most adopted cross-section of these overlapping NOS focuses, as declared by several studies (Abd-El-Khalick, 2012; Allchin, 2011; Deng, Chen, Tsai, & Chai, 2011), became the Lederman-identified set of NOS tenets (Lederman et al., 2002).

Group 3: Let the scientists alone to decide.

The third group argues for avoiding the theoretical controversies by going directly to the expert scientists to assess the NOS (Wong & Hodson, 2009, 2010) – an approach rooted in sociology of science and an assumption that scientists' view of NOS has a privileged status. However, "while scientists have privileged access to the various facets of their practice, they do not enjoy similar access to their practice's epistemological underpinnings" (Abd-El-Khalick, 2012, p. 368). Albert Einstein, for example, already pointed to such discrepancy in scientists' VNOS by advising us:

> If you wish to learn from the theoretical physicist anything about the methods, which he uses, I would give you the following piece of advice: Don't listen to his words, examine his achievements. For to the discoverer in that field, the constructions of his imagination appear so necessary and so natural that he is apt to treat them not as the creations of his thoughts but as given realities. (Einstein, 1934, p. 163)

History of the problem space

A similar approach to the one proposed by the third group was adopted by the US (with implications for the rest of the western countries) in the 1960s after the 1957 launching of Sputnik by the former communist Soviet Union (USSR) (Goldman, 2006). As USSR was an ideological adversary to Western democracies, the launching of Sputnik was seen as a major military threat. Driven by the heightened sensitivity toward military technology and the need to sustain technological advantage that was shattered by Sputnik, science education became the target of the blame as well as the perceived solution (Cahoone, 2010; Matthews, 1998). The curriculum specialists were replaced by professional scientists as the "post-Sputnik curricula of the 1960s and 1970s adopted the logic that science school education should be, by definition, instruction about the professional practice of science … [science] defined in a superficial, circular way as the professional practice of scientists who methodically discovered through a systematic method "facts" about how the world operates and then use these facts for the betterment of humankind" (Blades, 2008, p. 388). These assumptions, typical of rational-objectivist and positivistic view of NOS were already challenged by philosophers at that time (such as Popper, Kuhn, Feyerabend or Quine) but they were ignored (DeBoer, 2004; Eflin, Glennan, & Reisch, 1999) as the direction of science education turned toward "the political mission of creating more scientists as a way to achieve scientific and technological superiority

over communist countries"(Blades, 2008, p. 389). By the 1980s it was clear that the adopted expert-oriented approach failed to attract students to science and science-related careers (Blades, 2008; DeBoer, 2000). This 'second crisis' shifted focus in science education toward the goal of "reconstructing science education towards more authentic understanding of the nature and activity of science in the modern world" (Blades, 2008, p. 389).

This historical example highlights an important aspect often overlooked in research: It is the political and social mindset of the times that underwrites an educational system. In the outlined example, the shift toward science received generous funding as it was linked to cold war military budgets (Blades, 2008). But it is not only financial issues that have immediate and dire consequences: Education does not exist in a vacuum. Common public paradigms, media, fads and fashions all influence the environment in which education in general, and science & NOS education in particular, happens.

The issue of teaching the NOS started to move toward centre stage of science education as scholars in 1980s take part in a shift toward a broader scope and goal of science education, and stress the departure from a content-based science delivery to a science education that supports a better understanding of the project of modern science. By the end of 1990s, NOS studies were "a major goal, if not *the* major goal, of science education" (Alters, 1997, p. 39). Duschl (1990) presents the rationale for the necessity in shifting the focus of science education from content to understanding the development of theories in science, Mathews (1994, 1998) focuses on the importance of understanding the history of scientific development and philosophy of science (see also Yalaki & Çakmakcı, 2010), Hodson (1998, 2003) adds a cultural perspective (see also Pedretti & Hodson, 1995), and Roth and others include science education for social action (Kim & Roth, 2008; Roth & Désautels, 2002). All gravitate toward the goal of science

education to educate critical, democratic citizens, a direction where understanding of NOS plays a crucial role. The development of NOS understanding and implementation in the classroom now includes a large number of scholars who advance its definitions and practices, including Lederman, Abd-El-Khalick, McComas, Solomon, among many others.

Addressing the Problem

Society benefits from using scientific knowledge, and a scientifically literate citizenry is crucial to using science intelligently. It is important to stress that scientists cannot offer us certainty. It is the issue of a multileveled uncertainty that makes the teaching of NOS so challenging. Scientific knowledge is empirically grounded, but the deductive form of scientific knowledge tends to obscure the fact that science cannot offer a complete certainty about experience. Scientists can offer theories about what can happen under certain conditions, but they can offer no guarantee that our current theories will accurately predict the future development without failure. In addition, for better or worse, science does not incorporate value judgments related to the use of scientific knowledge; a scientist (as a scientist) cannot tell us 'the best solution'. In a democratic society this fact creates a space for informed citizens to participate in science and technology disputes. As long as we understand science as temporal and conjectural, intrinsically probable but not certain, we can accept that the ultimate responsibility and accountability for action is on us, the layperson, as citizens of a nation, state and of the world.

Taking into account that the most common outcome of the scientific process is not a fact but an intermediate step in understanding, one could define scientific expertise not so much in terms of 'accumulation', 'expansion' or 'betterment' of knowledge but by the skill of recognizing and managing uncertainty (Friedman, Dunwoody, & Rogers, 1999). Science

involves producing knowledge about what was previously unknown, therefore uncertainty is a normal, necessary and exciting condition of scientific work. Scientists do not attempt to eliminate uncertainty but find a way to manage it by attempting to arrive at deeper understanding of phenomena within a variety of conditions.

Regardless of the success of scientific development, an uncritical, blind faith in the knowledge science produces will not only misdirect the responsibility for future but also could misjudge the possible impact, negative or positive, of science on the individual and the society at large. An uncritical acceptance and implementation of a particular scientific idea allows this idea to be taken out of context, but there are connections to other contexts we may not have enough information about. For example, using herbicides that are 'scientifically proven' to protect crops and be safe for the environment have shown devastating effect on bees and other pollinators. The decision to use these chemicals (or continue using them) is in the hands of society; it is a political decision, not a scientific one. Scientific knowledge provides valuable tools for improving and managing our life and society as the development of Western societies attests but, an old Czech saying advises; a wise person will use the most fitting tools available to guide their decision, but understanding its limitations (i.e. the roots of the uncertainty embedded in those tools) is crucial to using them well.

Taking this advice, I reviewed, in the section *Dimensions and interpretations of NOS,* the available approaches toward benchmarking NOS understanding. Considering the options of either abandoning standardised tenets of NOS, accepting them or creating working scientists' version of NOS, while taking into an account the realities of teaching science, I looked at the possible problems with these approaches; I identified that within these available frameworks, the consensus-based approach of identifying main areas of NOS interest; e.g. 'tenets' of NOS, is the

most practical. As Abd-El-Khalick (2012) notes, “the consensus-based list of dimensions and the approach based on it is positive and pragmatic” (p. 355) and therefore, “scholars pursuing various frameworks will arrive to strikingly similar lists and results regardless of the process of definition and analysis” (Abd-El-Khalick, 2012, p. 356). He also presents some evidence that the education reform documents are based on this approach as well. He notes the consideration of the “pragmatic irrelevance of high level controversies about NOS … simply put, these documents leverage consensus and remain *silent* on controversial issues” (Abd-El-Khalick, 2012, p. 356). Therefore it is not surprising that the rationale and the instruments of research in understanding of NOS are based mainly on some variant of the accepted NOS tenets.

The set of ideas and understandings of NOS identified and described by Lederman is largely cited as a main source of NOS tenets (Abd-El-Khalick, 2012; Lederman, 2007; Lederman et al., 2002) and is the ‘essential ground’ of the dimensions of NOS that informs the research reported in this dissertation. As Lederman (2002) point out:

> Scientific knowledge is tentative; empirical; theory-laden; partly the product of human inference, imagination, and creativity; and socially and culturally embedded. Three additional important aspects are the distinction between observation and inference, the lack of a universal recipe like method for doing science, and the functions of and relationships between scientific theories and laws. (p. 499)

These dimensions were discussed and their interpretation clarified in the research literature (Allchin, 2011; Deng et al., 2011; Hoyningen-Huene & Huene, 2008; Liang et al., 2008; Pedretti & Nazir, 2011; Urhahne et al., 2011) and the latest description (Abd-El-Khalick, 2012) can be found in Appendix E. I agree with the practical approach of ‘tenet-based’ research

into NOS, but there are issues and problems that need to be addressed. In the next section I will turn to the discussion of problems embedded in the 'tenet-based' teaching of NOS.

Issue #1: 'Correctness' of view.

The NOS education based on the tenets identified by the experts in the field attempts to counteract students' inclination to naïve realism and its variants and to improve the understanding of the NOS. But these tenets indicate an assumption that there is some concrete 'correct theory of NOS', which is in direct contrast with the evidence that no such theory is available. In addition, strictly defining 'correct theory of NOS' may end up in a positivistic attitude; the prevalent approach toward teaching NOS in schools as revealed by Blades (2008) in his review of NOS approaches. Is it one of the reasons for the consistent failure to improve students' understanding of the NOS?

The 'tenets-based' approach incorporates an attempt to evaluate students' VNOS as seen from the scoring evaluations within studies of the level of students VNOS. This approach invites an idea that the evaluation represents whether students' VNOS conforms to a particular 'accepted-as-correct' view. The task is to look into the limits of students' understanding of NOS and possibly expand it, not to indoctrinate them with a 'correct view' (Lederman et al., 1998). The problem of indoctrination is one of the points raised by the education theorists who reject the idea of tenets of NOS and call for a more sophisticated discussion about the issues around NOS and students' VNOS (Eflin et al., 1999; Smith & Scharmann, 1999).

Issue #2: Constructivism.

Additional contradictions surface when we consider the meta-research into students' views of NOS. My review of the assumptions and frameworks related to NOS research studies correlates with what Deng et al. (2011) report: 90% of research is based on definition of a

'correct' VNOS. "The constructivist/relativist perspective is considered 'informed or adequate' and the positivist/empiricist view 'naïve or undeveloped'" (Deng et al., 2011, p. 972). Why is the 'constructivist/relativist' perspective considered adequate? Who decides what 'adequate' means in respect to understanding the philosophy and history of science?

Current educational practices are based on or heavily influenced by a constructivist approach to learning. These practices have roots in social constructivist theories (or socio-culturalism) that perceive the learner as 'information constructor' where the learner is not passive, but actively creates their own representation of new information. The research into teaching and learning NOS shows the overall acceptance of the constructivist approach, but this approach is not without problems (Hyslop-Margison & Strobel, 2007; Matthews, 1993, 2003; Perkins, 1999; Peter, 2006; Phillips, 1995).

Constructivism is a wide and heterogeneous movement, but Matthews (1993) shows that constructivism is basically a variant of the old-style empiricist epistemology, which had its origins in Aristotle's individualist and sense-based theory of knowledge. Although constructivists stress the creative aspect of knowledge production, "their model of creation is a sort of personal, cottage-industry, model. It is the personal, Robinson Crusoe, model of knowledge construction that leaves aside the necessary social and communitarian dimensions of cognition" (p. 367). Constructivists' recommendations for science curriculum therefore describe the goals with formulations such as students should 'make sense of the world around them', but such goals are at best limited. As Matthews (1993) explains:

> This talk of making sense is quintessential empiricist. It is also fraught with grave educational and cultural implications. It leads immediately, as it has historically done, to relativisms of all kind, and not just in science … Such relativism and personal empiricism

> is contrary to the critical pedagogy that constructivism is striving to encourage: if merely making sense is the goal of human understanding, then the interplay of ideas and the examination of beliefs can be easily cut short prematurely with the exclamation "it makes perfect sense to me". (p. 369)

Constructivism is widely accepted and, "although constructivism began as a theory of learning, it has progressively expanded its dominion, becoming a theory of teaching, a theory of education, a theory of the origin of ideas, and a theory of both personal knowledge and scientific knowledge, the 'grand unified theory' (Matthew 2003).

That is why educators will recommend the constructivist approach and, as we can see from the evaluation schemas in the NOS research, students' abilities to provide constructivist-oriented responses to NOS survey questions have become a goal that most science educators advocate (Deng et al., 2011).

Deng at al. (2011) identifies ten 'continuums' along which the distribution of student's understanding of the NOS was revealed in the empirical research of last twenty years:

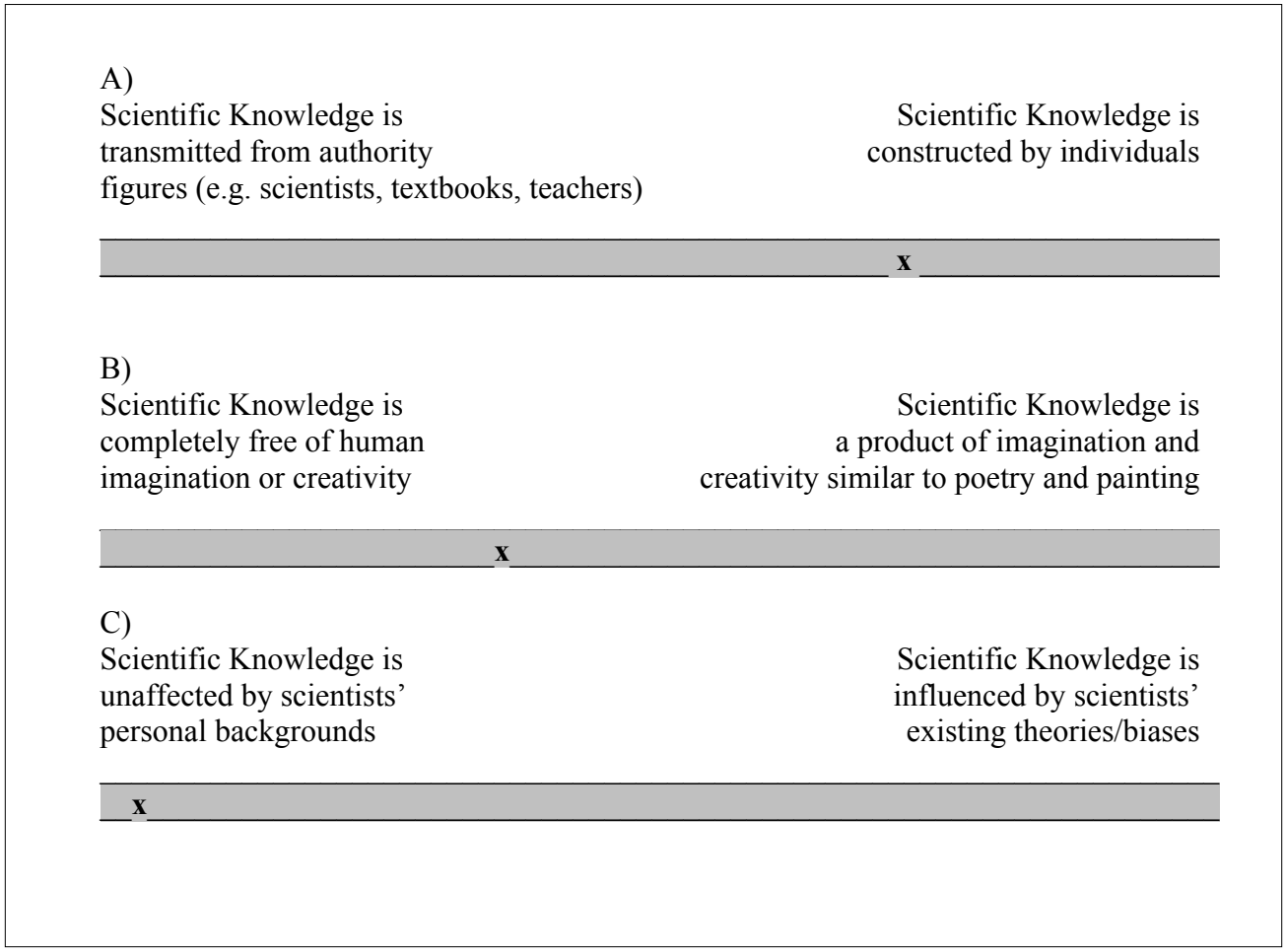
1. Source of scientific knowledge ranges from knowledge as transmitted from authority figures (e.g., scientists, textbooks, and teachers) to as constructed by individuals.
2. The imaginative/creative nature of science ranges from scientific knowledge as free of human imagination/creativity to as a product imagination and creativity.
3. The theory-laden nature of science ranges from science as unaffected by scientists' personal backgrounds to as influenced by their existing theories/biases.

4. Empirical nature of scientific knowledge ranges from scientific knowledge as based on logic/faith to as derived from observations and data.
5. The nature of scientific method ranges from acknowledging a universal step-by-step scientific method to appreciating multiple methods for solving scientific problems.
6. The nature of and distinction between observation and inference ranges from an inability to coordinate theory and evidence to an awareness of the difference between them.
7. The nature of and relationship between theories and laws ranges from assuming a hierarchical relationship between theories and laws to treating them as two kinds of knowledge representations independent from each other.
8. The changing nature of scientific knowledge ranges from scientific knowledge as unchanged to as tentative (but relatively stable).
9. The coherent nature of scientific knowledge ranges from scientific knowledge as a collection of isolated pieces to as unified system of interrelated concepts and principles.
10. The socially and culturally embedded nature of science ranges from as irrelevant with society and culture to as affected by social and cultural factors. (p. 970)

We can visualize these continuums as a set of orthogonal ‘slider bars’, each with a different position of the slider within a range of the bar where the beginning and end identify opposing extremes of views; the position of each slider is reflective of student’s view of nature

of science (VNOS) in one area of NOS interest, and the set of slider positions then identify the levels of the VNOS students demonstrate. *Figure 1* shows a sub-set of such sliders.

Figure 1: *Sample of VNOS continuum-based slider bars*



The research outcomes often show "mixed" results in the evaluation of VNOS (Deng et al., 2011, p. 979). I believe it is because students can have 'more' constructivist/relativist (i.e. 'more correct') view in some area and naïve in others. The 'correct' or 'informed' view would be one where the 'slider positions' in all dimensions are on the constructivist/relativist side. Of course there are studies tracing each dimension separately as well, but I think these studies, while

very valuable, do not have access to the complexity of views of the NOS. Studies provide a 'snapshot' of one independent area of NOS at one time in one context, so any possible internal connections or influences within the students' VNOS are usually not assessed.

Issue #3: Staticity.

The definitions of the NOS problem space covered by the tenets indicate that students' VNOS are treated 'statically', as a type of 'property', as something that people posses, acquire or hold (e.g. conceptions, understandings). Entangled with the 'correctness of view' issue, the idea of 'misconception' enters the discourse of NOS, and with it the attempt for curricular solutions to address (remove, change etc.) these misconceptions (Abd-El-Khalick et al., 1998; Abd-El-Khalick & Lederman, 2000; Bell et al., 2001; Bell & Lederman, 2003; Lederman et al., 2002). Matthews (1997) reminds us not only that education is not to focus on imposing proper beliefs, but to provide an opportunity for students to develop skills to find evidence for their own epistemological positions. He plainly states that teachers have the "unfortunate tendency to judge success in teaching NOS by the degree to which students adopt our views on the subject" (p. 306).

The issue of 'staticity' has two major shortcomings. First, it does not adequately reflect the fact that learning science and learning about science is a dynamic and ongoing process. Our life experiences and continuing development and maturation influences our understanding of science. Abd-El-Khalick proposes to include developmental scale into the tenets to address this problem (Abd-El-Khalick, 2012), but even though it allows developmental evaluation, it doesn't remove the basic 'staticity' of the approach.

Second, the 'static' approach toward NOS overlooks the influence of context on students' VNOS. It is striking that there is a modality to one's perception of science and scientific

knowledge depending on the role (or practical position) from which one approaches science; for example, is a problem addressed from the position of a student, scientist, teacher, philosopher, consumer, mother, citizen etc.? Each role will require a different set of arguments. The modality of the view also seems to be influenced by practical concerns; the perceived 'use' or 'need' (e.g. goal) similar to an attitude one would adopt when choosing, for example, a camera. An 'inner voice' may say: "For what you will need it, this camera model is the best one for you". I suspect we observe similar effect when assessing students' understanding of NOS. The context within which students' opinions are exercised may have major influence on their VNOS; yet not only does their VNOS internally change with time, but it may also change with context.

We often receive an education that, within the assumptions of the times, presents knowledge as 'rigid', 'completed', 'solved', 'known', never really clearly revealing its uncertainty and intrinsically changing character. If we adopt willingly such attitude toward NOS then the topic becomes more a prescribed ideology than a philosophy. Combined with the constructivist attitudes that "it increasingly presents itself as an ethical and political theory, as well as a learning, a teaching and an epistemological theory… constructivism is thought to be a morally superior position to its rivals in learning theory and pedagogy" (Matthews, 2003, p. 2) and other possible drawbacks of constructivism I outlined above, there seems to be a tendency negating proper exploration of the NOS.

As I explained in previous chapter, the fast changing scientific and technological developments within the Western societies have an acute impact on our life, and environment and the society needs citizens who can confidently and knowledgeably manage the direction of scientific discovery and its application. A static, unexplored, shallow and insufficient VNOS limits students' skills, capabilities and experience of reflecting 'anew' on the challenges they will

face in their future lives. This is one of the reasons why our approach to NOS education must actively resist the tendency of delivering an unexplored, 'static' or 'correct' type of understanding the NOS.

Issue #4: Non-existence of a unified theory of NOS.

A review of the research in NOS teaching and students' VNOS reveals that there is not a 'single' or 'unified theory of NOS' that clarifies what should be taught to students. Indeed, I think it may be impossible to define a correct VNOS; all we can do is to arrive to consensus on the issue of 'what do we think *today* that our students need to understand or think about to live in the world of *tomorrow*'. This list will necessarily change with time because of innumerable influences.

Lederman's 'tenets' (Lederman, 2007; Lederman et al., 2002), when understood as a description of an interconnected structure of one correct VNOS, may be evaluated and measured. However considering that the individual tenets may be independent, as the 10 continuums above show, an evaluation may prove difficult. These continuums merge each of the NOS dimensions with their explanations expressed within a range of 'evaluated' understandings. Let's say we remove the preference-based evaluation of these understandings (e.g. 'naïve' versus 'informed'). Considering the results along the 'slider bars' of students' VNOS continuums as discussed above, there would be a huge number of combinations (if we split each continuum only into two sections, the number of combinations is 2^{10} e.g. 1024, ten sections gives 10^{10}). This creates an enormously large space of possible data points.

This variety suggests that there is little internal connection among the tenets, and that each NOS area can be independently represented in an isolated way. This indicates that any

approach adopting a ‘correct’ VNOS is likely inadequate due to the myriads of possible position combinations on the slider bars; which combination is the ‘correct’ one?

The VNOS acquired by the students in school will likely change with maturity, life experience and under the influence of the society at large. In addition, particular goals and needs of the moment could be reflected in a particular view, making students’ views transitory. VNOS cannot be therefore considered to be some constant, established ‘property’ one acquires and keeps for use throughout life (like an alphabet). How will our students argue their ‘acquired at school’ VNOS in their everyday life if they do not have a grasp of, or experience with, the variety of approaches and understandings, including the reasoning skills and capacity to argue ‘for’ and ‘against’ different opinions?

Looking for harmony of project’s goals and rationales

As I noted above, there are four major disciplines that provide insights regarding NOS: Philosophy, history, sociology and psychology; all support education within a socio-political environment (another set of major disciplines). Streamlining rationales for learning/teaching NOS psychologically, socially, historically and philosophically allows us to see whether there is a consistent view, angle or dimension that would lead to integrating the identified questions naturally and help us to reach the goal of answering them.

Current psychological research learning theory indicates that knowledge is created and used in response to a problem or a goal, bound in time and space within the particular conditions (developmental, personal, social, cultural etc.) of the individual (Pasupathi, 2012). Educational approaches favouring practical, everyday-like problem solving as a way of learning, as for example PBL (problem based learning), reflect this feature of learning (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Hmelo-Silver, 2004). So does the adherence of educators to Dewey’s

pragmatic philosophy and approach to learning (Bell, Abd-El-Khalick, Lederman, McComas, & Matthews, 2001; Garrison, 1994; Kruckeberg, 2006; Pedretti & Nazir, 2011) with neo-pragmatism adding the essential, far-reaching influence of language on our learning and understanding of the world (Putnam & Boros, 2005; Rorty & Ragg, 2002; Rorty, 1993, 2002). These approaches assume a pragmatic quality to learning and therefore a pragmatic quality to acquired knowledge. This dimension to learning NOS seems to be undervalued or overlooked.

From a social perspective, we can see that the majority of rationales for science education and for NOS education state the need for science learning/teaching that is conducive to practical use, be it in science-related careers or for active participation in society (Bell & Lederman, 2003; DeBoer 2000; Priest, 2013). Considered historically, we live in times when science and technology is pervasive and, while offering benefits to the society at large, the unintended consequences of such evolution of our societies may as well possibly endanger our existence; again a problem-solving (or goal oriented) mindset is particularly called for.

Cahoone (2010) explains that philosophically, the two major schools of thought, (analytic/positivistic and phenomenological/constructivist) each tried to create a completed system and ground knowledge in some kind of transcendental form, however each succumbed to its own internal critique. In contrast, pragmatism as a method and doctrine of meaning never accepted such foundational projects and thus became a rich source of alternatives for thinkers from both other traditions (Malachowski, 2010) as seen in Rorty (Rorty, 1992a, 1992b, 2007), Putnam (Putnam, 1995) and other neo-pragmatists.

Pragmatism has a tradition that originated around 1870 in America. The main philosophers of the original pragmatism i.e., ‘classical pragmatism’, were Charles Sanders Peirce (1839–1914), William James (1842–1910) and John Dewey (1859–1952). The influence of

pragmatism declined during the first half of the twentieth century as analytical philosophers took a central stage in philosophy. Since the 1970s pragmatism has undergone a revival; the interest in the writings of pragmatism gained popularity and pragmatist ideas permeated many subject areas particularly in the fields of law, politics, sociology, psychology and history among others (Kloppenberg, 1996; Malachowski, 2010; McDermid, 2015). This development of pragmatism makes it difficult to categorize individual streams of thought that draw on one or more ideas of pragmatism and as a result the naming conventions, in respect of pragmatism, are still unsettled (Malachowski, 2010).

The new developments marking the revival of pragmatism are reflected in 'New Pragmatism', i.e., neo-pragmatism that, "has updated the philosophical approach of its predecessor and become more attuned to the present day ethos" (Malachowski, 2010, p. 3). One of those important developments is the accommodation of the so-called 'linguistic turn' that puts emphasis on language and draws our attention to how description and re-description influences changes in action (Noaparast, 2001). Also, in contrast to classical pragmatism that was mainly an American philosophy, neo-pragmatism became 'cosmopolitan' with a number of philosophers drawing on the traditions of pragmatism while preserving their differences. Two of such major thinkers, Richard Rorty (1931-2007) and Hilary Putnam (1926), who have been the main force behind development and promotion of neo-pragmatism, are the example how neo-pragmatism can "flourish on the input of both Rorty and Putnam without needing to reconcile all their differences" (Malachowski, 2010, p. 4). In education, pragmatism has a long and rich tradition, as the influence of John Dewey (Dewey, 1916, 2003a, 2003b, 2003c) remains an essential part of educational theory and practice.

Pluralism of Pragmatism and NOS.

Is it viable to ground the NOS tenets in pragmatic and neo-pragmatic assumptions? Although there is no clear 'pragmatist doctrine' listing vital articles or tenets that would be endorsed by all pragmatists, it is possible to highlight ideas that became more or less lasting features of pragmatism. Still, these may not be fully embraced by all pragmatists and some may not be an 'exclusive property' of pragmatism. In addition, there are differences how different thinkers of pragmatism define or approach the core areas of pragmatism (Kloppenberg, 1996; Malachowski, 2010; McDermid, 2015).

Looking at the source of Pierce's ideas published in 1878 in a paper entitled, *How to Make our Ideas Clear* is one way how to ascertain the basics of pragmatism (Pierce, 1995). Pragmatism rejects the idea that knowledge has a firm foundation either in 'reality' or individual consciousness; knowledge of one's mind is an inference as much as anything else, including one's knowledge of themselves that is no more certain then anything else. Pragmatism rejects there is an immediate relationship between object and cognition, claiming that there is no 'basic' data that can be un-mediated; there is always a dimension to one's knowledge that can be wrong; not only object and cognition have no immediate relation (as any relationship of thought to object is mediated by other thoughts), but inquiry has no foundation either, as there are no un-mediated relations between thoughts. Pierce saw 'thoughts' as 'signs' and all thoughts are inference therefore cognition is inferential. Pragmatism also rejects the idea of certainty, claiming that all judgements are fallible and certainty is un-available; there is never a point at which we can say regarding anything that we know everything about it and that whatever we know we can't improve upon (Cahoone, 2010; Malachowski, 2010; McDermid, 2015).

The search for meaning, according to Pierce, is in guidance of conduct: "It appears, then, that the rule for attaining the third grade[1] of clearness of apprehension is as follows: Consider what effects, that might conceivably have practical bearings, we conceive the object of our conception to have. Then, our conception of these effects is the whole of our conception of the object" (Pierce, 1995, p. 44); for example, knowing what gravity 'does' doesn't mean we know what it 'is' because what it 'does' is all it 'is'. As there is no foundation against which 'correctness' of knowledge can be assessed, 'truth' is understood through convergence; 'truth' is that which the community of inquirers will converge on over the long run; i.e., eventual consensus. The knowledge of the world needs to be re-confirmed over and over again over time finding 'what works' while constantly facing incomplete information (James, 1995). Pragmatism favours an instrumentalist and scientific anti-realist view; a view that scientific concepts and theories should be evaluated by how effectively they explain and predict phenomena, in contrast to how accurately it describes 'objective reality'. Pragmatism also stands by pluralism, i.e., a view that there is more than one way to successfully conceptualize the world. (Cahoone, 2010; Malachowski, 2010; McDermid, 2015)

If we look at the current, accepted tenets of NOS (see Appendix E) through a pragmatic and neo-pragmatic lens we may conclude that the NOS topics and their understanding reflect a number of pragmatic attitudes and views. For example, looking at the SUSSI's description of the first NOS topic, "science is based on both observations and inferences" but considering that this description includes the statement that, "observations are descriptive statements about natural phenomena that are directly accessible to human senses (or extensions of those senses) and about

[1] In his "How to Make Our Ideas Clear", Pierce (1995) describes three grades of clearness of conception. The first level is a clearness of a conception readily used in familiar senences, even if unanalyzed and undeveloped. Second level of clearness of conception, called 'nominal' underlines clearness on the level of understanding, clarified by analysis of what elements make the given idea applicable and for which we can derive practical and experiential consequences. The pragmatic maxim is the means for achieving the third grade of clarity in our understanding of a concept (Cahoone, 2010; Pierce 1995).

which observers can reach consensus with relative ease" suggests that a "consensus" regarding reality is possible, suggesting that the 'truth' of a observation statement is a negotiated truth, or something that, paraphrasing James, the community of inquirers will converge on over the long run.. The SUSSI statement that, "perspectives of current science and the scientist guide both observations and inferences" reiterates the socially-derived foundation of observations and inferences, which is a key assumption of neo-pragmatist thought. This demonstrates that the perspective of the NOS reflected in SUSSI aligns closely with the tenants of pragmatism. For example, SUSSI recognizes that, "multiple perspectives contribute to valid multiple interpretations of observations" shows pragmatic pluralism and tolerance, though it is expected that peer review and scientific community will attempt to converge on some accepted view that may change through time.

Placing the tenets into a framework of pragmatic understanding allows us to expand the angle of our reflection on students' VNOS, adding a pluralistic dimension. Taking the pragmatic stance also allows us to take a consistent approach to reviewing the students' VNOS using the accepted tenets of NOS, while shifting the exploration into the pluralistic and dynamic sphere within the identified constrains and goals of this research project.

Stochastic framework for exploring NOS.

Accepting there is no consensus on the definition of dimensions of NOS and its interpretations (e.g., tenets), I adopt the tenets-based approach as supported by the consensus of experts in the field, because it is positive and pragmatic. However, I reject the idea that there is a 'correct view' of NOS based on constructivism that teachers can test for. I adopt a neutral stand toward constructivism as it may not be the only theory that can support an appropriate view of NOS. I propose that a pluralistic, dynamic approach to exploring the issues of NOS is needed to

capture the changes of students' VNOS. Exploring the available approaches to capturing complexity of dynamic systems we can look at the stochastic (probabilistic) framework used in modern science.

Advances of modern science, particularly quantum physics (Day, 2001; Einstein, 1934; Quine, 1951; Orzel, 2009), fractal theory (Devaney, 1990) and theory of chaos (Briggs & Peat, 1989; Gleick, 1987), as well as other disciplines like non-linear thermodynamics, show that strict, classical determinism (i.e., the assumption that given a known set of initial conditions, all future states can be computed) is limited; the time of certainty is gone (Prigogine, 1997). To understand and de-code randomness and complexity, probabilistic (stochastic) models provide insights into the unpredictability of complex systems. Increasingly, patterns rather then lines support the visualization of scientific phenomena in graphs and models. The use of these patterns revolutionized some disciplines; stock market analysis being a prime example. The field of education may greatly benefit as well.

One way to analyze patterns is by introducing stochastic modelling. Brillinger (2006) describes a stochastic model as a simplified description of a circumstance in mathematical language that includes some element of randomness. Stochastic models lead to effective summarization and analysis of complex circumstances. Stochastic approaches focus on a collection of variables and attempts to characterize the evolution of the system over time. Instead of describing a process as it may evolve only in one way, stochastic processes allow several (often infinitely many) directions in which the process may evolve (Orzel, 2009). Using the stochastic approach helps us to understand where we are likely to be and where we are likely to go from there. In contrast, the deterministic approach assumes that we understand where we are and which way we want or should go from there.

The research into students' VNOS, as reviewed above, shows that there is one direction assumed in the evolution (change) of students' VNOS; the change toward a 'correct' VNOS. Once we adopt a neutral evaluative stance toward VNOS that allows for change of context, we may have an opportunity to reveal a more complex behaviour of the studied phenomena and see the changes of students' VNOS in a plurality of directions.

Drawing on a metaphor (Lakoff & Johnson, 1980) of the uncertainty principle in quantum physics, we can readily ask: What is your *position* on a particular issue of NOS? Can we find new ways of looking at the uncertainty of this *position* through the lens of modern science itself and re-use its patterns of thinking? Quantum physics is a theory of possibilities and it is the probability of these possibilities that define what is because only at the moment of decision (e.g. use, action) all possibilities collapse into one; i.e., the observed or 'actual' one (Orzel, 2009).

Students' VNOS may as well be varied 'possibilities' of views on NOS; under the influence of context (the moment of decision, use, action) these possibilities may 'collapse' into a particular VNOS (and be registered by an NOS questionnaire). Different contexts may therefore deliver different VNOS. What is needed to test this hypothesis is an opportunity to create a large number of contexts within a reasonably short period of time and succeed in recording students' VNOS for each context. This is the challenge of the NOS approach explored in this research project; how to assess students' VNOS using accepted tenets of NOS within an environment where students are immersed in a variety of contexts within a short period of time. The students will need a deep reflection and decisions to multiple practical goals requiring the use of their VNOS in different contexts. Recording students' VNOS for each context may reveal there is a stochastic nature to these VNOS.

The opportunity to explore NOS in a number of contexts reflecting everyday life that allow students to test variety of VNOS in practical situations supports their learning and understanding of NOS. As Pasupathi (2012) in her review of psychology of learning shows, a variety of practical learning contexts, "work better for learning because … it approximates how we are going to use the information we are trying to learn" (p. 49). She sees a direct relationship saying that, "the more your learning method approximates the way you are going to need to use the information you are learning, the better your learning will be" (ibid); an education environment that provides 'testing' or 'exploratory' opportunities for the students to learn and connect their ideas to new situations, contexts and problems therefore can have a positive impact on learning. It is reasonable to expect that students' VNOS will also benefit from the exploration of the possibilities and probabilities of context-based variations of VNOS. Highly abstract ideas, such as NOS, may be difficult to explore in practical contexts. A challenge for teachers is to shift the exploration into many specific situations, illuminate the possibilities and keep them open and available to the students for use in their future lives. We should not 'collapse' the possibilities prematurely into simplified answers by teaching and testing the 'correct' answer. Adopting the stochastic approach to explore the dynamism of students' VNOS may provide a unique insight into the natural way students learn about NOS; as I have shown, this approach corresponds to learning theory, reflects the pluralist ideas of pragmatism, and may provide an opportunity to create a fuller, more sophisticated set of understandings of NOS.

I have reviewed the existing dimensions and interpretations of NOS and shown the problems within the current approach to learning and teaching NOS to students, mainly its 'staticity' that considers students' VNOS as something a person learns once and for all, and demands for 'correctness' as if a particular VNOS has to be adopted to satisfy some prescribed

ideology. I have provided the rationale for a new conception of understanding of NOS as dynamic and dependent on context, grounded within the pluralistic pragmatic paradigm; I have explained the opportunity of using a stochastic approach to reveal if there are changes of students' VNOS reflecting the impact of varied contexts. In the next chapter I will explore ideas that may lead to creating an environment of multi-contextual background, and therefore productive pedagogical environment for exploration of students' VNOS.

CHAPTER TWO: NARRATIVE & FILM

Looking for a way to introduce multi-contextual environment for learning I will look at the way such environment could be described in stories. In this chapter, we examine the extent in which storying plays role in our lives and in our learning. Exploring the leading approaches toward understanding story, story telling and definitions of narrative will provide in depth understanding of the multilayered activity of storying. In the section *Storytelling and Learning* I will highlight the loop-based repetitive quality of storying and re-storying that facilitates our capability to adapt to new environments and new information. I will then focus on the role of audience, particularly the audience of "self", which facilitates self-explanations that underlie learning science. Finally, in the section *Film and filmmaking*, we will examine the story-telling medium of film through the educational lens to review the possible benefits of filmmaking for learning the NOS.

Story as an essential part of human life

Since time immemorial people have told stories; to themselves, to each other, to others. Through stories we come to understand the world around us as well as our place in it. We are a 'storytelling animal' with a keen drive to make sense out of our experiences (Olson, 1994). Anthropologist Geertz explains that our need to give experience a form and order is as real and pressing as the other, more familiar biological needs (Geertz, 1973). We are an organism that cannot live in a world that we cannot understand; many note this underlying core need for storytelling (Barthes, 1979; Fulford, 1999; Geertz, 1992; Shweder, 2007). Storytelling "is often conceived as a universal human trait, even, in the arguments of some cognitive scientists, a habit of the mind that precedes language" (Keen, 2003, p. 5). Focusing on this cognitive action or

"habit of the mind" (ibid), possibly without being expressed in language, is what I call 'storying' in the following text.

Our experiences, all of what happens to us, are complicated to describe and recount. In order to be able to tell stories and put experience into a coherent, sensible and meaningful order, a child has to developmentally reach a level when language has emerged, sense of self is developed (usually by age of 18 mo.), and memory functions well (Pasupathi, 2012). So-called 'childhood amnesia' (i.e., we do not remember our early childhood) can be explained by the lack of all three elements of storying being developed (Wang 2003). We take quite a few years during early childhood (until about the age of eight) to organize our experiences in such a storied form that it makes sense, can be communicated and remembered (Pasupathi, 2012; Wang, 2003; Wyer, 1995). The large amount of details, a lack of the distance necessary for simplicity, and fuzzy storyline can cloud the direction and reasons for our communication even in adulthood.

Stories, in order to become stories, must provide simplified descriptions of experiences, organized in time and space and be understandable to an audience through themes and possible interpretations (Andrews, Hull, & Donahue, 2009; Wyer, 1995). Fulford (1999) reminds us that, "there is no such thing as 'just a story'. A story is always charged with meaning otherwise it is not a story ... and there is no such thing as a value-free story. We can be sure that if we know a story well enough to tell it, then it carries meaning for us" (p. 6). In other words, stories disappear as they loose understandable meaning to us and some stories may be unjustly forgotten but no stories are unjustly remembered as they continue to offer us possible interpretations and meanings. (Denning, 2000; Fulford, 1999; Rossiter, 2002).

Our shared stories help us make sense of the world and our place in it; stories allow us to function in our everyday life and pass on our understandings to the next generation. Stories can

also bind us in cultural groups and support the familiar and comforting environment of our life generated by our culture (McEwans et al., 2005; Wyer, 1995). “If a story has been swimming in the vast ocean of human consciousness for decades or centuries or even millennia, it has earned its place” (Fulford, 1999, p. 7); such a story still has an audience as it continues to hold meaning, an explanation or an example for us. Telling stories in our everyday life is so pervasive that we meet ‘stories’ in many shapes and forms from gossiping to literature, art and science. Storying is an activity of organizing events in time and space and includes organizing information to help the listener to understand and emotionally connect to the experience of the storyteller.

Under the spell of scientific progress and success, science became artificially separated from the storied way of thinking and organizing information. Storying started to be seen as too simplistic or primitive to relate information of science; storytelling professionals separated themselves from science claiming that scientific products and thinking are ‘context-free’ and abstract while storying is context bound, concrete and testable through ordinary interpersonal checking (Genette, 1980; Robinson & Hawpe, 1986). This perceived conflict estranged science from storytelling.

However, humans yearn for understanding; to rely only on analysis seems not enough to cover all the ways we relate to new information. Our ‘storied nature’ always searches for stories that logically organize, describe and explain the world around us including in science (Fisher, 1985; Shanahan et al., 2010). Fulford (1999) considers this question:

> Why can't we simply *study* our experience rather than recounting it chronologically? The answer is that narrative, as opposed to analysis, has the power to mimic the unfolding of reality. Narrative is selective, and may be untrue, but it can produce the feeling of events occurring in time; it seems to be rooted in reality. This is also the reason for the triumph

> of narrative, its penetration and in some ways its dominance of our collective imagination: with a combination of ancient devices and up-to-the-minute technology, it can appear to replicate life (p. 15).

Narrativity has been an important concept in the humanities during the last quarter of a century. As Rorty explains, the 'linguistic turn' was a narrative turn as well (Rorty, 1992). "Whereas in earlier centuries the world was thought of as a stage, in the last quarter of the twentieth century it was conceived as a text woven by the narrative threads human beings read in their efforts to make sense of their perceptions and experiences" (Simon, 2007, p. 2). As narrative became considered the basic blueprint for cognition, comprehension and explanation as well as the most important means for construing identities and histories, we need to re-discover its strengths and benefits to science and science education. Therefore, I will now look at the current understanding of narrative as a way to tell a story.

Defining narrative as telling a story.

The word 'story' and 'narrative' are often used interchangeably and therefore their definitions vary, highlighting a variety of meanings embedded in these words. Keen, who presents a comprehensive overview of the theories of narrative (Keen, 2003), devotes five full pages looking at the variety of definitions of story and narrative, concluding they are quite fuzzy words because most of the time it is assumed that readers naturally recognize narrative. "For most people, narrative is defined by examples—novels, short stories, films, histories, music videos, epic poems, biographies, ballads, television series, and private conversations that tell stories true and made-up" (Keen, 2003, p 4).

According to Oxford Dictionary, the origin of the word narrative comes from late Latin word "narrativus" meaning 'telling a story', but Keen's explorations of the etymology of the verb

‘narrate’ (to relate, to recount) suggests that it derives from an original meaning for ‘skilled’ and ‘knowing’, or a particular part of document, which contains a statement of ‘essential facts’. It is as well a history, tale, story, recital (of facts, etc.) and the practice or act of narrating as well. It is ‘something to narrate’ and something ‘what the narrator does’ at the same time. In the end, she concludes, theorists propose definitions comprised of bare minimums: narrative tells a story (Keen, 2003). The concept of narrative therefore allows exploring *how* events are told as narrative organizes events of a story into an understandable and intriguing arrangement.

The combination of the possible meanings explored gives us narrative that tells stories as “the recounting (as product and process, object and act, structure and structuration) of one or more real or fictitious events communicated by one, two, or several (more or less overt) narrators to one, two, or several (more or less overt) narratees” (Keen, 2003, p. 9). This ‘recounting’ creates a representation of a series of events meaningfully connected in a temporal and causal way.

How a narrative creates these meaningful connections is explored in depth by theories of narrative. Today’s views of narrative have a long history, but with Plato and Aristotle started the traditional division between ‘telling,’ or relating information (diegesis), and ‘showing,’ or enacting (mimesis). According to Plato, the poet acts as a narrator (in diegesis in his own name, in mimesis as ‘pretend’), telling about agents and events; the mediation of a narrator therefore becomes a core characteristic of narrative. From Aristotle’s narrative theory derives the observation of the importance of plot, and that plots have beginnings, middles, and ends (Bruner, 1991; Fisher, 1985; Keen, 2003).

The idea of plot addresses the common distinction between story as a description and narration. In description, story recounts events in chronological order as Event 1 is followed by

Event 2, Event 3, Event 4 and so on; it seems that 'story time' stands still, regardless of the events implying passing time. There is a chronology in descriptive storytelling, but while description may have the objects, characters, and even the happenings of narrative, it presents them without suggesting the succession of events that set a plot in motion.

A plot is composed of causal events; events that are significant because they have important consequences. The narrator creates a plot by selecting events as they cause a particular development of the story. For example, using the descriptive story order above, we can show plot as a story line: because of Event 4 the Event 2 caused Event 5 and so Event 1 resulted in Event 10. A plot focuses on and highlights the important events in a story as they relate to one another in a pattern based on cause and effect; this pattern consequently constitutes the meaning of 'storyline' (Zucker-Scharff, 2011).

What characters in a story do, feel, think, or say also influence plot, because these events may make a difference to what happens afterward. For example, Dibell (1988) explains the effect of emotions as they influence plot.

> Thought or emotion crosses the line into plot when it becomes action and causes reactions. Until then, attitudes, however interesting in themselves, are just potential, just cloudy possibilities. They're static. They're not going anywhere. Nothing comes of them. No thought, in and of itself, is plot. No action, however dramatic, is plot if the story would have been about the same if it hadn't happened at all. Any action, however seemingly trivial, can be vital and memorable if it has significant consequences and changes the story's outcome. Plotting is a way of looking at things. It's a way of deciding what's important and then showing it to be important through the way you construct and connect the major events of your story. It's the way you show things mattering. (p. 6)

In comparison to the descriptive storytelling with its chronologically passing time, plot consists of the major events that *move* the action in a narrative and cause a change in the development of the story. Narrator can use plot to design a story for particular medium and audience. As we will see later in this chapter, plot in filmmaking provides the fundamentals for the screenplay where the film treatment (i.e. what is the film about) contains the plot.

Considering narrative as the process and means by which the narrator arranges the events of a story into a plot, which concerns itself with the sequence of the events, the complexities of describing narratives become evident. Narrative concerns itself with the myriad of ways events can be put together into one coherent unit; it may enact a variety of ways to reorder the events of a story and echo the medium through which the stories are told. Narrative can set the story's events completely out of chronological order or combine them with elements and themes from outside of the story to not only articulate what is going on but also to build dramatic effect for the audience, all through the structure of the plot. Plot is therefore a fundamental ingredient of narrative and as such is described and studied through variety of narrative theories (Dibell, 1988; Keen, 2003; Zucker-Scharff, 2011).

Structuralist narrative theory distinguishes the 'what' of the story from the 'how' of the narration. This creates an arrangement where narrative becomes a fusion of a fabula (story) and sjuzet (discourse); the events as they actually happen are contrasted with the events as told by the narrator (Keen, 2003; Rimmon-Kenan, 2006). Without events, without a teller, or without a sense of order in time, the basic materials of narrative would be missing.

Some thinkers of narratology, who at the beginning started as structuralists, developed a strong post-structuralist approach where the distinction of 'what' and 'how' is diminished, as we

can see form the work of Genette, one of the most influential thinkers about narratology (Chatman, 1980; Keen, 2003; Lucaites & Condit, 1985). Genette (1980) defines 'story' as the content of narrative, while narrative is the 'text' itself (the signifier). He focuses on the narrative (independent of medium), because he considers it the only 'item' in the triplet of story-narrative-narrating (i.e. content-form-action) that is directly available for textual analysis. Narrative therefore allows us to access not only the content, but the process of narrating as well. From this perspective we can say that the events (regardless if actual or imaginary) or happenings are reflected in the narrative under variety of selective modifications (Genette, 1980). Prince, a major theorist of the 'recipients of narration', emphasizes the importance of the listener, viewer or reader in the structure of narration; the presence of the audience may not be a part of the story itself, but because the listener is the reason for the narrator to tell the story, the implied recipient of narration has an organizing power over the narrative and controls the activity of the narrator (Keen, 2003; Prince, 1980, 1983).

According to Genette (1980), the structure of narrative influences whose approach might be the most accepted can be grouped under *tense* that identifies the temporal relationship between the story (events) and narrative, *mood* that identifies the forms and degrees of narrative representations, and *voice* that is indicative of the way in which the narrating itself is implicated in the narrative. These categories allow a detailed understanding of how the connections among the events, the time-line, the narrator and the audience manipulate the story.

Narrative found a wide application in broad spectrum of human activities including education (Boeschoten, 2011; Griffin, 2009; Harter, 2009; Huisman, Murphet, & Dunn, 2005; Langellier, 2004; Vick, 2006.), but some theorists claim that narratives have no place in science (Genette, 1980; Mink, 2001; Robinson & Hawpe, 1986). They point to an alleged contrast

between the narrative thinking and scientific thinking. While both try to organize and give meaning to human experience "the product of scientific theorizing is principle, that is context-free and abstract and testable only by further formal scientific activity … while product of narrative thought, story, is context bound, concrete and testable through ordinary interpersonal checking" (Robinson & Hawpe, 1986, p. 114). 'Context' is then the main divisive element and science is perceived to function in a vacuum; Mathews (1997) has shown that Robinson's writing is heavily influenced by the then dominant logical empiricist tradition in philosophy of science, but this tendency can be seen in other literary experts and narratologists (Genette, 1980; Mink, 2001).

As shown above, a narrative tells stories that are a representation of a series of events within a context. Storying is the mental activity that allows to inter-connect the events in a temporal and causal manner allowing the narrator to tell the story in many ways controlling the story's tense, mood and voice. Storytelling, i.e. creating a particular narrative[2], involves making all the decisions needed to simplify, organize and rearrange the pertinent events and their participants to convey an appealing story to a particular audience. In the next section we will take a look at how this sophisticated activity of storytelling connects to learning.

Storytelling and learning

The benefits that storytelling brings to learning are well recognized. Many educators applied storytelling techniques in a variety of subjects and found far-reaching benefits to not only comprehension and literacy but emotional involvement as well (Bahk, 2010; Cesarone, 2008; Childhood et al., 2006; Good & Robertson, 2005; Miller & Saxton, 2011; Ohler, 2008; Trbic,

[2] The words 'story','storytelling' and 'narrative' are often used interchangeably, in this dissertation it is used in distinct and consistent way; as 'narrative' involves one or more stories, the act of creating a narrative constitutes storytelling and the act of creating a story (which could build into a narrative) is storying. Storying and re-storying are therefore the basic elements of building a narrative.

2013; Wieringa et al., 2011; Zagalo, 2010). As Davidson (2004) point out, “storytelling is a means for sharing and interpreting experiences. Stories are universal in that they can bridge cultural, linguistic and age-related divides. Storytelling can be used as a method to teach ethics, values, and cultural norms and differences” (p. 186).

Psychological research suggests that in order to learn, we depend on learning meanings of categories and scripts and these are learned via stories where information and change is organized in space and time (Pasupathi, 2012). In early childhood, before our storytelling capabilities are fully developed, children readily immerse themselves in play. Play is a way of exploring scripts of life. As Vygotsky (1966) observes, “in play a child creates an imaginary situation” (p. 8) and reacts to it by action; that action is play. Reacting or acting in an imaginary situation depends on knowing (or defining) the rules of behaviour in order to be able to enact particular event, relationship, etc. Vygotsky argues that, “what passes unnoticed by the child in real life becomes a rule of behaviour in play” (1966, p. 9) because, “in play child deals with things as having meaning … word meanings replace objects” (p. 13). Similar kind of ‘play’ continues as children mature into adults but it converts into complex internal processes as internal speech and abstract thought, all guided by storytelling.

This is why storytelling and drama education offers a successful approach to learning via story making in the classroom (Barton & Booth, 1990; Booth, Barton, & Barton, 2000; Booth, 2005; Miller & Saxton, 2004, 2011). In drama education, storying activities engage students “in filling in between the lines, digging within the words, arguing about the textual intent” (Booth, 2005, p. 66) and allow students “to explore rather then to demonstrate what they know” (Booth, 2005, p. 29). At the same time “sharing stories and making drama help to make the abstract more concrete, diverse facts more understandable, and arouse interest in learning” (King, 1993, p. 3).

Story making demonstrates the storying thinking within a group of students and adds a collaborative experience to the story that shows itself in a different variation of the story each time it is told; i.e., re-storied, since "every experience will follow different path, dependent upon the context of the group at that time" (Booth, 2005, p. 66). The activity of re-storying and re-telling the story may also need to adapt the story to completely new conditions and situations (context) that may include different time and place, as well as different audience.

This research project is looking at a story making activity of filmmaking with the interest in the possible changes of students' VNOS due to variety of contexts embedded in the film story. The research focuses on the re-storying that happens as students adapt to new situations represented by the film characters. In the next section we will therefore take a closer look at the processes taking place within storying when a new situation prompts the changing of a story in order to adapt it to a new context.

Storying and re-storying as adaptation. There are several definitions of the word 'adaptation' the Encyclopaedia Britannica (2014) suggests; in broad terms, adaptation is a change or adjustment to improve something, or to make it suitable to a different situation. In biology, adaptation is a change that may afford an organism a better chance to survive in its surroundings. The biological focus on organisms considers the meaning of adaptation in respect of time; non-permanent change to a new environment is mere acclimatization, while permanent change gets encoded in genes, becomes heritable and constitutes adaptation. Such adaptation plays a major role in evolution, and evolutionary processes give rise to diversity at every level of biological organization (Suarez & Woudhuysen, 2010).

Narrative requires relating the events of the story organized in space and time to the audience. As any element of this organization changes, so will the story. The idea of adaptation

allows us to add the breadth, flexibility and complexity to storying that the variety in which story is presented to the audience demands. It addresses the changes to the 'raw material' that is derived from experience (real or imaginary) in the process of adapting from one source to another ('source' is meant in the widest sense; an idea, a heard/told story, but also a novel or a film etc.) for an audience (as the generalized 'recipient of narration'). Adaptation is the re-storying activity required to match the changes, the new context, and as such it involves selection and choice; it requires condensing or expanding the material, simplifying and clarifying where needed, so the audience (one or many) can follow with relative ease.

Telling a story is complicated, as we are usually facing material that is very rich with complexities; in order to tell a story, much of the material must be let go: "the adaptation is a new original. The adaptor looks for the balance between preserving the spirit of the original and creating new form" (Seger, 1992, p. 9).

Reflecting on a story involves personal adaptation when we are re-storying for our own understanding; in this way we create self-explanations. When we tell story to a friend, we already tell it differently, we adapt it to the audience. This re-storying serves as adaptation to address every change: temporal, spatial, personal etc., and assists our abstracting capacities and generalization (Kottova, 2012). Adaptation is necessary to assist changes in the medium as well; story is built differently for oral presentation, for novels, for drama, for film (Seger, 1992).

Our capacity and need for re-storying may be in our underlying biological capability to adapt to new environments. Adaptability is the hallmark of evolution as it allows a change of behaviour to fit different conditions (McEwans et al., 2005; Thompson, 2010). Meeting new information, assimilating and making sense of it by creating a new modified story of how the world works means adapting to a new situation and the roots of adaptations are in self-

explanations. Expanding the audience from I to one or many others widens the scope, reach and complexity of the stories. We are naturally so attuned to this evolutionary trait that storying is an inherit part of our lives, and as such it is in the foundations of learning (Pasupathi, 2012). Storying therefore can also influences the way we learn science. I will explore the connection of storying and learning science in the next section.

Self-explanation & learning science. Learning science can be understood as encountering new information that call for a modification to our existing understanding of how the world works (Pasupathi, 2012). We need to exchange an older, less sophisticated model of phenomena with a new one that is more complex or 'accurate' (at least according to current scientific knowledge). Research indicates that 'self-explanations' are at the base of our learning science (Hodds, Alcock, & Inglis, 2015; McNamara, 2004; Nokes-Malach, VanLehn, Belenky, Lichtenstein, & Cox, 2012; Pasupathi, 2012). Talking ourselves through our understanding of the meaning of the new model (i.e., how it works and relates not only to its internal phenomena but also to other models we are aware of) is essential to our re-organizing current knowledge in a way that allows us to adopt and assimilate the new information a meaningful way (Driver, Newton, & Osborne, 2000; Kruckeberg, 2006; Lorsbach & Tobin, 2005). As such, self-explanation is a type of story we tell ourselves in order to find new schemata, a relatable script for understanding the behaviour of studied phenomena (Pasupathi, 2012). Based on the definitions we explored earlier, self-explanations are individual recountings of a series of events meaningfully connected in a temporal and casual way and communicated to oneself. Based on the exploration of definition of narrative we conclude that self-explanation is a narrative as it tells a story.

In the case of science learning, self-explanations need this type of storying to be repeated to allow us to 'process' new information thoroughly within a variety of situations and contexts. Such re-storying permits the transformation of the information and incorporating it into the previous knowledge or experience (Pasupathi, 2012). These repetitions of the activity of self-explanation can be seen as a feedback loop. The concept of feedback loop is an essential element of modern communication theory and appears in disciplines that study dynamic systems. A feedback loop refers to a situation where part of the output of a system is used for (or becomes) the new input; it is used for modelling complex systems as well as simulating social phenomena (Gleick 1989, Mill 2010; Page 2008). Learning that starts the story of self-explanation from a certain set of initial conditions (e.g., a level of personal understanding of the individual), then arriving to a new understanding that is subjected to re-storying by a new story of self-explanation and so on is creating a feedback loop. The variety of conditions under which our understanding can be challenged increases the number of occurrences of the feedback loop of storying for self-explanation, and consequently deepens the encoding of the new information, increases the level of understanding and also the level of memory retrieval (Pasupathi, 2012).

In self-explanations the audience is the same person as the narrator: I. The narrator is as close as is ever possible to understanding audience, because the narrator <u>is</u> the audience. The narrator in self-explanations is often placed 'outside of the story' narrating flow of events within a new model, the narrator is acting as 'authorized commentator on the action'. We must take into an account that the new model was already delivered to the narrator, therefore we can say that in self-explanation the narrator modifies, adapts the explanatory story to be accessible to the audience.

Storytelling and Audience.

In the previous sections I reviewed the structure of narrative and story and elaborated on the ways in which different functions of narrative constitute self-explanation. I extended the meaning of storying and re-storying into a feedback-based process of adaptation and pointed out the connections to rule-based play. I showed that the roots of learning lie in storytelling and process of self-explanation. So far I looked only briefly at the influential role of audience, particularly the difference between an external audience (i.e., friend) and internal one (i.e., I), which shifts storying into self-explanations, the roots of learning.

An audience is the recipient of narration and as mentioned earlier, the narrator is there for the audience; this is a dual linking that doesn't make sense in separation (Keen, 2003; Prince, 1980, 1983), as no story can be constructed without a perception of audience; there is always at least one listener, the 'I'. The narrator fulfils a narrative function in respect of the story, directing function in respect of the 'text' (the narrative's form; i.e., speech, storytelling, novel, film) and communicating function in respect of his or her audience (Moffett, 1968). An audience influences all features of narrative. The selections, choices and decisions the narrator makes are rhetorical. Theory of rhetoric has a long tradition and studies the type of expression and language that have a persuasive or impressive effect on its audience (Enos, 2010; McKerrow, 2015). Rhetoric as the art of presenting a subject successfully to get the expected or desired response from others (Moffett, 1968) empowers the narrator to succesfully deliver their story.

The narrator as a communicator also fulfils an affective function by offering testimonials for the story and an ideological function as the authorized commentator of happenings (Genette, 1980). The success of both, the affective and ideological influences of the narrator, depend on an

affective attitude of trust (Jones, 1996); the trust the narrator invokes in the audience is in turn dependant on the narrator's choice of mood and voice for the narrative.

The narrator's access to the perceived audience also influences how the rhetoric choices are made so the trust of the audience can be successfully managed. For example, talking to a friend in close proximity may include an intimate knowledge of the friend's life and values; it may make the storytelling well matched to the audience and context. Speaking to a large audience already modifies the story for a large number of people in the audience that the narrator may not know; the narrator must make assumptions in order to gather the attention and trust of the audience. Writing a novel shifts the storytelling even further from the audience. The narrator looses the personal contact with an audience, which may also shift in time as novels can be read any time in future. Communicating through film adds shifts in the realm of the visual dimensions of storytelling and concerns with how will the audience understand the visual cues in the story including but not limited to the body language. Each form of narrative will exhibit its strengths and weaknesses in how well it communicate to an audience across space and time.

The research project of this dissertation uses film as the narrative form within the dynamic process of its creation. In order to show the function of narrative, storying and adaptation in the research project, we will now look at film and filmmaking.

Film and filmmaking

Narratology focuses on the storying and the narrative structure it supports regardless of the medium. Still, each particular medium will intensify certain functions of a narrative and weaken others. Narrative has to be tailored to a particular medium to succeed in its rhetorical goal of addressing the audience (Seger, 1992). For example, in a novel the dramatic action leading the storyline usually takes place inside the head of the main character. As Field (1994)

notes “in novel, action takes place within the mindscape of dramatic action” (p. 8). In a theatre that operates in the realist mode the story of the play happens on stage where the audience becomes the ‘forth wall’, eavesdropping on the lives of characters; there is a link between the stage and the audience with a subtle influence on the performance, drama ‘happens’ in this space (Fields 1994; Seger 1992). In theatre a play has characters that *talk* about their hopes, dreams, plans, etc., so story happens mainly within the language of dramatic action. Film is a visual medium that dramatizes storyline with pictures, sounds, images and snippets of action film: a phone ringing, a clock ticking, rain on a window, car key turning, a door opening, someone watching, etc. The textual representation of film, or screenplay, uses words that tell the story in pictures, in dialogue and description, all placed within the context of dramatic structure (Field, 1994).

As Metz (1974) says, “all one retains of a film is its plot and *few images*” (p. 46), and he wonders that still photography that can be seen as individual ‘frames’ of film was never intended to tell stories; why should it have the power to tell a story just within the juxtaposition of several pictures? “Going from one image to two images is to go from image to language” (Metz, 1974, p. 46). Metz who applied both Sigmund Freud’s psychology and Jacques Lacan’s mirror theory to the cinema and pioneered the application of Ferdinand de Saussure's theories of semiology to film (Fell, 1983; Flitterman-Lewis, 1994), considers film to be a kind of imperfect reflection of reality and a way to submerge into the unconscious dream state (Metz & Guzzetti, 1976).

Bordwell, on the other hand, developed a cognitive theory of film comprehension using the concepts of schemata, cues and inferences (Bordwell, 1985). He argued that film narrative presents stories that are inherently incomplete; audience, i.e., spectators, must use their knowledge of schemata to organize the story of the film into a coherent mental representation.

From his perspective, film contains cues that can activate the application of schemata; for example, gaps in the film are the most evident cues, because they require the spectator in the audience to fill in the missing data and generate inferences to fill in the gaps (Buckland, 2009; Shermer, 2011). When comprehending a narrative film, Bordwell and others agree that most often one structure in particular guides our inferences: the Aristotelian canonical story format consisting of a beginning, a middle and an end (Bordwell, 1985, 2006; Buckland, 2009; Field, 1994; Ohler, 2008; Seger, 1992).

When viewing a film, the audience experiences events and actions as arranged by the plot (sjuzet); 'plot' refers to how events are presented on the screen. Each viewer must reorganize these events and clarify their order and relationships for themselves. In doing so, viewers gradually put together a personally comprehensible self-story (fabula) reaching the understanding of the narrative level of what happens (Bordwell, 1985). As Buckland (2009) explains, "because film's story is a mental representation the spectator constructs during his or her experience of the film's plot, the story is in a constant state of change, owing to the spectator's ongoing generation of new inferences, strengthening of existing hypotheses, and abandonment of existing inferences" (p. 7). This is reflective of the re-storying process I mentioned earlier, a process where we adapt a story to the newly encountered information. Even if a film purposely directs audience toward misleading inferences (in respect to the intent of the narrator) about the story's direction, upon completing the story structure the viewer will have to adjust their expectations or understandings of what was presented to make the story intelligible. These adjustments are also needed when the canonical story is breached, for example in puzzle-films or game-films that all represent an unpredictable and complex storytelling (Buckland, 2009). The viewer can only create an interim understanding that may be tentative, kind of 'it

seems it is so…' and it will naturally progress to the 'aha' moment, when the viewer finally arrives to organization of events that make sense to them.

Film attempts to mimic life (e.g. make the film story feel possible), and on the way it creates a 'filmic reality' that is capable of delivering a life-like, unique and memorable experience (Rushton, 2011). The information in film comes to us not organized for 'direct' understanding; it is organized by plot to guide our attention, and we have to make sense out of it to comprehend the story. Similar to everyday life, our film experiences present information that only through reorganization and abstraction can be organized into a story or schemata describing the particular behaviour of the world to us (Kottova, 2012; Moffett 1968; Pasupathi, 2012).

As no story contains all information about the events narrated, so does no experience contain all information about observed events. We gather information and experiences from different sources during different periods of time, and the stories that organize this vast amount of information coalesce and adapt to the new information with a new story that gives better understandings of happenings. We can understand our experiences only after we can relate them to a number of similar occurrences, and abstract and group our experiences into categories that help us to understand self, others and the world (Pasupathi, 2012).

Film 'simulates' this seemingly random way of collecting information but provides direction. Film story has dimensionality within which it reveals the background of characters, develops themes and environments etc., giving additional cues as to how to understand the main story (Seger, 1992). By the end of a film, the events 'make sense' and give the audience the sensation that they 'arrived' somewhere, that they completed a journey. The audience have 'solved the puzzle' of the presented problem by understanding the narrative's story. Solving the puzzle doesn't mean finding a 'correct' answer, or solution; it means having made sense of the

problem, even identifying areas we can't understand is a meaningful result of re-organized information. This processs is the difference between feeling 'puzzled' and feeling the film was nonsense.

Film captures (preserves) experience and the audience can share the experience. The audience can 'feel it' when they can 'see it' in the film; in other words, to recreate experience is to show it (Mariano & Norton, 2011). To share the experience a film presents, the audience taps into their previous knowledge and incorporates the film's experience, guided by the cues and themes in the film. The film's multi-dimensionality of the underlying stories guides the audience to arrive to personal re-storied version of the film; this reflects an understanding of the film. Viewing a film therefore allows a free exchange of understandings, a dialog of one era (represented by the story within its history, culture, values, opinions) talking to another, to a personal and current one (Mariano & Norton, 2011).

In a certain way, film always presents a puzzle, a game where some 'rules' are shared and already known, some are created by individual films; the 'language of film' is modified, transformed, expanded, pushing the audience to create new, temporarily unusual inferences and constructs. The 'language of film' is in constant development. What was unusual in one film might become an accepted way of expressing relationships, suggesting inferences in another. People need time to adapt to visual telling of stories and they learn new ways of relating to film with every viewing.

Looking at the process of storytelling, re-storying and self-explanations that include an internal dynamism of storying for different audiences through varied narrative texts such as film, we see again the repetitions of storying within a feedback loop. Dynamic systems, driven by recursion and repeating a simple process over and over in an infinite feedback loop are embodied

in fractals (Devaney, 1990; Gleick, 1987; Page, 2010a). The feedback loops of storying we explored give a fractal quality to the storying activity. A fractal is a never-ending complex pattern that is self-similar across different scales. A good example of fractal is a tree; each branch (or section of it) is similar to the look of another branch or the whole tree.

A learning theory that considers learning as information processing stresses the benefits of self-similar repetition in learning; this repetition is not of the simple repetitive memorization type (i.e., rote learning), but one that approaches similar problems with a variety of situations. This kind of repetition supports an elaborative encoding of information, and deepens the understanding of the studied subject (Pasupathi, 2012). We can conclude that enabling students to actively make a film themselves extends the fractal repetitions of the storying and self-explanations and therefore may deepen learning.

Filmmaking is the active creating of film. It starts with writing a screenplay when a source material, be it a real life experience or situation, novel or play or even another film, is adapted for presentation on a screen, i.e. film. Numerous books are devoted to explaining the patterns and rules of screenwriting and the problems of film adaptations (Batty, 2011; Field, 1994; Ohler, 2008; Seger, 1992). It is during screenwriting that the main structure of the story line (the plot, characters and conclusion) is developed. The written representation of the film, descriptions of the environment, characters and images, as well as the description of the action and dialog is passed to the filmmaking team that in turn transform this description into an actual film. Writing a screenplay is a more or less an individual activity; rarely is there a large team involved in writing a screenplay, however during the process of filming usually a film crew in a larger group completes the production of the film.

Within the creative process of making a film, a large number of choices and adaptive feedback-based storied explanations and understandings take place. Filmmakers are imitating happenings (i.e. story) on film and ultimately they choose what is presented. A screenplay acts as a vital guide, but guide only nonetheless. The selections and preferences of choice are guided not only by the purpose or goal of the film (the message and feeling the film is planned to deliver as described in the screenplay) but also by the team's understanding of the expected audience, as the filmmakers strive to fulfil the rhetorical function and make an impact with their film. The team cooperates, discusses and clarifies options and choices, and although in a professional filmmaking environment the Director and the Producer seem to have the final say the impact of the entire team, including the Editor, is undeniable. A film considered to be made three times; when it is written, when it is shot, and when it is edited. Actually, a film is re-created innumerable times not only during production but after it is completed as well, since a film's story is re-created every time it is seen; the film experience is different for each viewer. In this way, film's story exists in uncountable number (possibly infinite if we take into account passing time) of adaptations that via re-storying include nuances of understandings of each member of the audience.

I have shown how is the storying and re-storying activity inherent in learning manifested in film and filmmaking. Given the benefits of self-similar repetition to further learning and the abundance of contextual multidimensional re-storying involved in filmmaking I will now discuss filmmaking through an educational lens as a possible pedagogical method.

Filmmaking as a pedagogical method.

By creating a film, the film crew and students are immersed in the creative environment of filmmaking where the demands of the feedback-based process of re-storying will be

constantly present and pressing in increasingly multiplying levels. The making of a film is highly dynamic, constrained in time, options are 'on the table', selections and decisions must be made, and through the adaptations to each decision, re-storying must take place (in each filmmaker) to reflect the nuances of the film story being created. The story during filmmaking is in constant flux and filmmakers on the set have to continually reflect on that as the team brings new solutions to finish the story and complete the film. The whole film crew is like on "a river raft going through increasingly precipitous rapids. There is no stopping, no turning back, and every decision must be instantaneous and correct, otherwise disaster is imminent … " (Bettman, 2003, p. 15) … this captures the intensity of story-making during the film production phase. Regardless of the meticulous preparation for production, the filmmakers constantly face possibly disastrous changes, for example an actor quits the day of shooting possibly necessitating re-writing the script, bad weather, misplaced props etc.; such intensity requires the team to 'think on their feet' and be extremely flexible problem solvers; it also provides experiences captured in the exciting stories about the filmmaking.

In everyday life we face decisions and tell stories, we use self-explanations to understand the stories we hear and adapt our stories accordingly; I find that in a filmmaking environment all these activities are unusually multiplied and compressed in time. The variety of stories created during filmmaking and the nuances of problems or meanings they address are unparalleled. As I explained in the previous section, the increased multiplicity of feedback based self-explanations and re-storying combined with facing a breadth of possible and actual audiences (from self or crew members, to the audience of the film) are proliferated even further by the unique, out of sequence filming process required by film production. As I explained in the previous section, this multiplicity has the potential to intensify and deepen learning.

Let's look at the additional increase of re-storying and self-explanations brought by the filmmaking exercise. This time I will focus on the combinations that 'time' imposes on the structure of the story. There are two main time structures that influence a story; first the chronologically based structure that follows happenings as they would naturally happen in time. This time structure may be the most natural to follow as, for example, the description of life story of a character. Second, there is a plot-based chronology that orders the events of the film according to the plot. Film production adds another dimension to the re-storying; film production puts the time sequences of the film story in complete disarray by filming sections of the film in 'out of sequence' order; the grouping of scenes produced together is completely arbitrary, organized based on availability of locations or actors, etc.

Focusing on the filmmaking process it is clear that the learning-enhancing self-similar repetition of re-storying and re-adjustment required of students to not only understand the film story but also to adapt to particular production day content, new situations on the set and within the team suggests that filmmaking could be a fruitful pedagogical method. To explore further the benefits of filmmaking, I will now look at each section of filmmaking process separately to highlight the layered multidimensionality of re-storying involved in filmmaking.

Screenplay, film script. When students read the screenplay, it is organized in a plot-based sequence; in their mind they create a story flow that is reasonable and believable to them. They build this view by re-storying the screenplay, adapting it to their current understanding (usually arrived to chronologically) of the environment of the story's space, time and characters. They create personal images of how the story may look on film, and through self-explanatory stories of how characters may behave in a particular situation, etc. They experience the effectiveness of the structure of the film story undisturbed by outside influence because reading

is a private activity and at that moment the audience is ‘I’ or ‘self’. Learning the details and contents of the story happens in a similar manner and in similar level of re-storying as for example reading a novel, or a theatre play script.

In the cooperative environment of the team, students face a complex environment of stories, ideas, opinions and understandings. The film crew is made of people who bring their experiences into the understanding the film story, and tend to tell their personal stories in order to explain their views. In this way the storied environment continues to grow. With each new opinion a new story comes to life to fulfil the role of an example. These stories function as ‘eye witness’ examples, where the narrator fulfils the affective function by offering the testimonials for the story. For the listener these stories function as a way to learn about the audience.

Effectively this is the first level of communication with an audience; it is a narrow audience, but it can ‘talk back’, argue and clarify. Among the members of the team, students negotiate how to ‘play-out the film story’. This environment will require them to place themselves in a mind set similar to a child’s play. As Vygotsky (1966) fittingly described on his example of children playing ‘sisters’, the children have to identify what it means to be ‘sisters’ and have to describe this meaning to one another to create the rules of the game. For example, they decide that sisters lend toys to one another, or share candies or play with one another more than with others, etc. Once the rules are discussed and decided, children can play the ‘game of sisters’ and behave according to the rules that clearly articulate how these children understand sisters behave, or how sisters ‘are’ (Vygotsky, 1966). This requires telling a story; the story about what sisters do in a particular situation, how it differs from any other role or relationship and what it is that makes such relationship different. In a similar manner, students during filmmaking have to discover and discuss the meanings of issues such as, ‘what is science and

how people react to it' or what does it mean to 'be a scientist'; they will have to imagine and explain their view of 'scientist in action': how scientists talk, act, argue and persuade. Students get immersed in different self-explanation stories and re-story their understandings as they progress toward an agreement on how to portray and visualize the film story and characters in a way that others (i.e., an audience) can understand and follow the story of the film.

These discussions activate the negotiations necessary to set up the most acceptable and understandable rules of the 'game,' as we saw with Vygotsky's example. Students can address parts of the film story that don't seem to make sense and find out why is it so; they have to decide what would make sense to others, therefore expand their understanding of the audience. Students will need to show where their self-explanatory story breaks down for them, and why it might break for others. Through re-storying, students would need to clarify their personal understanding of individual sections and objects of the film story, expose their understanding to others, and effectively attempt to adapt the story as if they are someone else; the Other or the audience. By testing these explanations on one another within the team, the students consider other re-storying adaptations and evaluate them; they adopt or challenge them.

Regardless that the script organizes the story according to the plot, the self-explanations and re-storying for understanding of characters and events may conform more to the chronological structure, and stories may be prevalently told in a sequential time order. For example, there may be a section in the script where a character Maggie starts yelling at a bystander; possible dispute may be a self-explanation such as this: 'I don't think it makes sense for Maggie to loose nerves like that; she just met her boyfriend, got a present and generally had a good time, she was just smiling, there must be something else that makes her to loose her temper.'

The film is discussed as a relative whole through the screenplay, self-explanations will tend to bring chronologically organized stories in order to explain how the situation ‘came to be’. The feedback-based cycle of re-storying and adaptations continues until students arrive to an understanding of the story and characters of the film that is reasonably acceptable to the whole team; the meanings are uncovered and the ‘rules of the game’ are set.

Storyboard. Storyboard outlines in pictures the basic look of several frames in each scene of the film. It conveys the film in static pictures similar to comic books. The plot guides the main film story but the image-based expression of the plot highlights what the audience needs to pay attention to. Selecting and organizing images of basic shots and their order has many functions in telling the story; it builds suspense, support curiosity, intrigue and possibly purposefully confuse the audience. Storyboarding requires the team to explain and tell a story of what these images mean; again, an individual self-explanatory story is used to describe what these images (or their order) mean to me in the attempt to test if the meaning is the same for others. Finally an agreement is needed to accept such meaning as one that may be understandable to a wide audience. The storyboard follows the story of the film in a plot-based structure and therefore the re-storying in plot-based chronology may dominate the discussion. Explanations of meanings of individual still images in the storyboard may continue storying in a chronological order; for example, to explain why a character would behave a certain way one may reason with the biographical description of what happened to the character earlier in life, and how this character would be shaped by their life-story.

These processes of explanations efficiently multiply the feedback loops of re-storying on several levels at the same time, and reflect the adaptations of understanding the narrative with the purpose of telling the story to an increasingly wider audience; an audience that is more distant

(unknown and imagined) and therefore the self-explanations reflect an increasingly more uncertain understanding of such audience.

Filming. The filming period of filmmaking brings an additional layer to the storying processes. The production breakdown that practically and efficiently combines scenes to be shot at a certain time together breaks the films story-structure sequence. The acting and filming of scenes will proceed in different order then the one in which the film story narrates the events.

In the previous sections I reviewed the varied feedback loops of re-storying and self-explanations as the students arrive to an understanding of the film script and preliminary visualization of the film when both plot-based storying and chronological storying takes place. At this stage of production the film story is filmed in a sequence that is, story wise, usually out of any logical order. The sequences in which sections of scenes are recorded each day of filming are organized by the practical considerations such as availability of locations, people, equipment, weather etc.

The stories arrived to in all these previous stages of filmmaking have to be remembered and are constantly referred to in order to keep the continuity of the film story intact. The team now includes the talent; actors who are selected to play particular roles and who bring additional understanding of the characters they play within the story. This will require further re-storying of both, the plot based story nuances as well as chronology based context stories nuances to help to incorporate the actors' understandings of their roles into the film, while keeping the consistency of the overall understanding and expression of the film story. Keeping consistency becomes harder and harder as the filming progresses; the decisions made at the beginning of the filming process (which may include scenes from the middle or end of the film) strictly define what representations of story would be in harmony from that moment on. The accumulation of these

decisions captures a ‘final explanation’ of the film story; final in respect to the decisions made when a section of the story and the character were filmed. The continuity team supervises these defining ‘final explanation stories’ but the whole crew has to constantly keep these stories in mind. I want to stress how challenging this quality of working in film actually is. The ‘final explanation stories’ do not grow naturally either in chronological order nor film story plot order; they stabilize or ‘freeze’ at the moment when they are filmed.

Small sections of the film script are filmed in several takes, each take requiring feedback based storying and re-storying activity that allows the adaptation of the actors to the team vision of the film story. The team members now focus on minute details of each shot, evaluating if the take reflects well not only the story as whole. This will require another round of re-storying activities as the evaluations are described and explained.

Working with actors present an additional storying challenge as the body language, voice and expressions of the actors are tailored to represent the meanings identified for the character. In depth ‘rules of the game’ need to be re-storied for each actor as they attempt to deliver the ‘right look and feel’ as well as the correct dialog of the take.

Selecting the best take of each filmed section engages the team in comparing activities. The filmmakers have to compare several often very similar takes, and in this situation they will pick up some truly deep nuances of the visual meaning of the message in the take.

Filmmaking becomes most intense during the filming period, therefore filming was selected as the focus of the research project of this dissertation.

Editing. Editing puts together the selected takes and organizes them in the film story structure approximating the screenplay; additional shots called inserts are put in the edit to deliver the intended look and feel of the film. Editing completes the film including music and

credits. Editing is done most often by one person (the Editor) and modified based on the feedback received from the core team, usually the Director and the Producer. For practical purposes, editing is not part of the research project reported in this dissertation. Students participating in this study have the opportunity to see the final cut and tell a story about the viewed film that they were part of creating. As reviewed in the previous section, this re-viewing is a form of re-storying as the students modify the stories from the production phase into the post-production phase.

Filmmaking as a research project.

A narrative can be in the form of a film; film is experienced as a kind of 'story puzzle' that is solved and translated by the audience in a process of re-storying and adaptation. Transferring the functions of storytelling into the active environment of filmmaking allows us to connect storying as a form of 'child's play' or 'game'; a way of identifying meanings of happenings around us and allowing these meanings to guide the play and become the 'rules of the game'.

The goal of filmmaking is to create a film that visually presents story with believable characters in a variety of life situations and contexts. I have shown how the process of filmmaking continually adds new levels of feedback-based re-storying and adaptations. The filmmaking team, working in a collaborative environment, is constantly shifting and translating personal views to understand individual characters of the film story, which demands re-storying to happen. Each re-storying will address the subject being discussed for the particular audience present or imagined (i.e., expected), setting up the meaning and therefore the rules of how the section will be acted and visualized in the final film.

I described the feedback-based process of re-storying necessary to communicate a story visually to the viewer. During filmmaking, the variety of stories communicating nuances of varied understandings demand deep reflection and may allow the emergence of the dynamic quality of views of both, the film's story and students' VNOS.

Learning is based on expanding the possibilities of action. If we understand more possibilities, we may en-act them when needed. Filmmaking provides an environment where our innate capacity to play and tell stories intensifies our review of meanings for things we usually do not think about; such as what science is and how we approach everyday life with the knowledge provided by science. The multilayered diversity of feedback-based re-storying adaptations enlivens the modality of storytelling in respect of its temporal and spatial structure as well as its rhetorical positions. Both plot-based and chronology-based storying are required, and support each other as the stories communicate information to an audience that is constantly shifting from the closest 'self' to the distant and possibly unknown 'other'.

I have shown that the feedback-based adaptive process or re-storying creates an unusually high diversity of possibilities; perspectives, opinions, understandings and stories, enhanced by the capability of storytelling to shift timelines and perspectives, with each team member being the 'creator' as well as the 'receiver' of the storying activity. The value of different perspectives is recognized in our society and it is one of the principles of modern science as scientists with different backgrounds and diverse perspectives can bring many points of view to bear on scientific problems. In addition, the complexity of challenges faced by today's society has produced a stronger reliance on teams and the need for group cooperation has become critical. I have shown that filmmaking enlivens the processes of self-explanation and feedback-based storying and re-storying within a cooperative team that has a common goal; this allows the team

to explore a variety of meanings, combine ideas and find new understandings to the phenomena explored by the film story to reach the goal and complete the film. Filmmaking may therefore offer a robust way of learning because it is based on collaborative work that enlivens a large number of learning-enhancing activities.

The project of this dissertation explores if filmmaking can offer a fruitful way of learning about science, particularly in the area of exploring the issues of NOS. Can it enhance the depth, scope and diversity of students' VNOS as the students use self-explanations and a storied way of learning NOS? The film project looks not only for the modality of students' views of NOS but it also attempts to appreciate the benefits of using film production as a pedagogical method. Through the activity of making a film we focus on exploration of questions such as: is there a pattern in students' understanding VNOS? Does students' VNOS change within different contexts and situations simulated by the film? What is the range of VNOS each student demonstrates? In what ways the film project influences the sophistication of student's VNOS, and finally, how will the students respond to the experience of filmmaking? Answering these questions requires a methodological framework that we explore in the next chapter.

CHAPTER THREE: METHODOLOGY

The goal of this research project is to answer the research questions that were derived from a review of the topics under investigation. Considering the necessity to introduce and explore the area of the nature of science (NOS) in school and the difficulties with the concept itself, as well as with the in-class delivery that I explored in Chapter One, I argue that the 'static' approach to teaching and learning NOS is inadequate.

In Chapter Two I explored storying and re-storying as a natural and efficient way of learning science and proposed to use a narrative medium of film and filmmaking as an activity to explore students' views of the nature of science (VNOS). Filmmaking provides a multi-contextual environment for learning, particularly NOS, and may establish a fruitful pedagogical method to probe the possibilities of understanding NOS and dynamism of students' VNOS. The research project is designed to investigate whether student VNOS are dynamic and context-based.

The project's research questions are therefore layered; the main focus is on finding the modality of students' VNOS but the research also attempted to identify the benefits of using filmmaking as a pedagogical method. Following is a review of the research questions that guided the structure of this research project.

1. What is the pattern in students' understanding VNOS?
2. Is their VNOS changed within different contexts and situations?
3. How do different life situations (as simulated by the film) affect students' VNOS?
4. What is the range of VNOS each student demonstrates?
5. How do the qualitative results support or contradict the quantitative results?
6. In what ways did the film project influence the sophistication of student's VNOS?

7. How did the students respond to the experience of filmmaking?

In this chapter I will focus on the research project's methodology and describe in detail the project's progress, timeline, selection of participants, structure and types of collected data, and explain the methods used in data collection and analysis.

Philosophical Framework

Research is necessarily grounded in a basic set of beliefs, assumptions and understandings that guide the inquiry (Bergman, 2010; Guba & Lincoln, 2005). In Chapter One, I explained in detail the problems with the approach to NOS that would favour either a positivistic or a constructivist view. I highlighted the need for a new conception of NOS as stochastic, dynamic and context-dependent; all these are rooted in pragmatic approaches to knowledge. The positivist notion of 'the one and only' truth that is waiting to be discovered by an objective and value free inquiry is the hallmark of quantitative methods. On the other hand, the constructivists, for whom there is no single objective reality favour qualitative research methods (Feilzer, 2009). Pragmatism is an alternative to these two approaches.

The history of development and evolution of the philosophy of pragmatism is long, complicated and marked by some "muddleness" (Rorty, 1991, p. 64) as its recent reinterpretation and implementation in a variety of theoretical and practical areas has lead to the possibility to identify more then one type of pragmatism (Mounce, 1997).

Looking at pragmatism as a research paradigm allows looking at the organizing structure or "accepted model or pattern" (Kuhn, 1996, p. 24) of the philosophical view in respect to the studied phenomena. There is a problem with accepting a paradigm as a strict epistemological stance that directs and controls research efforts and re-asserts itself because then regardless what the stance may be, positivistic, post-positivistic or constructivist, such paradigm becomes

prescriptive, necessarily demanding certain research methods and prohibiting others (Feilzer, 2009). As such it can restrict intellectual curiosity, creativity and imagination, possibly limiting researchers when new aspects of studied phenomena and new ideas and theories may be available.

Pragmatism, as shown in the works of philosophers from Pierce and Dewey to Rorty (Dewey, 1958; Mounce, 1997; Putnam, 1995; Rorty, 1991), allows researchers to "sidestep the contentious issues of truth and reality, accepts, philosophically, that there are singular and multiple realities that are open to empirical inquiry, and orients itself toward addressing practical problems in the 'real world'" (Feilzer, 2009, p. 8). It is this liberating force behind pragmatism and neo-pragmatism that releases the researcher from the dichotomy between post-positivism and constructivism and allows to combine methods to address the research problems (Creswell & Clark, 2011, p. 26). Pragmatism also acknowledges that the world of our experience can be presented in a variety of different elements and layers, as Dewey fittingly describes in his book *Experience and Nature* (1925); some presented as objective, some as subjective and others as a mixture of these. In his book Dewey devotes a chapter to, "Existence as Precarious and as Stable," where he discusses the interplay of recurrence that allows some prediction and control as well as ambiguities resulting in uncertainty (Dewey, 1958). Dewey's argument here is that both positivistic and subjective research approaches are of the same kind in that they both attempt to find 'the truth', they just postulate the foundation of knowledge differently. Looking at the philosophical development of positivism and some leading modern pragmatists, like Rorty (who started from within the analytic mode) (Misak, 2013) or Putnam (who was originally recognized leading positivist), we can see that the internal criticism of foundations of knowing within the positivist philosophical school ended in 'bankruptcy.' Pragmatism never adopted a

foundationalist approach and therefore ideas of pragmatism offered new perspectives to some thinkers in their search for new solution (Cahoone, 2010; Malachowski, 2010; Mounce, 1997).

Pragmatism is 'anti-dualist'; therefore it supports using methods from different paradigms as each position in an extreme may represent a stereotype. Pragmatism as a research paradigm questions, "the dichotomy of positivism and constructivism and calls for convergence of quantitative and qualitative methods, reiterating that they are not different on epistemological or ontological level and that they share many commonalities in their approaches to inquiry" (Feilzer, 2009, p. 8). Merging and combining different perspectives may allow the researcher to arrive to an enriched understanding of the studied phenomena.

The pragmatic critique of foundationalism is at the centre of the 'anti-representational view of knowledge' characteristic of pragmatism (Cahoone, 2010). Rorty (1991) reminds us that we cannot, theoretically, accurately represent reality or achieve a precise description of how things are in themselves. The goal of research has to change and focus on usefulness to us (Rorty, 1991). Even though this is a complicated and controversial statement begging the questions about usefulness to whom, Hanson (2008) clarifies that from the perspective of research, the utility lies in whether the research helped to find out what the researcher wants to know and answer the research questions. Research under a pragmatic paradigm recognizes, accepts and commits to uncertainty. This approach recognizes that knowledge produced by research is not absolute and relationships, particularly causal relationships, are hard to identify and confirm. Accepting uncertainty is not the same as skepticism that denies we can know anything. Pragmatism just recognizes that structures and patterns are opened to shifts, changes and modifications and are dependent on unexpected and unpredictable occurrences and events (Mounce, 1997). Feltzer (2009) states:

> The acknowledgement of unpredictable human element forces pragmatic researches to be flexible and open to the emergence of unexpected data. This means that in Kuhn's terms, as paradigmatic constraint, pragmatism reminds researchers of their 'duty' to be curious and adaptable. (p. 14)

Methodological framework

The research project in this dissertation focused on exploring a new conception of understanding of students' views of nature of science (VNOS). The technique used to enliven and expose the dynamic nature of students' VNOS is filmmaking during a 4-day intensive film production weekend camp. The project therefore offers the possibility to investigate the benefits of filmmaking for enhancing and deepening students' reflections and understanding of NOS.

Using a methodological lens that honours the contextual, holistic, and pragmatic accounts of participants' views within a solid framework and permits to capture students' static VNOS and may allow to show the practical, dynamic and context based VNOS is necessary; it also needs to allow following students' spontaneous meaning-making during the filmmaking project. From the variety of available methods I found the mixed methods approach best addresses the project's research questions.

Mixed methods research is rooted in the pragmatic worldview that "arises out of actions, situations, and consequences rather then antecedent conditions" (Creswell, 2009, p. 10). Using this method allows the researcher to concentrate on the research questions and apply a variety of approaches to best discover their answers. The multilayered research questions of the project require the flexibility provided by a pragmatic acknowledgement of the multilayered world (natural, physical, social and psychological) we inhabit and that the knowledge we create is based on the interactions within those layers. Pragmatism also consistently supports the ideas of

constant change and adaptation, making knowledge and understandings tentative and dynamic (Johnson & Onwuegbuzie, 2004).

The matching characteristics of the research questions that are focusing on dynamism of students' VNOS and mixed method research approach satisfy the demands of my research project; as such a mixed method approach is best suited the task of answering the research questions. I used a mixed methods approach within a convergent parallel design (Creswell & Clark, 2011; Creswell, 2008, 2009; Meissner, Creswell, & Klassen, 2011) that is based on collecting qualitative and quantitative data in parallel, analyzing them separately and then merging, converging as well as comparing the results.

The mixed method approach was used in the hope of achieving a greater insight into the research problem. Creswell and others recommend that this approach allows to reveal finer nuances of the problem than would be possible if I obtained either type of data, quantitative or qualitative, completely on its own (as the only type of data) or separately in different time frames and not in parallel (Bazeley & Kemp, 2011; Creswell, 2008; Morell & Tan, 2009; Feilzer, 2009).

The project and its participants

In this section I describe the processes and actions necessary to explore students' VNOS through filmmaking and how I addressed the limitations of the mixed methods methodology described above.

Research project description.

In order to explore students' VNOS this research project immersed the students in a 4-day intensive film production camp. A group of high school students, paired with an experienced film crew, produced a short film entitled, *The Shadows of Hope*. The research project proceeded in several stages consisting of participant selection process, pre-production meetings, filming

during production stage, completing the film and evaluation data. The complete detailed project process was subjected to ethical review by the Human Research Ethics Board at the University of Victoria and received full ethical approval under protocol number 12-180. In the next sections I'll provide an in-depth description of all stages of the project.

Participant selection process.

This project created an opportunity for students from high schools in a large, urban city of Victoria, British Columbia, Canada to join in the making of *The Shadows of Hope*. The program was planned for two consecutive weekends, and therefore it did not affect students' school attendance; the program was offered free of charge.

I prepared a set of information meetings for interested students and planned to freely advertise in the majority of high schools in the area. I didn't expect any objections, as there was no demand for any of the school property, administration or teachers time. Demands by school districts for an in-depth and lengthy individual approval by school principals in order to display the project's flyer at school delayed the information distribution and significantly shortened the time for advertising of the program. Upon receiving the approval from several secondary schools, I distributed information flyers through these schools (For a sample flyer, see Appendix A). In order to mitigate the time loss, I contacted a teacher from one of the schools, who was willing to personally promote the film project to her students. To further support the information exchange and flow I set up a Facebook page, 'The Shadows of Hope' that provided additional details about the film and expanded the reach of the advertisement by allowing the public to learn about the project. Within the first two weeks of its publishing I noted 635 views of the page.

I led three information meetings, where interested students, usually with their parents, came to find out details and ask questions about the project. I explained that they would be participating in a research project, but I didn't expose directly the purpose or questions of the research. The goal of the camp for the participants was to make a short film called *The Shadows of Hope* that dealt with a topic of an unexpected illness (multiple sclerosis) in a family.

I explained in detail the requirements of the research as well as the demands of filmmaking; I included clarification of participant's rights and freedoms during the project. Students that didn't wish to apply and join the project could leave the meeting at any time. Others completed the meeting by filling out application forms (Appendix B). Part of the application included completing a NOS questionnaire *Student Understanding of Science and Scientific Inquiry* (SUSSI) (Chen, Adams, & Macklin, 2006) found in Appendix C. By the last planned information meeting, twelve students applied to join the film camp. The time constrains of the project timeline did not allow for a longer advertising period that would possibly produce a larger number of applicants towards the ideal number of eighteen participants. I concluded that twelve students was an acceptable group for the research purpose, as it might represent smaller class or an afterschool club and so accepted all the applicants for the film camp.

The final count of participants was ten, as one student (female) decided to leave the project after the first pre-production meeting and one student left in the middle of the project. The program was opened to both male and female students of any high school grade; the final student participant team consisted of 36% of females and 64% males. The overview of the student participant team is in Table 1.

The majority of the participants (55%) were informed by their teacher about the project, only two received or reacted to the school flyer (18%) distributed in the schools, and three

participants found the information on the web (27%). This exercise allowed me to see in action the challenges of reaching audience beyond the classroom. If one plans to run such a project in a cooperative spirit, possibly connecting different schools, the most successful approach would require interested teachers joining efforts and supporting their students to take part in such a project. On the other hand, several teachers at the same school may join their students within a project to form a successful and complete production team.

Table 1:

Student participants' gender and grade level

Name	Male/Female	Grade
Ethan	Male	9
Emma	Female	9
Layla	Female	11
Ella	Female	11
Caleb	Male	11
Aubrey	Female	11
James	Male	11
Jack	Male	11
Ryan	Male	11
Lucas	Male	11
Alexander	Male	11

I anticipated that the students who would likely apply to join the project would be self-selected by their interests in art, drama and film but not necessarily directly in science. Based on the participant's description of their interests and hobbies four (36%) noted arts-related activities like writing, drawing or music, only two (18%) mentioned technology or scientific interests, three (27%) were deeply involved in active sports and the rest preferred computer games. Not

surprisingly, five participants (45%) disclosed they really like playing video games. Focusing on their likings of school subjects five participants (45.5%) liked social science subjects (History, English etc.), five (45.5%) exact science subjects (Physics, Math, Biology, Chemistry) and one (9%) noted "I don't like any science subjects." This spread of interests indicates a well-balanced group of participants.

The majority of student participants (73%) indicated that they had some experience with drama in school; be it a school play or Christmas shows. Most had experienced stage production and some acting. Two students (18%) also had film experience and some media related education from school. One student (9%) claimed had no experience with drama or filmmaking.

Why did they join the project? Majority (64%) joined for pure curiosity, based on their idea that it will be a "fun" or "interesting" experience. Four students (36%) reported being already interested in filmmaking, possibly having some experience or plans for the future. Surprisingly, except two students who were not sure about the direction of their future career, eight students (73%) saw themselves in a science-oriented career (architect, programmer, biomedical engineer, medical staff etc.), only one in an arts-related career.

One feature in the group that was revealed by their questionnaires was "shyness." Four students (36%) openly noted they are very shy; one was extremely shy and left the project after first two days because he found it too stressful to be so close to the centre of attention. Personally observing the dynamics of the group during the project, I noted in my field notes even higher number of participants (eight students or 73%) would fit the profile of 'introvert' while only three were truly 'extroverts' (Cain, 2012). This may suggest evidence that some (particularly quiet) students will have the tendency to gravitate toward filmmaking as they can join in the

production, avoiding the limitations that their shy personality may impose on their involvement with theatre and the live stage.

Participant organization.

The participants worked in teams. There were six teams of one to three participants, each team supported by a film consultant. Each team was responsible for one of the six departments needed to cover the most basic areas of film production (see Table 2). The team size allowed a balance in decision-making during the project and allowed avoiding possible 'stale-mate' on the team as decisions had to be made quickly in order to complete the film in the allocated time. The members of each team rotated from one department to another to experience all aspects of film production. The rotations prevented excessive immersion of participants into the technical issues of a particular department, and allowed them to keep focus within the domain of creating the meaning of the film story.

Table 2

Departments & roles

1	Directing department	1 supervising film consultant, 2 participants
	Roles	*Director, 1st Assistant Director,*
2	Sound department	1 supervising film consultant, 2 participants
	Roles	*Sound recordist, Boom operator,*
3	Camera department	1 supervising film consultant, 3 participants
	Roles	*Director of Photography (DP), Camera operator, Slate operator*
4	Lights department	1 supervising film consultant, 2 participants
	Roles	*Lights operator, 1st Assistant,*
5	Art department	1 supervising film consultant, 1 participant
	Roles	*Set & Props,*
6	Make-up department	1 supervising film consultant, 1 participant
	Roles	*Costumes & Make-up*

Support. A group of independent filmmakers worked as film on-set consultants and provided the scaffolding of technical support to the participants during the production stage. This support ensured the project progressed toward completion within allocated time and allowed the participants to focus on the content and visualization of the film story instead of focusing on the in-depth technical knowledge required to produce a film. Cooperation with film consultants also minimized or possibly eliminated the negative impact and frustration the students might experience due to their lack of technical knowledge of filmmaking. The professional film set that the support team created presented a unique learning environment for the participants. Students expressed in their interviews the appreciation of the opportunity to work with professionals in the field. It serves as evidence of the benefits of such learning opportunity. For example, Lucas[3] felt really special because, "not many students in Grade 11 have been on it [film set] or gotten a chance to work on a film," and James called his experience "very, very riveting" to mention just few from the selection of descriptions of the excitement of being on the film team. Emma highlights that she works with "very interesting people, they always want to help, no one's being excluded, and it's just a fun environment to be around … you learn a lot of stuff … just being someone who has no idea what they're going to [do] and now I know so much … it's only been one day." Aubrey's observation that "it feels pretty hectic, like there's a lot of things going on all the time and it's a really like fast paced environment" may be seen as the rationale for higher rate of learning. Ella reflects on the fact that this project was no fake or 'made for school' activity saying, "I feel really professional with all the lighting and all the real everything ... all is real on [the] set" and Layla, who is one of the students with an already developed interest in filmmaking and several school courses regarding film and media under her belt says that, "it gives you more

[3] Names in this dissertation I used pseudonyms for the participating students to maintain the principle of beneficence.

of a, a sense of feeling about movies and how they're made and how long it takes and what actual work goes into it and it just gives you a new kind of respect."

Film consultants on the project were filmmakers with independent filmmaking experience and members of CINEVIC, Victoria not-for-profit organization that unifies, supports and serves the independent filmmakers in Victoria. CINEVIC members have a proven track record of filmmaking experience and an ability to support different film production areas within the filmmaking technical team. During our pre-production meeting, I explained to the consulting team their role as technical support and 'know-how' guidance: They were to guide in technical matters but maintain the independence of student's decisions in respect of portraying the script. As the researcher I was performing the administrative duties such as distributing and collecting the forms with Character quizzes and collecting field data via behind the scene documentary footage. The forms of data collection will be outlined later in the chapter. The Producer and main Supervising Director were responsible for the schedule and coordination of teams during the production. Participants followed a schedule to make sure everyone had the chance to work in each team. Any timing modifications were reflected in the schedule and new plans were executed in cooperation with the student-participants.

Cast. The project was focused on the participants making a film where they directed a team of actors to deliver the lines of the script to create the film. During the pre-production phase, simultaneously with acquiring the participants, I organized auditions for prospective actors, and together with the Supervising Director, selected the talent for all characters in the film.

There was a strict time-line for each of the production days. The shooting schedule identified which actors are to be on the set at what time. The participants therefore never worked

together with all actors at the same time, but in groups as required by the shooting schedule. The out-of sequence shooting time-line and constantly shifting creative team influenced the on-set discussions and decision-making and highlighted the disjointed nature of creating the film narrative. The students worked with the actors to merge the actors' acting ability and understanding of the script with the direction received from the directing team. The students together with the cast decided on the final version of the dialog used in the film. This flexibility was to allow as much of the students input into the film as possible but it negatively affected the script continuity and proved challenging to edit the final film. The research project was not designed to follow in detail the particular changes from the written script to the 'on-screen' script.

Individual students' perceptions of each character in the story were captured by Character Quizzes administered by the researcher. These quizzes and the timing of data collection will be outlined later in the chapter. The film production takes of particular scene in the film were the result of interaction among the group of actors and group of students. These takes therefore included the results of the group dynamics and decisions within the production team for which this project didn't implement any research controls.

Researcher on the set.

In this project, as a researcher who is interested in the collected data I was as well part of the film project in the role of author, Producer and a documentarist. It is therefore essential to consider any impact of the researcher to identify and mitigate any bias.

The observer's background and knowledge of the studied subject can influence what is 'seen' and how it is described. The research in NOS, particularly the classroom based research, is weighted with many such concerns (Lederman et al., 1998; Schwartz & Lederman, 2002). I

considered these concerns in the planning stages and placed this research project outside of the classroom, outside of traditional instruction, into an informal learning environment (Davies, 2008; National Research Council, 2009; Yore, Kottová, & Jagger, 2010). As such, there was no intention or plan to teach the students involved in the project the issues of NOS. The project was strictly focused on making a film.

To minimize interpretive bias, I consciously stayed in the background of the production. I did not join any discussions so there was no need or time for imparting my personal views on the issues of NOS or Philosophy of Science to the participants. There was also no reason for students to know the researcher's opinions on the issues reflected in the film. There was no motivation to meet teacher's expectation to score high on a test, as there was no test coming. My personal presence on the team was directed to the administrative tasks of the distribution and collection of quizzes and 'behind the scenes' camera operator. All participants' coordination in respect of tasks and time-line on the production set was done by the Supervising Director or Supervising Producer and the practical guidance of each particular team was provided by the support consulting crew.

I consciously adopted a neutral position on the set, allowing me to gather 'as-it happens' video footage. This video footage is the daily record of the day-to-day relationships development and happenings on the team as they worked toward the film completion. As a form of field notes, this footage also records decisions regarding to what to focus on in the attempt to document the dynamics of the team. The video data together with written notes I kept during the production helped me to illuminate discrepancies or confirmations of studied patterns, as well as disclose or mitigate the issue of any undue influence or impact.

The project planning and execution demanded that the researcher play different roles, but these roles rarely overlapped. Even though I planned the project with the goal of answering the research questions, the execution of the project focused on the film completion where the most important factor was time, efficiency and progress toward the completion of shots required by the script. Within the highly demanding and time-constrained film production environment, I didn't attempt to evaluate the collected daily data and therefore my opinion about the data could in no way influence the project. Only after the project was complete I reviewed, evaluated and correlated the data gathered during the research.

Authorship.

I created the preliminary script for the film *The Shadows of Hope*. There are many considerations that need to be taken into account when making a film, and these were compounded by the requirements of this research project that demanded a particular topic to be used for the film story as well as other limitations regarding the context of the story.

In the film industry, authorship is strictly protected and making a film based on published story requires permissions and often payments for the right to use the story (Bettman, 2003). I needed a script that defined a problem space within which the interplay of the researched attitudes toward NOS can emerge. Searching for appropriate script was time consuming and unfruitful because of the lack of scripts with an appropriate, science-related content. It could be beneficial for teachers to maximize the reach of the learning opportunities via film and have their students to write the script for the film, but in this project it was outside of the scope of the research.

The students had an opportunity to modify the script during the pre-production meeting. The script at the end included edits and modifications of the coordinating director and dialog

alterations made by the participants and the production team during filming. The opportunity to read, think about and discuss the script ahead of production allowed the students to learn the story, as well as to find their own 'feel' of the characters' personalities. This enabled them to fill out the character-focused quizzes, completed over the course of the production; these quizzes in particular provided evidence of students' change in their VNOS.

The Story & Characters.

The call for students to join the project was based on very simple description of the story.

> "Kayla, a high-school student, upset about her parents separation, thinks that life can't be any more frustrating, but an unexpected illness throws her into a hurricane of uncertainty and competing ideas with no right answer; but she must make a life and death choice. What will it be?"

The film required eight characters, each with their own story, personality & knowledge level; the character overview can be found in Table 3.

Table 3:

Characters overview

Kaila	Kaila Blackford	High-school student	female, 16
Mother	Nancy Blackford	Music Teacher	female early 40
Mother's Friend	Sandra Newman	Marketing	female 35
Hospital Doctor	Dr. Peterson	Doctor in hospital	male, 50 ties
Father	Peter Blackford	Architect	male 40
Family Doctor	Terri Williams	Family Doctor	female 43
Father's Friend	Dr. Robinson	Medical doctor,	male 50
Healer	Paean	Holistic, New Age,	either, any

While writing the story, I made some assumptions as to the attitude toward science each of the characters would have, and shaped their behaviour accordingly to support the dramatic structure of the film. The story of this short film is inspired by real events, and follows realistic explanations and content (See Resources Section B for complete script). It generally focuses on the turmoil caused by a sudden incurable illness, and the decisions people face when dealing with such situations.

Kayla has an episode that brings her to a hospital, where they diagnose the illness as Multiple Sclerosis (MS). It is a debilitating neurological illness that is not fully understood by the scientific or medical community and there is currently no cure. A doctor in Italy has proposed a solution called 'Liberation Therapy' that is based on the procedure of angioplasty. This procedure seemed to have positive results in some patients. The success stories were circulated over the Internet, and suddenly the medical community has been inundated with the demands by MS patients who wanted to undergo the procedure. The medical establishment system reacted by banning the procedure, first in British Columbia and then in all of Canada. The MS patient community was shocked and started raising money, not for the MS research (as they usually did), but to get the funds necessary for the procedure to be performed overseas. This is the environment where I placed Kayla's story.

Kayla's mother, separated from her husband and not on very good terms with her teenage daughter, feels alone dealing with such an enormous issue and looks for help. She reaches to her friend Sandra, who helps her to connect to a family doctor, Terri, who has not only the education in the field but also personal experience with MS and Liberation Therapy. Sandra suggests that they all meet together with Kayla's father to discuss the issue and make some plans for the uncertain future. Kayla's father Peter, who is an engineer, agrees to the meeting and brings his

friend, Dr. Williams, who is a medical researcher, part of the medical establishment and very knowledgeable about MS. The meeting and the discussion that ensues is the main part of the film. During the meeting all characters present, discuss and react to all the hopes, fears, uncertainties and medical realities they are facing to help Kayla. The interplay of different attitudes influences each character. In the end, it is Kayla, who has to make the decision if to proceed with the unproven and possibly dangerous procedure.

Data Sources and Collection

Data sources. During the project I collected a variety of data. An overview of the types of data and manner of collecting it can be found in Table 4 in the *Data Collection* section. The primary source of data for this inquiry are sets of nine evaluative questionnaires and quizzes completed by each participant, their written responses as well as narratives; that is, transcripts from interviews and group discussions with the participants (Casey & Murphy, 2009; Jick, 1979; Mertens & Hesse-Biber, 2012; Oleinik, 2010). These primary sources allowed to gather 1) graphical data from continuum based slider bar mark locations, that were measured resulting in collection of numbers referring to the mark location on the continuum slider bar, 2) Likert-style evaluative answers and 3) written descriptions and explanations connected in multiple ways through the context of the film story and character. In order to understand this context and its impact on the primary data gathered, additional data sources were taken into an account.

Additional data source include the short film, *The Shadows Of Hope* that represents the characters and story context of the Character Quiz data of this study. It also represents the final look and feel of the story and characters as created on film by the participants and the crew and therefore represents the combination of students' views and the cast's views intertwined during the film production as they directed, acted and filmed the characters. The film is the essential

background to understanding the complex task the students were addressing via their questionnaires and quizzes. Behind the scene footage was collected during the production stage; this footage is a form of video field notes and include interviews with students. Students understood these interviews were done for the purpose of informing others about the experience of creating a film. From the research perspective it added a public dimension of the review of students opinions about the film as well as 'likes' and 'dislikes' based on complete and complex view of the filming process, story and characters. These field notes enhance the understanding of students' expressed VNOS and sometimes differ from student evaluations of the characters captured in the questionnaires and quizzes. Complementary sources of data (Coffey & Atkinson, 1996; Jick, 1979) also include field notes written by the researcher at the time of production and subsequent reflections on the data prepared during data analysis stage; these complementary sources were used to inform the findings and implications of this inquiry. These additional sources of data helped to capture tendencies or inclinations the students demonstrated during the filming process within the group, their cooperative and collaborative skills, everyday life discussions and jokes; they also helped to grasp and contrast the personalities of the students with the primary data collected via questionnaires and quizzes. As primary data attempted to dissect and separate views and opinions on particular NOS issue and evaluate it within the connection to context, the complementary additional data sources were the hallmark of understanding the students as whole and unique individuals within a complex problem space.

Collection Tools and Data Types. The guiding instrument used to collect data was a questionnaire entitled *Student Understanding of Science and Scientific Inquiry* (SUSSI) (Chen, Adams, & Macklin, 2006; Liang et al., 2008). This questionnaire includes a Likert-type questions combined with related open-ended questions to assess students' understanding about

how scientific knowledge develops and tests the levels of sophistication of student's views of nature of science (VNOS). In the past decades, a number of such instruments were developed and used, such as "Test on Understanding Science", "Science Process Inventory", " Nature of Science Scale", "Nature of Scientific Knowledge Scale" and other modifications and extension (Abd-El-Khalick & Lederman, 2000; Aikenhead & Ryan, 1992; Cooley & Klopfer, 1963; Kimball, 1967; Lederman, 1992; Rubba & Andersen, 1978), but these instruments were often written from the point of view of an expert and seemed to assume that all scientists have the same view or that NOS was 'clearly' known and defined. In addition, as Alters and others show (Alters, 1997; Eflin, Glennan, & Reisch, 1999), those experts did not adequately represent perspectives of neither of scientists and philosophers nor science educators. Aikenhead and Ryan developed an instrument entitled the "Views on Science-Technology-Society" (VOSTS) (Aikenhead & Ryan, 1992) that presents number of extensive, specialized questions that makes the task of completing the questionnaire a major one. Perhaps the most influential NOS assessment tools on students' understanding of NOS today are the 'Views of Nature of Science Questionnaires'. These questionnaires were developed by Lederman, Abd-El-Khalick, Bell, and Schwartz and exist in several variants (A, B, C, D) (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). These questionnaires are also large and procedurally complicated, as they consist of a substantial number of open-ended questions accompanied by follow-up interviews. None of these questionnaires were suitable for the purpose of my research; this research required a NOS questionnaire that can be filled a number of times (for each context and character), and in a reasonably short amount of time.

SUSSI is one of the more recent instruments used in several studies with students and with pre-service teachers (Chen et al., 2006; Golabek & Amrane-Cooper, 2011; Liang et al.,

2008, 2009; Miller, Montplaisir, Offerdahl, Cheng, & Ketterling, 2010), proving a wider reach across age groups. The questionnaire is compact and avoids overly complicated scientific language and problem-solving-like questions and did not require extensive writing; most students completed the instrument in less than half an hour. The instrument, now in its third version, was internationally tested in China, Turkey and the US, achieving reliability (Cronbach's Alpha) between 0.67 and 0.61 (Chen et al., 2006; Liang et al., 2009). This level of reliability is satisfactory (Cho & Kim, 2014) and thus the instrument provided useful data for the purposes of this research project as it provided an insight into students' VNOS from the perspective of traditional NOS research.

The SUSSI questionnaire is based on a collection of short and simple definitive statements about science with which the student expresses a degree of agreement via Likert-scale rubric. However, using such definitive statements repeatedly for each film character within the short period of film production time would not yield enough flexibility to show the nuances of students' views across different contexts, so a different approach was used for this data. To gain insight to student views during production I used the results from an NOS meta-study (Deng, Chen, Tsai, & Chai, 2011) and created a questionnaire form (see Appendix D) that could be correlated with SUSSI questionnaire. The definitive statements of SUSSI instrument were replaced by NOS question-topic as identified by the meta-study (explored in Chapter One), and placed on a continuous slider bar to allow flexibility in recording a range of answers. These question-topics functioned as the 'extreme' naïve or constructivist statements (respectively) at each end of the continuum slider bar. This form became the "Character Quiz" used to gauge student VNOS during the film production stage of the project.

Participating students completed a Character Quiz repeatedly for each of the film characters; the set of quizzes was used to determine the consistency of students' views across different contexts and life situations as demonstrated by the characters and happenings in the film story (Andrews et al., 2009; Johnson & Onwuegbuzie, 2004; Feilzer, 2009).

The mixed methods approach within a convergent parallel design (Creswell & Clark, 2011; Creswell, 2008, 2009; Meissner, Creswell, & Klassen, 2011) is based on collecting qualitative and quantitative data in parallel, analyzing them separately and then merging or converging them as well as comparing the results arising from each set of data. Data were collected during the project in parallel as shown in Table 4 in the next section *Data collection and timing*.

Quantitative data that were collected during the project were in a form of graphical data from continuum slider bar mark locations, which were measured resulting in collection of numbers, and also Likert-style evaluative answers from all questionnaires and Quizzes.

Qualitative data included the written responses from SUSSI questionnaire and Character Quizzes, as well as the data source from video recordings of group discussions, video field notes and documentary interviews, and also the completed film *The Shadows of Hope*.

These mixed methods captured well the life-shaping processes of each participant and allowed the researcher to make inferences about the generalizability and transferability of the research findings to other contexts (Roth, 2005). This merging approach allowed better clarity and understanding of the nuances of VNOS in this project and helped to reveal the levels of its dynamic nature (Barone, 2003; Patton, 2002).

Data collection and timing.

Data collection started with the participant's selection process prior to the filming of the short film *The Shadows Of Hope*. During the application process the applicants completed personal information form (see Appendix B) and filled in a SUSSI questionnaire NOS questions (see Appendix C). This represents their set of NOS views before the project started, and without the context of the film set, film story or the characters. This questionnaire is based on a set of statements pertinent to the problematic of NOS and includes a section with Likert-style scale capturing degree of agreement with the presented statement as well as a section with worded answers. An overview of data sources, data types and collection details is presented in Table 4.

Table 4:

Research Data Details:

	Data type and description	Data Collection timing
SUSSI Questionnaire	Worded answers Likert-scale evaluation	Before commencement of the production
Character Quiz SELF	Slider bar marks retrieved as numbers Worded answers Likert-scale evaluation	First day of production in the morning
Character Quiz KAYLA	Slider bar marks retrieved as numbers Worded answers Likert-scale evaluation	First day of production during lunch
Character Quiz HEALER	Slider bar marks retrieved as numbers Worded answers Likert-scale evaluation	Second day of production in the morning
Character Quiz MOTHER	Slider bar marks retrieved as numbers Worded answers Likert-scale evaluation	Second day of production during lunch
Character Quiz	Slider bar marks retrieved as numbers Worded answers	Third day of production in the morning

SANDRA	Likert-scale evaluation	
Character Quiz Dr. WILLIAMS	Slider bar marks retrieved as numbers Worded answers Likert-scale evaluation	Third day of production during lunch
Character Quiz FATHER	Slider bar marks retrieved as numbers Worded answers Likert-scale evaluation	Forth day of production in the morning
Character Quiz Dr. ROBINSON	Slider bar marks retrieved as numbers Worded answers Likert-scale evaluation	Forth day of production in the morning
Video Interviews	Collected as direct audio-visual record Transcribed	During the production days
Video field notes:	Collected as a documentary audio-visual record	During the production days
Photographic record	Photographic record	During the production days
Film takes	Sections of scenes as filmed out of sequence - film takes	During the production days
Film	Completed film "*The Shadows of Hope*"	Postproduction

First day on the set, the students were introduced to the process of filling out the Character Quiz forms. This set of Quizzes includes a continuum based 'slider section where the measure of a statement can be marked, as well as a Likert-style scale section capturing degree of agreement or disagreement with the character's view, and also section for worded explanations (see Appendix D). The participants first filled one quiz for themselves, capturing their own opinions about NOS and, at the same time, they became familiar with the form they would use later for all the characters in the film.

Each production day was meticulously planned, broken down into scenes and shots (see Resources section C, the breakdown sheets). The characters that appeared in these scenes were

the characters for which the participants filled out quizzes that day. Thinking about those particular characters during the quiz completion helped guide their discussion and direction during filming. On day one of the production they filled out a Character Quiz for themselves & the main character Kayla, day two included scenes with the Healer & Mother, day three they reviewed Sandra & Dr. Williams and on day four Father & Dr. Robinson. The participants filled these Character Quizzes during lunch break or during any of the 'down times' throughout the production day that ran from 9:00 AM to 5:00PM.

The participants also received a set of questions intended for an on-camera interview as part of the behind the scene documentary. I prepared a list of questions (Appendix F) related to different areas of the filmmaking experience to capture extensive breath of experiences and opinions about the project. Time constrains would not allow all questions to be answered by all participants therefore students selected 5-6 questions from the list according to their interest. Students then participated in a filmed interview where they answered the self-selected questions. The choices of questions showed the particular student's inclination toward an area or issue they found interesting within the filmmaking project. The intention was to see impact of additional context; context that included a holistic look at the project and a personal description of the project for a perceived distant (external) audience.

The students' question choices and their answers helped to further validate this research (Moskal & Leydens, 2000) as it presented additional evidence illuminating the inferences that were made of student responses by the other types of data (Norris, 1997; Westen & Rosenthal, 2005). The process of answering the selected questions took part throughout the production phase. All of these data collecting efforts were focused on coordinating the students' thinking about the characters, film and cooperation within the team.

A traditional research approach attempts to detect any participant changes from (caused by) the program participation that is based on collecting data at two particular time intervals. Participants are evaluated at both the beginning of the project (pre-test) and after completing of the project (post-test) with the goal to examine the effect of the project on students' knowledge or views. Although there are known limits to this approach, this pre-post test approach is believed to measure changes in participant knowledge, attitudes, or behaviours regarding the program content (Colosi & Dunifon, 2005; University of Washington, 2010). This research project was not designed to use the traditional pre-post research construct as the main evaluation of changes in students' views and attitudes. In Chapter One I challenged the attitude of looking at knowledge as 'static' and therefore this research project was intentionally departing from an attitude of assessing 'correct' or 'incorrect' answers and focused on the dynamism of changes of views as related to the context. The data collected at the beginning of the project were not to establish pre-program 'static' knowledge but served to provide context-free views, meaning the views of students free of the influence of the context (the film story and its characters). Collecting data continually during the running of the project provided an opportunity to capture responses during a relatively short period of time, within a number of contexts. The collection of these sets of views represented *formations as they happened* and allowed the researcher to reach closer to the event that informed the ideas students created about NOS. This relative closeness to the context within which students' VNOS were created allowed examining the effect of context on students' views.

The structure of concurrent data collection allowed to assemble video and text based qualitative data, as well as quantitative data based on SUSSI survey (Chen, Adams, & Macklin, 2006) that test the levels of sophistication of student's VNOS. Simultaneously collected

correlated Character Quizzes allowed determining the consistency of students' views across different contexts and life situations, as demonstrated by the characters and happenings in the film story (Andrews et al., 2009; Johnson & Onwuegbuzie, 2004; Feilzer, 2009). During analysis, the intertwined data sets enabled a better understanding of the nuances of VNOS.

Data Analysis

A mixed methods approach within a convergent parallel design (Creswell & Clark, 2011; Creswell, 2008, 2009; Meissner, Creswell, & Klassen, 2011) requires collecting qualitative and quantitative data in parallel that this study satisfied as shown in the previous section. Mixed methods approach to analysis involves analysing quantitative and qualitative data separately and then attempt to merge, converge, and compare the results. The approach to analysis is what I will explain in this section.

Each set of data gathered during the research was evaluated in a way that respects the specific data type in search of finding a pattern that can indicate an answer to the research questions. Evaluative data and numerical data were used to find graph patterns and comparisons, while the texts reflecting students utterances were subjected to methods appropriate for qualitative analysis such as Discourse Analysis.

Discourse Analysis (DA) allows investigating 'discourse' as a particular way of talking about and understanding the world (or an aspect of the world). DA focuses on language and how language is structured according to different patterns that people's utterances follow when they take part in different domains of social life (Coffey & Atkinson, 1996; Jorgensen & Phillips, 2002; Macqueen, Mclellan, Kay, & Milstein, 1998; Norris, 1997; Roth, 2005; Shenton, 2004). Reviewing in-depth the collected texts and becoming thoroughly familiar with them, highlighting words or expressions related to understanding of NOS allows emergence of common themes that

provide further understanding of the group or individual (Coffey & Atkinson, 1996; Flick, 2014; Guest, MacQueen, & Namey, 2011; Macqueen et al., 1998; Roth, 2007, Saldana, 2013). Discourse Analysis was applied to the texts of the qualitative data of this research to search for patterns corresponding to the taxonomy of the SUSSI instrument (Appendix E). The linking and overlapping of data from both qualitative and quantitative perspective (Firestone, 1987; Guba & Lincoln, 2005; Hanson, 2008; Jick, 1979; Morgan, 2007; Oleinik, 2010; Strauss, n.d.) formed the basis of the findings of this study.

The merging, comparing and correlation of data during analysis shed light on the fluidity, flexibility and dynamism of VNOS, as well as on the benefits and disadvantages of each of the specific data set types. Finally, the analysis offers an insight into the level of usefulness of film production as an educational method. All data analysis was directed toward answering the research questions.

1. What is the pattern in students' understanding VNOS?
2. Is their VNOS changed within different contexts and situations?
3. How do different life situations (as simulated by the film) affect students' VNOS?
4. What is the range of VNOS each student creates/uses/demonstrates?
5. How do the qualitative results support/contradict the quantitative results?
6. In what ways did the film project influence the sophistication of student's VNOS?
7. How did the students respond to the experience of filmmaking?

The initial SUSSI questionnaire-based quantitative data were considered the 'spine' of the individual VNOS structure to allow connecting the SUSSI results to the quantitative sets from the context-based sets of quizzes. In order to reflect the corresponding questionnaire's content properly, the question domains of SUSSI were aligned with Character Quiz domains as

shown in Appendix J. By its nature, the SUSSI instrument is evaluative and assigns 'level of correctness' to each answer given; it uses this evaluation to arrive at overall description of students VNOS, namely 'naïve', 'transitional' and 'informed'. These descriptions reflect the SUSSI evaluation of students' VNOS like on an evaluation scale ranging from undesired positivistic that is called 'naïve' to desired constructivist called 'informed' (Chen, Adams, & Macklin, 2006). As I explained in Chapter One, the 'desirability' of particular 'correct' VNOS is currently the objective of NOS instruction with a variety of curricular attempts to 'improve' students' VNOS toward the correct view. Chapter one also explains the problems with this approach. Therefore, to focus on keeping the context-tracking Character Quiz neutral this researcher removed any sense of 'correct' or 'incorrect' from the form. There are no numbers or values hinted on the continuum scale providing the continuum slider bar with a neutral way to reflect individual's VNOS. However, in order to align SUSSI to Character Quiz the slider bar scale can be seen (only as an analysis approach) evaluative in the a manner similar to SUSSI.

The continuum-based Character Quizzes used a slider bar of constant length on which marks can be recorded reflecting student's VNOS on the topic (see Figure 1). The slider bar's extreme points were associated with positivistic (the left-most point), and constructivist (the right-most point) views. By marking a point on the bar, students indicated their view somewhere within this range and therefore the 'position' of the students' VNOS could be measured. By design, the closer to the left a students' mark was on the slider bar, the more positivistic view the student indicated.

To align SUSSI questionnaire to the Character Quiz self-assesment, I followed the SUSSI questionnaire's correctness scale to normalise SUSSI based quantitative data to the continuum slider bar scale. SUSSI evaluation of NOS correct answers is constructivist therefore an

evaluation point for a correct (constructivist) answer will be higher then incorrect (positivistic/naïve) answer. By assigning point value to the SUSSI correctness key (see Appendix E) and using simple normalization I could adjust values measured on different scales (of the SUSSI Questionnaire and Character Quiz) to a notionally common scale. I generated a set of quantitative SUSSI data normalized for the scale of the 'slider bar', and thus the data from the SUSSI questionnaire and the Character Quiz self-assessment could be compared. The practical steps taken to arrive to a common scale allowing comparison of the SUSSI questionnaire results and the initial continuum-based Character Quiz self-assessment are illustrated in Appendix H.

The influence of context on the students' VNOS was reflected in the Character Quiz by having students mark a continuum slider bar position for each NOS question and each film character separately. The students were asked to 'evaluate' the character's view of NOS. The collected mark positions created sets of data for 1) each character (e.g. context), 2) each student and 3) each NOS area.

The Character Quiz also included a Likert-style scale where students indicated their level of agreement or disagreement with the character's perceived view of NOS on a symmetric agree-disagree scale for a series of statements. The range (from 'strongly disagree' to 'strongly agree') reflects the intensity of students' feelings for a given NOS topic that allowed the study to capture the distinctions and variations of views that point to the underlying VNOS (I. E. Allen & Seaman, 2007; Carifio & Perla, 2007).

The individual student's VNOS represented by the pairing of a slider bar position and Likert data (i.e., level of agreement with a view represented by the slider bar mark), when compared across different contexts, resulted in a large variations of VNOS for each student; data tables in Appendix G illustrate this variation.

The qualitative data were subjected to Discourse Analysis (DA) that focuses on the language use in spoken conversation or written media (Coffey & Atkinson, 1996; Jorgensen & Phillips, 2002; Macqueen, Mclellan, Kay, & Milstein, 1998; Norris, 1997; Roth, 2005; Shenton, 2004). Here I analyzed the stories and self-explanation descriptions and utterances captured during the project via questionnaires, quizzes or video. The coding structure description, established for the SUSSI instrument (Chen, Adams, & Macklin, 2006) was used for the analysis of the qualitative data set (Appendix E). SUSSI description provided the accepted understanding of the NOS construct and helped to recognize the construct's features in the natural language of students' description of VNOS. Using specific NOS tenet helped to frame the analysed text and allowed to look for coded segments as simple as a word or phrase that the students used frequently to express a particular idea or experience.

Code-words or short phrases were highlighted as they were considered units of meaning that reflect a salient, essence-capturing, and/or evocative attribute for a portion of the analyzed text. I used two cycles of open thematic coding (Flick, 2014; Saldana 2013) to search for the themes that could explain and connect the students' explanations of the various NOS areas. As Saldana (2013) advises:

> The portion of data to be coded during First Cycle of open coding processes can range in magnitude from a single word to a full sentence to an entire page of text to a stream of moving images. In Second Cycle coding processes, the portions coded can be the exact same units, longer passages of text, and even a reconfiguration of the codes themselves developed thus far. Just as a title represents and captures a book or film or poem's primary content and essence, so does a code represent and capture a datum's primary content and essence. (p. 3)

The texts were coded in the first cycle in finer granularity; in the second cycle the codes were combined into larger thematic categories from which the theme could be identified. For example text such as:

> I think that scientific knowledge is transmitted from authority figures because they have the background and proof to confirm their statements of science to be true. If someone were to say something occurs because of something without anything to back it up, it would be unscientific (Jack Q.1 Q.1)

Shows the importance of "proof", "evidence" and notion of "truth" in respect of these utterances. Looking for continuous use of notions reflecting these ideas in all other texts allows to identify the similarity (i.e., expressions that point to similar understanding) as well as frequency in which these ideas re-appear and sequence if any; sometimes there is noticeable correspondence of ideas as they are expressed in relation to other ideas or topics under discussion (Saldana, 2013); additional examples of the coding flow used for analysis of the qualitative data collected during this study can be found in Appendix I.

The goal was to code the text in such a way that the information could be combined meaningfully with the quantitative data and infer accurately from the statement and its context what the intention of the speaker was. The text and utterances subjected to DA offered needed clarification of students' understandings, preferences and character evaluation delivering additional insights into the nuances of students' VNOS.

To maximize the benefits of the mixed method approach, I focused not only on comparison of quantitative and qualitative data but also on true merging of data from both sets (Firestone, 1987; Guba & Lincoln, 2005; Hanson, 2008; Jick, 1979; Morgan, 2007; Oleinik, 2010). The data analysis representations coming from on-set stories, argumentation or

questionnaires and quizzes merged in a form resembling a stochastic graph with a range of students' VNOS that captured the variety of possibilities the students themselves experienced during the filmmaking project.

The merging, comparing and correlation of data required by the mixed method research design provided responses to the research questions. The context sensitivity and dynamism of students' VNOS was revealed by the variations of individual VNOS, which reflected the contexts enlivened within the filmmaking process. The quantitative data sets for each student were compared for similarity and stability as described in detail in Chapter Four where I also explain how qualitative data sets through DA revealed the dominant theme for each student. Merging of the qualitative and quantitative data consisted of combining the quantitative data representing the students' view of the character with the students' agreement with the character and looking for a consistency within these parallels. The revealed dynamism of students' views is described in Chapter Four.

In the next section I will look at the issues of research quality and credibility to identify the strengths and weaknesses of this study.

Quality and Credibility

The credibility issue for research inquiry, as Patton (1999) advises, depends on techniques and methods for gathering high-quality data that are carefully analyzed, with attention to issues of validity, reliability, and triangulation. Due to the research components involved in this research project that include both quantitative and qualitative data, the conventional concepts of validity and reliability may not apply well (Aikenhead & Ryan, 1992; Norris, 1997; Patton, 2002) as the qualitative perspective focuses more on the trustworthiness and authenticity of data

(Erlandson, Harris, Skipper, & Allen, 1993; Norris, 1997) than on the consistency across constructs and measurements.

Reliability refers to the consistency of a measurement procedure and can be considered as an instrument's level of error relative to the variability of the values generated by the used questionnaires (Pasta & Suhr, 2006). Any measurement procedure will have some inconsistency. Reliability measures help to assess the level of these inconsistencies (Pasta & Suhr, 2006). Internal consistency reliability looks at the extent to which all the items that generated the studied data are behaving consistently across participants and is generally measured by Cronbach's Alpha coefficient. The SUSSI questionnaire reported Cronbach's Alpha between 0.67 and 0.61, depending on the country where the questionnaire was used (Chen et al., 2006; Liang et al., 2009). The use of SUSSI questionnaire in this study yielded Cronbach's Alpha of 0.60. This level of reliability is at the accepted threshold of satisfactory reliability (Cho & Kim, 2014; Pasta & Suhr, 2006).

SUSSI Questionnaire considers the target aspects of NOS inter-related, not independent of one another, therefore Chen et al. (2006) provided the overall Cronbach's Alpha for the SUSSI questionnaire. Calculations of the overall coefficient for the Character Quiz used in this study reached Cronbach's Alpha of 0.94, pointing to a solid internal consistency of the used questionnaire. The inter-connectedness of the targeted NOS aspects is an issue that might need further consideration; although we found a theme-related similarity of students' VNOS, their views on studied NOS constructs changed in different contexts. Looking at the data for individual NOS target areas in the Character quiz and calculating Cronbach's Alpha for each area separately, we found the coefficient falls between 0.70 and 0.86 indicating an acceptable level of the internal consistency of the Character quiz.

Validity as the degree to which a study accurately assesses a specific concept is concerned with the study's success and rigor at measuring what the researchers set out to measure (Moskal & Leydens, 2000). Although reliability can be calculated, and often established, validity is never proven beyond a reasonable doubt; poor reliability though severely limits the validity of the instrument (Pasta & Suhr, 2006). The accepted validity procedures related to qualitative research in respect of both, external and internal validity, were fundamentally incorporated into this study; this includes the study's design, multiple sources of data, acknowledging researcher lens, astute pattern recognition and analysis that is analytically rigorous, mentally replicable, and explicitly systematic (Mertens & McLaughlin, 1995; Patton, 1999) including the discussion of extent to which the results of this study are generalizable or transferable (Johnson, 1997; Norris, 1997; Shenton, 2004).

Validity and reliability are dependent on one another with reliability focused on the accuracy of the actual measuring instrument or procedure; appropriate 'reliability' practices, such as 'informant check' that allows to reveal the consistency of subject's answers by presenting the questions several times in varied forms and finding patterns among multiple sources of data (Lance & Vandenberg, 2009; Yin, 2003) were key part of this study's design as I discussed in the Data Collection and Analysis section above.

The multi-method approach to data collection and data analysis of this study allows for triangulation. The triangulation term used in research is derived from construction, surveying, and navigation at sea. The premise is based on the idea of using two known points to locate the position of an unknown third point, by forming a triangle (Britannica, 2000). The intent in research is to use two or more aspects of research to strengthen the design to increase the ability

to interpret the findings (Campbell & Fiske, 1959; Castro, Kellison, Boyd, & Kopak, 2010; Denzin, 1970; Harrits, 2011; Johnson, Onwuegbuzie, & Turner, 2007; Polit & Hungler, 1995).

The basic idea underpinning the concept of triangulation is that the phenomena under study can be understood best when approached with a variety or a combination of research methods. Triangulation is most commonly used in data collection and analysis techniques, but it also applies to sources of data. Questions that commonly arise in discussions of triangulation tend to address one of two concerns: the issues of using triangulation as a test of validity and reliability of research findings and the practical difficulties of using more than one method to study the same phenomenon (Johnson, 1997; Mertens & McLaughlin, 1995; Patton, 1999; Westen & Rosenthal, 2005).

Researchers strive to design studies that will not only give a multidimensional perspective of the phenomenon (Foster, 1997) but will also provide rich, unbiased data that can be interpreted with a comfortable degree of assurance (Breitmayer, Ayres, & Knafl, 1993; Jick, 1979). One of the goals of a researcher is to design a study that has strong internal and external validity and reliability (Lance & Vandenberg, 2009), a comprehensive multi-perspective view (Boyd, 2000), and procedures to decrease potential biases within the research (Mitchell, 1986; Shih, 1998). One way to increase the validity, strength, and interpretative potential of a study, decrease investigator biases, and provide multiple perspectives is to use methods involving triangulation (Denzin, 1970).

Triangulation techniques are helpful as the logic of triangulation is based on the argument that no single method can sufficiently explain possible competing explanations of the studied phenomena. Different methods can reveal different features of ‘reality’ therefore multiple methods of data collection and analysis can provide more comprehensive view of the studied

subject. In addition, each particular method can be vulnerable to a particular type of error linked to that method (e.g., loaded interview questions, biased or untrue responses) but with multiple methods the different types of data provide cross-data validity checks (Patton, 1999).

This study collected a variety of types of data as described in section Data Analysis; numerical sets of data reflecting the slider bar mark positions for different context, Likert-style data on a symmetric scale indicating level of agreement for a series of statements within varied contexts, worded answers with explanations for sets of statements and combinations of interviews and observations. Each data group was compared or set against one another (or groups of others) creating a number of combinations within which the data can be viewed or explained.

Following Patton's (1999) advice, I employed various types of triangulation such as the comparison of the SUSSI results with the continuum-based results and comparison of the quizzes' evaluations against the worded answers; these comparisons served as a 'methods triangulation,' i.e., checking out the consistency of findings generated by different data collection methods. I examined the consistency of different data sources within the same method, e.g. 'triangulation of sources' by comparing the sets of continuum-based quizzes related to different context and also by comparing these sets within different NOS topic. These sets of comparisons yielded additional insights by contrasting them with the Likert-style data as opposed to interview data. These results are reviewed in depth in the section of Findings where I approach the results interpretations from multiple perspectives to strengthen the conclusions by 'perspective triangulation' (Patton, 1999).

However, it is necessary to review a common misunderstanding within the notion of triangulation; that is that different data sources or inquiry approaches should produce effectively

the same result. As Patton (1999) appropriately points out it is important to test for such inconsistency and look for ways to understand it:

> Different kinds of data may yield somewhat different results because different types of inquiry are sensitive to different real world nuances. Thus, an understanding of inconsistencies in findings across different kinds of data can be illuminative. Finding such inconsistencies ought not be viewed as weakening the credibility of results, but rather as offering opportunities for deeper insight into the relationship between inquiry approach and the phenomenon under study. (p. 1193)

In fact, within this study the inconsistencies within the data sets revealed by triangulation yielded key insights into the dynamic nature of the students' VNOS.

In this chapter I have explained how I approached analysis of the collected data to maximise the benefits offered by the mixed methods; an approach where I analysed the quantitative and qualitative data separately and then attempted to merge, converge, and compare the results. I described how individual instruments enabled evaluation of students' VNOS and explained the process that allowed me to compare the data derived from the SUSSI questionnaire to the Character Quiz data. I have shown how moving away from an attempt to evaluate correctness of student's VNOS I could draw on the data sets from the Character Quizzes that provided variations of students' views reflecting the context in which the data were collected. I have explained that the context-based sets of different VNOS each student demonstrated may be described by a range within their VNOS. I addressed the qualitative Discourse Analysis and how it helped in understanding the data in a more profound way. Finally, I reviewed the issues of quality and credibility pertinent to this study.

In the next chapter I will show and discuss the results of different data sets comparisons and explain the emergence of the dynamic, context-related variability in students' VNOS.

CHAPTER FOUR: DISCOVERY

Addressing the research questions

The aim of this chapter is to reveal the experiences and NOS perceptions of the research participants considering the phenomenon explored. Data are organized and presented in relation to this inquiry's guiding questions: Can we find a pattern in students' understanding of science (VNOS) and if or how it changes within different contexts and situations? This chapter reveals how a practical approach to different life situations influenced student views. Further, the process of filmmaking is examined and how this process enabled an exploration of students' VNOS use in everyday life and how these views are in contrast to the 'school like' opinions revealed by the SUSSI questionnaire.

The collected data demonstrate an internal structure that was imposed by the particular method of data collection. Quantitative data, derived by an instrument based on an approval of a NOS statement, included an evaluative tendency. Patterns emerged only by comparing quantitative data sets and cross-referencing it with the qualitative data. I was surprised by the limits embedded in the quantitative data sets. Making sense of the data reveals internal variations and diversity within personal VNOS leading to questions regarding the level of consistency of an individual's personal view of science (Roth, 2005). Only thanks to the larger number of NOS accounts as gathered by the sets of quizzes during a reasonably limited period of time (two consecutive weeks) could patterns can be recognized and compared.

1. Ideas about science are not rigid: lack of common pattern to individual's VNOS.

Comparing data from the SUSSI instrument to the students' self-assessment through the Character Quiz revealed no stable common pattern to individual participants' VNOS. Both instruments attempted to capture students' VNOS before introducing the various contexts of the

film story. The students completed a SUSSI questionnaire and a self-reflecting Character Quiz at the beginning of the project to capture their general VNOS without reference to the contexts provided by the characters and film story during the filmmaking activity. Both of these questionnaires, the SUSSI questionnaire and the self-assessment through Character Quiz, were based on the NOS tenets and recorded students' personal VNOS in a relatively context-free situation.

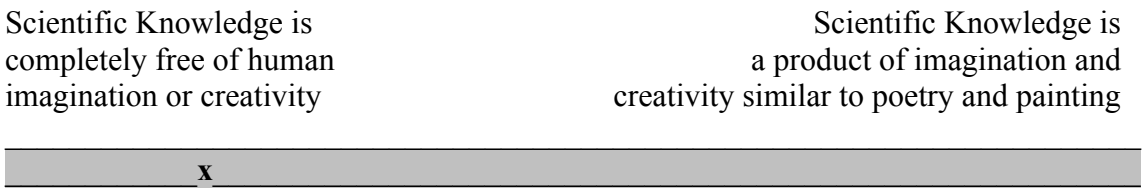
Considering that the two tests are internally reliable, as we discussed in previous section, how do we make sense of the lack of common pattern between the two instruments? There is a possibility that students may be unable to consistently self-report their views on nature of science if there is a lack of awareness of the goal or desirable outcome of the test (McCaig, 2007). The two questionnaires used in this study differ in the presentation of questions, where SUSSI by its wording and structure presents the topics as if there is a correct answer, while the Character Quiz form doesn't provide any indication of the desired outcome. The impact of this difference is further discussed in the following sections. The Character Quiz format may be more sensitive to the background context of students' everyday life then the SUSSI format. The self-assessment through the Character quiz data may be an expression of another context-bound outcome similar to the outcomes demonstrated for contexts provided by the film characters.

As reported in Chapter One, there is a number of VNOS tests, as well as ongoing development of new methods or revisions of old tests. However, no specific test has been demonstrated as the most effective model to assess students' VNOS. At the same time there is little attempt to correlate the varied tests and methods. The results of this study suggest there may be a need to examine inter-test reliability more carefully in educational research.

In this study I looked at the quantitative data of the two questionnaires that reflected each

student's answers to a particular NOS tenet and compared them. For example, if in the SUSSI questionnaire the student indicated that science doesn't involve any creativity, the corresponding answer in the self-Character Quiz should indicate a similar view in the form of a mark close to the left end of the slider bar (see *Figure 2)*

Figure 2: *VNOS continuum-based slider bar with marked view*



I expected some level of consistency within the quantitative data of the two sets of answers to each of the NOS topics (tenet) as both, the SUSSI questionnaire and the self-Character Quiz, reflected student's general or context-free (in respect of the film story) perspective on science.

Comparing the results of the SUSSI questionnaire and the self-Character Quiz, I found a varied resemblance within the quantitative data. There is a different range of variations for each topic of NOS and each student, as the NOS topics have limited internal relationships.

Considering the full continuum slider bar on which students marked their view as the maximum value of 100% we can conclude that the smaller the variation of students' VNOS the more consistent is their VNOS on particular NOS topic. Looking at the range within which the answers to each of the NOS topics fluctuated for the whole group of students, we can see large variations in the range of indicated students' VNOS. The minimum range of the differences between answers to SUSSI and self-Character Quiz for the studied group varies from 1% to 40%

of the slider bar scale; maximum range varies from 28% to 88%, and the average range varies from 15% to 65%; an overview of these variations can be found in the Appendix G.

Although these variations are large, they differ for each student and particular areas of NOS; some topics manifest larger variations than others. Looking at the distribution of minimal and maximal range in the VNOS students indicated in respect to the NOS questions, we can identify the areas of NOS in which the students' VNOS were most and least consistent (respectively); the questions regarding the empirical character of science, scientific method and change in science tend to have smaller variation where 54% (6 out of 11) of the students had minimum variations in that category. On the other hand, the answers to questions regarding the source of scientific knowledge and relationship between science and culture appear to be the least consistent; for this NOS topic, 36% (4 out of 11) of students had maximum variation, and no student had a minimum variation.

The variation indicates how consistently the students hold their VNOS view across varied topics and contexts. Although the quantitative data on its own appear to point out the areas of the NOS that can be considered most problematic for students to understand or comprehend, there is a need to bring into the analysis new dimensions that would help understand the lack of consistency within the students' VNOS. The quantitative evaluation of the NOS patterns indicates that additional information is needed to understand the quantitative data thoroughly and identify the phenomena influencing students' VNOS.

A pattern of VNOS for each student appears only upon the qualitative analysis of the worded answers (Wiggins, 2011). This pattern is reflective of the particular NOS question, as each question covers an area within the tenet topic of NOS; this naturally offers a range of points and perspectives. The answers students offered in one situation address a particular point that

was not necessarily the same point answered in the next quiz, as new situations bring different issues into focus. It is therefore problematic to use an evaluative attitude to issues of NOS. Not only is a 'correct answer' difficult to come by as we discussed in Chapter I, but also the view may vary depending on the context (including the student's current life situation).

For example, James demonstrates this variation well with his answers to questions about the creative side of NOS. Answering to the relevant SUSSI question, he says: "scientists should not be able to use their imagination too much. I feel creativity and imagination can be considered through data collection. However, any sort of bias through interpretation may create un-reliable conclusions." In his response to the self-Character Quiz question he states: "I feel scientific knowledge is incredibly creative. Without creativity, a large portion of scientific knowledge would not have been discovered. A lot of discovery occurs from just creatively experimenting." The quantitative evaluative approach of the SUSSI instrument evaluates his answer as 'naïve' while his understanding, based on his additional answers from the Character Quizzes would be evaluated as 'informed.' Clearly James's answers would belong to opposite categories; on one hand, science doesn't need imagination, actually it is even considered detrimental to 'good' science. On the other hand, science depends on creativity and imagination. It is this type of contradiction that has the potential to skew the quantitative evaluation of the answers resulting in insufficient similarity of NOS patterns and large variations of the opinion range.

Including the worded descriptions in the data analysis brings out the nuances of James's understanding of the role imagination has in science. We can see he is able to relate to or recognize the difference between discovery and justification in science. James requires "not to use their imagination too much" through the stage of justification, while within the context of discovery he recognizes the importance of imagination and chance.

Comparing the quantitative data of students' answers to the qualitative showed similar inconsistency within their answers, while uncovering the guiding themes that influenced each student's understanding of the presented NOS issues in their responses to the NOS questions. Identifying these themes was instrumental to recognizing the pattern of their VNOS.

2. Individual's view of science exhibit a central theme.

The pattern of individual's VNOS appears centred on one prevalent statement or theme e.g., 'science is a fact.' All other answers within the topics of NOS more or less follow that theme. It is possible to recognize the tendency toward the self-storying attitude as discussed in Chapter Two. The self-storying approach follows a logical reasoning of this type: "If *I* think that science is a fact then all scientists *have to* see the experiments in the same way to discover this fact." Such tendency is clearly recognizable from Aubrey's answers.

Aubrey's main theme in pondering the questions of NOS is the idea of 'fact.' Her answers reflect her attitude that "science is based on fact" and therefore there is really not much to discuss. As the questions about NOS were repeated within different contexts, her answers sometimes include the words "again, it's a fact." Within the 64 possibilities available to her, she made statements for 34 (53%) of them with 13 (38%) of her statements including reference to "fact." For Aubrey who let us know she doesn't particularly like science and was not enthusiastic filling the quizzes, her references to "fact" come across as a persistent feature of her attitude toward science. She is not alone; Caleb who is an art-oriented student presents a very similar view with 43% of his answers mentioning "fact" and "theory is just a theory." The questionnaire and quiz data show that students do think about the influences of an individual, society, culture and time on scientific knowledge, but the idea of 'fact' is prevalent among the students as four out of ten students (40%) leaned toward description of science through 'fact.'

Aubrey's responses so closely and clearly linked with the idea of 'fact' indicate that her VNOS is naïve, but the SUSSI questionnaire evaluation of her VNOS shows her as having mostly (4 out of 6) 'informed' view. This is possibly the result of the very simple sentence structure of the SUSSI instrument questions that could limit capturing the underlying subtlety of student's understanding of the NOS topics. It may as well call into question the instruments' validity. SUSSI instrument was designed to measure student's VNOS (Liang et al., 2009) but it may be more suited to measuring the level of acceptance or knowledge of particular teaching outcomes; this possibility is discussed in the next chapter.

Table 5

Prevalent themes in NOS descriptions

Student	Theme	# of answers	Theme related	%
Ethan	pure knowledge; should	48	23	48%
Layla	intertwined; middle ground	64	25	39%
Ella	constant, objective; data-based	64	25	39%
Emma	*not established*; undecided in 78%	64	n/a	n/a
Caleb	fact, proof, 'just' a theory	46	20	43%
Aubrey	fact	35	13	37%
James	*not established*	64	n/a	n/a
Jack	proper evidence, tested & proven, fact	64	29	45%
Mike	true, observation, data, fact	37	13	35%
Alexander	equipment, proven, repeatable, tested, valid	32	15	47%
Ryan	*not enough data*	n/a	n/a	n/a

Most students (80%) leaned toward a theme that influences their VNOS (see Table 5) and this 'defines' in a particular way their response to other NOS questions. For Ethan, his idea of

"pure knowledge" tilts 47% of his answers toward what "should" be done when doing science; Layla, despite her conception of "definitive proof" in science, holds tightly to the 'middle ground' and in 39% of her worded answers uses the words "both" or "intertwined" to describe the relationships within the discussed domains of NOS.

Maturity may have an effect on student's confidence in evaluating different VNOS. For example, Emma, a Grade 9 student, clearly understood the characters but she was mostly (78%) "undecided" in evaluating the characters' views and withholds agreement even when the character's view (in Emma's opinion) is matching hers. In contrast Layla, a Grade 11 student, was easy to give her opinion of the characters' views and would choose "undecided" only in 6 % of answers.

Recognizing the themes within the data was instrumental to the understanding of the answers from both the SUSSI questionnaire and the Character Quizzes Students showed a tendency to express their view of the character's attitude toward science in the Character Quizzes as briefly as possible, limiting the amount of writing needed; they tended to skip underlying explanations to each question, sometimes rendering their answer (when considered without context to the bulk of their other answers) incomplete or seemingly misplaced. Themes became apparent, however, thanks to the number of questionnaires and quizzes (9) the students filled out as the nuances of their VNOS were embedded in their word choices as they repetitively described a particular NOS topic.

3. Changing context dynamically reshapes individual's VNOS.

The pattern of student's VNOS changed dramatically depending on a particular context. During the project students were immersed into 'creating' different personalities of the characters within the story of the film. Every day of production required them to fill in and

answer the Character Quiz ‘for’ or ‘on behalf of’ each character and then, stepping out of the role of the character, students indicated if and how much they agree with that character’s view. These sets of answers allowed the exploration of student’s reaction to context and changes in their own VNOS due to this context.

It can be seen from student’s evaluative answers that they may strongly agree with an character’s attitude or action, even though they strongly disagree with the character’s VNOS; the students oppose the character’s attitude toward science but they approve of or agree with an action based on such attitude. This is a seemingly absurd result.

Ella demonstrates this situation well. Her responses according to the SUSSI evaluation belong into the ‘naïve’ or ‘transitional’ category. She also agrees most often with the character of Dr. Robinson, who has a strict view of science as a rigorous discipline. That is consistent with her opinions. It is therefore not surprising that she most often disagrees with the character of Healer. On the other hand, she finds it logical and reasonable that the character of Mother chooses the Healer’s services to solve the problem at hand, and names Mother as the character she understands and likes the most. It is reasonable to expect that Ella would take a similar action as the character of Mother, should she find herself in the same situation (as Mother), regardless of Ella’s naïve VNOS. This indicates that students can hold completely contradictory VNOS simultaneously.

Layla demonstrated a good grasp of the issues and a mostly informed VNOS according to the SUSSI questionnaires, yet within the film context she most often agreed with the character of the Healer and most often disagreed with the character of Dr. Robinson. In Layla’s case, it is obvious from her continuum-based Character Quizzes that she avoids extremes; the responses she identifies with were within the middle of the slider bar scale indicating she opts for

intertwined and combined influences of positivistic and constructivist views allowing her to accept VNOS and approach on the level of the Healer character.

James's responses indicate that he most often disagrees with the character of Dr. Robinson, but it is this character that he describes as the one that is closest to his own opinions. All students demonstrated shifting of their ideas under the influence of the film story and characters. This is evidence that there is a noticeable impact of the context within which the students applied their VNOS, and that a change of context can significantly alter their previously documented VNOS.

The data form the sets of Character Quizzes show that students' VNOS are constantly changing, unstable, plastic and continually forming under the influence of context. The vast literature into learning and teaching NOS as described in studies and meta-studies focuses on a myriad of topics inherent to the subject of NOS (Deng, Chen, Tsai, & Chai, 2011), on the best methods of educational approach (Clough, 2006) and the problems and benefits of varied forms of delivery (Lorsbach & Tobin, 2005; Taber, 2014) including multidirectional approaches (Loyens & Gijbels, 2008), all to identify the best ways to affect, change and improve students VNOS; no studies, however, explored the concurrent dynamism of VNOS formation as revealed in this research.

Data from student participation in filmmaking revealed that students were able to almost simultaneously hold several very different, sometimes opposing and contradictory VNOS. This situation is described by the theory of cognitive dissonance as a state of interior unpleasant tension due to the simultaneous presence of two cognitions that are psychologically inconsistent (Elliott, Hufton, Willis, & Illushin, 2005; Graesser & Mello, 2012; Ramachandran, 2012; Simonson, 1977; Walton, 2011). According to the theory, this "cognitive dissonance" is

supposed to lead a person to modify one of the two cognitions to restore consonance (Bourdieu & Passeron, 1977; Ramachandran, 2012). Surprisingly, the students didn't show awareness of any dissonance within the set of their personal VNOS. They were seemingly comfortable with their concurrent contradictory VNOS and they didn't reveal or react to possible unpleasant tensions within these views. They experienced the dissonance of their personal VNOS, but it didn't bother them; they didn't care or even know about it. What they did react to was the dissonance they experienced between the 'school science' and every day practical application of science that is discussed in the next section.

4. School science generates a culture with its own context.

The SUSSI instrument reveals that school environment creates its own context, a particular perspective in which subjects are studied. Students strive to recognize what 'the teacher wants to hear,' and attempt to give 'the correct answer' within this context (Chabrak & Craig, 2013). When faced with everyday life situations, students can have very different views as the incongruity of students' SUSSI answers and context-based film Character Quizzes reveal. Within the variety of contexts presented in the film the underlying 'real' opinion about science came out, and discrepancies between the 'school knowledge' and practical applications of science were revealed.

The SUSSI instrument is based on sets of statements. In their responses, students mark the level of agreement with each statement. These SUSSI statements are short, simple, well structured and easy to understand. The students answered these questions at the very beginning of the project, before they learned anything about the film and its story. Students filled in the questionnaire 'like at school'; sitting in a classroom, all together as a group and at the same time

and needed to be reminded this is not a test. The difference of students' views when compared with their work 'for the film' is clearly visible from their answers.

The SUSSI questions are structured in a way similar to what students might expect in a typical school test. Layla and James were both able to answer the SUSSI questions 'correctly' but their everyday application of NOS ideas strayed away from the SUSSI instrument's 'school-like' answers. Layla realized the discrepancy between her views of school science and everyday life and expressed her opinion that, "the science community is very contradicting with itself and [uh] it's different from the way we learned science in school because it tells me straight forward and there's no (other) possibility … cuz we always do more textbook stuff theories and not the way we learned it in this film."

The juxtaposition of 'school science' versus everyday life application of scientific knowledge created a situation where students realized that school science presents a simplified, ideal view of science. Students reacted to the discrepancy and showed behaviour that suggests they experienced cognitive dissonance.

When experiencing cognitive dissonance one can respond in several ways from modifying cognition to cope with new facts to avoidance process or selecting appropriate information and changing behaviour or values by looking to new facts to restore coherence (Chabrak & Craig, 2013). Here we need to consider cognitive dissonance in the context of an education system. Students with their beliefs and personal attitudes that have been acquired throughout life are incorporated into an education system that has an assumed designation to pass on knowledge, skills and qualifications to them within a 'social contract.' Students generally acknowledge this 'social contract'; they accept the legitimacy and the authority of pedagogic

actions that condition their perceptions and mental schemes. They transfer their respect (as disciples) to the education authority (as master) (Bourdieu & Passeron, 1977).

What students learn at school might or might not be in harmony with their personal values so there may be tensions, leading to a possible cognitive dissonance. Chabrak and Craig (2013) point out that dissonance within the education system

> is resolved mostly by espousing generally allowable attitudes. Hence, the role of credentials (good grades, a graduation diploma etc.) is to render students less conscious of how they internalize objective structures. Students are unaware of the gap between what they think and what they are taught; and between their personal values and the authority discourse expected of them — parroting ideologically sound responses when prompted to do so. (p. 93).

From the perspective of school this gap *seems* to be resolved, but actually is <u>not</u> as we can see from students' responses during this project, it's only <u>accommodated</u>.

The filmmaking project removed the need to conform to expected answers and illuminated the gap between what the students think in everyday life situation and the theories they learned at school. The students expressed this realization; for example Mike shared that, "in school we learn based on textbooks and like what the teachers are told to teach us" and James agrees with him: "well of course what we learn in school is like that … but, yeah, just learned that there are many scientific perspectives, opinions that factor into research and knowledge."

The student's reactions and answers indicate that they reacted to the cognitive dissonance of the discrepancy between 'school science' versus 'everyday life science' by adopting more fitting and useful view of the information received at school. The students discovered that school provides a simplified version of NOS that may not always reflect the everyday life accurately.

By realizing the diversity of NOS views they and others hold, the students' capability to account for contexts other than school was possibly enhanced, which in turn could expand their understanding of the NOS.

5. Filmmaking actualizes an environment to experience the uncertainty of using science in the everyday world.

The students realized that at school they learn 'ideal' situations that rarely reflect the everyday life. Students' comments show their reactions to situations where they had to take action based on incomplete information. These reactions ranged from pure hope, like Jack, to sticking firmly with scientific advice, like Alexander.

Through the discussion about what might be the participants' course of action Jack explained that he, "would most likely consider definitely the procedure … I mean regardless of whether or not it has any conclusive evidence of if this will work or not work it's still a shot, I mean," while Alexander said: " I'm kind of pessimistic so I would probably, if there was no real proof that like this therapy would help I would probably end up avoiding it."

Student's answers revealed their search for an authority they can trust the most. There is a key reference to "they" in the students' discussions. Students referred by "they" to the scientific community but when students reflected on whom to trust, they referred to a particular person (or character) by name. Students also tried to evaluate their chosen advisor (or the one to trust) based on an emotional attachment. Alexander expressed his need to, "figure out how to do this [the decision]... like what my parents would think… probably more my dad than what my mom would think." Layla expressed the same attitude within the role of a character and named the character of Terri as the most trustworthy, "because she's kind closer to the family because isn't Terri the mom's friend? I think I might be going with Terri because she's closer and I might trust

her more and her husband got better due to it so there's a closer relation than Mr. Robinson [the scientist]."

Through the film's story students faced uncertainty and reacted to this uncertainty by accepting anecdotal evidence for the solution, often arguing for a 'trial and error' action with the understanding of the possible sacrifice for future generations. Emma explained that, "instead of just sit there and wait for it to end I'd rather try and find the cure or try and help people in like next generations to have a cure or something;" James explained, "cuz I, I'd want more than just like liberation therapy that's not that proven, I'd wanna be part of bigger research even if it doesn't help me it may help somebody else" and Caleb added: "because even if it doesn't help me it would still provide research for future MS victims, so I think that would be helpful."

The students also came to realize that science 'exists' in a much wider context than they previously considered. Ella reacted to the impact of media when she said: "I realized that the therapy is actually sometimes different from what it is portrayed in media and to public and sometimes it [is] just portrayed in advertisements as a good therapy and it always shows as the like good sides of it but in actual science it feel there's a lot of contradictions and problems with it." The inaccuracy of reporting on scientific results is captured by Jack, "well, one thing I learned that the scientific community typically conflicts with it," and Layla added, "I agree with Jack, its just that the science community is very contradicting with itself."

The issue of uncertainty within science took the form of 'contradictions in science' during the students' discussions. They tended to separate the 'science we know' as, for example, the science they learn at school and 'research stage science.' Mike noted that, "at school we learn from textbooks …but in the film its very research stage, the doctors have very different opinions on it as well as factual parents … everyone is opened to everything, so it sort of contradicts

itself," and Layla added, "in school … it tells me straight forward and there is no [other] possibility … and in this film its more in the research stage and its more, more opinionated." These views indicate that the students attempted to come to terms with complexity and uncertainty of science in everyday life while still holding onto the idea of simple, clear and certain 'school science.'

Students experienced the complexity of the ideas within the working scientists' world and reacted to it in their discussions. Aubrey observed that and said: "I've learned that science is like you come to conclusions in a group setting and you don't [do it] alone it's not just one scientist like just coming up with theories and proving them by himself and a lot of things can factor into it" and James added: "yeah [I] just learned that there are many scientific perspectives [and] opinions that factor to research and knowledge." Ethan, who realized this complexity, still felt that regardless of the fact that "science is a lot of perspectives … but there's kind of two main views … there's true and false…with Terri Williams and Dr Robinson how she said that it's been really proven but he said that it hasn't, so is it proven, is it not, true or false? Two different perspectives … other than that there's a lot of views, lot of other opinions from other scientists," which is consistent with his general VNOS expressed in his questionnaire and quizzes. He looks for the clear separation of 'true', 'false' and 'maybe.' He is not alone; some students agreed, like Caleb, who claimed that, "there's not really a grey area when it comes to science."

Layla reflected in discussion to the complexity of decision making that, "we should be more critical of what we are presented to because like in [the case of] Kayla's mom, she's presented with so many opinions and she has to make her own and criticize others opinions too to see what she actually wants for herself."

Students' views indicate that filmmaking successfully simulated realistic events and realistic possibilities of everyday life, brought out the practical complexities of decision-making based on incomplete information, and allowed for the experience of taking responsibility for action while facing uncertainty. Facing this uncertainly encouraged students to develop a more sophisticated VNOS. By exploring the diversity of contexts and situations through the film characters, students arrived at an understanding of a multiplicity of concurrent VNOS. This experience shattered the simplistic, monolithic view of science often presented by school and society (Clough, 2006), and allowed for a more accurate and advanced exploration of science in everyday context; filmmaking enabled a multileveled deepening and expanding of students' understanding of the NOS that is the essential support to creating more sophisticated and mature VNOS.

6. Mixed method approach exposes dynamism and complexity of students' VNOS.

The mixed method approach used in this study was essential for showing the complexity of the issues that were examined. Each instrument provided evidence to statements that, without collaboration, would fail to show the dynamic nature of student's VNOS and possibly be seen as contradictory or meaningless. For example, Ethan's evaluation of his own view of empirical nature of scientific knowledge in numerical form was 65; he evaluated film character Sandra's view at 165, which is almost at the opposite end of the evaluation scale, but at the same time, he agreed with her view! The qualitative descriptions reveal that Ethan "follow[s] the school way of science;" he sees Sandra as a person who tries to do the same even though within the context of the film story she supports action based on non-scientific belief that provides no proof. Similar kind of 'inconsistencies,' sometimes extreme, are prevalent in students' responses as discussed in

previous sections. The different types of data not only revealed these ‘inconsistencies’ but also provided a possibility to analyze and understand them.

The impact of the particular context is clearly identifiable. Supported by data from the set of ten questionnaires and quizzes (for each student) that differ in context in which each quiz was filled, the concurrent differences in students’ VNOS are highlighted delivering the understanding of the embedded dynamism, plasticity and complexity of personal VNOS. By combining both quantitative and qualitative data and results the stochastic, context-based nature of VNOS could be revealed. The data tables in Appendix G provide further information and examples of the variations in students VNOS as influenced by the varied contexts simulated by the film story.

The quantitative data revealed in numerical form the decisions and evaluations students were making about themselves and about the variety of characters and their actions in the film. The qualitative data clarified the context within which that evaluation happened. Comparing the contexts and the evaluations within this data served to identify the ranges of VNOS each student demonstrated. The diverse array of VNOS is the evidence that students’ VNOS are dynamic as they change with context.

The qualitative data were essential to shed light on the underlying personal guiding theme the students demonstrated, which in turn enabled clarification of the stochastic quantitative data ranges as discussed in the sections above.

In conclusion, the findings were arrived to through quantitative and qualitative data merging and comparison; this approach was the major source of discovering the fluidity and complexity of students’ VNOS. Without reference to varied sources of data, the individual quantitative or qualitative results considered separately present an impoverished and possibly inaccurate view of this complexity.

In this chapter I looked at the findings as they relate to the research project's guiding questions: Can we find a pattern in students' views of nature of science (VNOS) and if or how the view changes within different contexts and situations? I have shown that although the pattern of students' VNOS before the project as measured by the two data collection tools (SUSSI and Character Quiz) was inconsistent, I could trace a central theme embedded in students' VNOS. I have shown that contexts, as simulated by the filming project, have impact on individual VNOS. I discussed how the data reveal that 'school science' represents its own context and may be at odds with everyday life. I have shown how the filmmaking activity actualized an environment for students to experience deeply the uncertainty of using science in everyday life where the answers to problems and potential solutions are not so simple and clear cut as in the ideal world presented by school. Finally I discussed the benefits of using mixed methods and how it helped to inform the findings of this project.

In the next chapter I will discuss the conclusions arising from this research project and the implications of the findings. I will further expand the discussion arising from the research outcomes and its consequences in connection to the prevalent view of teaching and learning VNOS.

CHAPTER FIVE: CONCLUSIONS

This research project asked how a filmmaking project might influence high-school students' view of nature of science (VNOS). This study also asked if and how their VNOS varied with different contexts created by a film story. Keeping in mind that this was only one (and first) small-scale research project involving initially twelve students, the results of the study suggest that through participation in a filmmaking project, students' views considerably expanded and diversified. Results also indicate that students' understanding of NOS became deeper and more sophisticated with increased maturity of the views via exploration of science in a particular situation. This study also demonstrates that filmmaking can be employed as a productive way of teaching NOS.

The diversity and dynamism of students VNOS was revealed by the results of context-based questionnaires and quizzes reveals that students hold a large coexisting variety of VNOS; these views were the result of problem solving in different contexts. The students didn't seem bothered or discomforted by the inconsistencies of their views; instead, students found their views reasonable and natural; to these students, their views were not incongruent VNOS since each seemed to relate to different context. It follows that even though not all possible contexts can be covered, with every new possible context the students may encounter, new modifications of their views may arise; this demonstrated sensitivity to context exposes the dynamism of students' VNOS. Students' responses show that environment of a film production is capable of bringing science-based problems to life and highlighted the limitations of 'school-science' in encouraging mature views of the NOS.

These results conflict with the underlying principles of constructivist teaching theory that argues that cognitive dissonance (Aronson, 1997; Festinger, 1957, 1962; Krause, 1972) is

necessary to arrive at conceptual change (Baviskar, Hartle, & Whitney, 2009; Hartle et al., 2012; Thomas, Menon, Boruff, Rodriguez, & Ahmed, 2014). I suggest there is a need to reconsider this principle and to include cognitive diversity approach in education. Data from student interviews revealed that their concurrent diversity of views didn't create any discomfort, which challenges the view that a 'dissonance' is needed in order to learn and expand knowledge and understanding. Given this discovery, science educators may need to change the 'flat' view of the learning process and consider process that includes the influence of contexts and cognitive diversity. I offer and discuss *cognitive contextual expansion* as a process of learning that allows for dynamism of views, supports testing of multiple everyday life contexts' influence on students knowledge and VNOS in support of deepening and maturing of students' learning.

It was the film environment in particular that altered students' perception of the learning environment, especially their focus was on the film as it shifted their attention to the actions, situations and consequences that influenced the film characters. The students did not notice that their own views dynamically modified with the context as well; this reveals that students' understanding of NOS is reflected in the process-oriented interaction between the character and the environment and that this understanding constantly changes and adapts to new situations. Film has a capacity to compress a large number of contexts that can be sometimes even unrelated. Each character has its own history that presents numerous contexts, the story has its own context, and so does the problem featured in the film. All of this demands to be considered by the film production team in order to re-create the story in the film; as contexts clash and support the plot of the film, the team must consider the implications, course of actions and viability of solutions for each character in the film. Though other methods, particularly drama in school, provides similar opportunities for reflection (Booth, 2005; Miller & Saxton, 2011;

Wieringa, Maples, et al., 2011; Wieringa, Swart, et al., 2011) these methods will be hard pressed in comparison to the intensity and saturation of ideas and actions natural to filmmaking due to the condensation of reflections and learning into short periods of time. Filmmaking may present a valuable tool to allow *cognitive contextual expansion* of students' VNOS providing deeper, more mature, sophisticated and usable views that steer students toward informed decision-making, foresight and diligence. The shared nature of language and the necessity of cooperation in society are well simulated within the filmmaking setting. The opportunity to engage with film and connect to the community of filmmakers allowed students to take part in authentic professional tasks; tasks that are involved in the process of making movies. This filmmaking project shows that as students start to understand the "… processes that experts use to handle complex tasks" (Collins, Brown, & Newman, 1989, p. 457) they begin to join in that community of expertise and attempt to solve problems as experts might. This "… ability to understand the master's performance depends on engaging in the performance in congruent ways," suggesting, "… if learning is about increased access to performance, then the way to maximize learning is to perform, not to talk about it" (Lave & Wenger, 1991, p. 21). Students expressed that they felt proud to perform, i.e., to work and complete the same tasks with the same expectations as an expert, in a 'professional capacity' on a team where they felt equal to one another. The project serves as an example of "celebration of learning through the creative process of filmmaking" (Crichton, 2002, p. 2).

Based on the number of benefits and advantages for learning NOS that I explored in this study, I show that filmmaking offers complex but viable pedagogical tool that can provide a comprehensive and in-depth exploration of the issues of NOS. The questions of NOS are important to explore but it proves problematic to facilitate such exploration in an individual

classroom. Using filmmaking brings the studied issues into a highly cooperative environment possibly connecting across curricula variety of teachers, school subjects, students and professionals within an activity that truly connects learning to everyday life and school to the community. This filmmaking inquiry demonstrated the complex manner in which philosophy of science via students' VNOS is practically used in everyday life.

Implications: Exploring the tensions

This inquiry explored a new way of looking at NOS and with it at the dynamic and context-based way students modify their VNOS. In order to enable controlled access to this complex behaviour a unique, never before used approach of filmmaking was adopted and tested. The findings exposed tensions and additional insights that I will explore in this section that is organized according to the major areas or themes this research project focused on.

VNOS & diversity.

In Chapter One I reviewed the struggles within the science and philosophy communities to arrive to some 'agreed to' philosophical stance on the questions of NOS, finding that no such complete theory exists. The educational community aligns itself mostly with particular set of NOS views (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) that is based on the static view of NOS as I discussed in Chapter One. I have also shown in the chapter that the classroom delivery of the NOS subject is facing additional obstacles in the form of teachers' education, their willingness to cover the topic in depth as well as lack of time and efficient methods of classroom delivery of the subject. The research consistently reports students have simplistic, immature and insufficient views of NOS and shows that little progress has been made in finding pedagogical methods that are successful in deepening and expanding students' VNOS.

This research project explored the dynamic and context-dependent development of students' VNOS and the benefits of the flexibility this exploration provides for students' VNOS. One must ask how to address this situation in educational setting fairly and accurately.

The project highlighted that students seem not to adhere to one particular view but tend to have a concurrent *mixture* of VNOS. It was clearly indicated by a wide range of their acceptable usable VNOS in the research data. Is this the result of lack of knowledge or ignorance allowing keeping inconsistent or incommensurable VNOS? We might explore this paradox by examining the issue of diversity.

In this section I will therefore look at the traditional understanding of diversity and how 'identity diversity' translates to 'cognitive diversity'. I will explain the current trend of using diversity through a 'wise crowd' in solving complex problems. I will point to the strength of the diversity prediction theorem including examples. Shifting the idea of a diverse crowd into the sphere of a single cognitive mind, I will expand the idea of an individual's cognitive diversity through the explanation of the 'many-model thinker' and a 'T-shaped student' as the goal of developing an efficient and inspired problem solver. Finally I'll show the similarity between a cognitive diversity of the many-model thinker and the concurrent multiplicity of students' VNOS demonstrated in this research, and I will argue that the expansion of student's cognitive diversity may be a desirable outcome when teaching NOS.

When we talk about diversity, particularly in the Canadian context, we usually talk about identity diversity; diversity in the sense of the variety of where people come from or how they look; culture, race, ethnicity, gender etc. There is a rising support to diversity in the scientific realm because it promotes efficiency, innovation, robustness and ingenuity in solving problems (Miller & Page, 2010; Page, 2008). It is important to realize that we do not solve problems with

identities alone but by thinking and reasoning. Even though our identities form the ground of our way of thinking, it is essential to highlight the importance of cognitive diversity when one person cultivates many cognitive models. Cognitive diversity allows for differences in *how* we think; it is what allows a person to address specific problems from more points of view, each entirely different. Cognitive diversity including *perspectives*, the way in which we encode problems; *heuristics*, the cognitive tools we use to solve problems; *categories*, the ways in which we parse the world into similar things and *models*, ways how we think about causal relationships allow to arrive to a larger set of possible solutions (Page, 2012).

Originally, cognitive diversity was thought of as a sort of specialization, where one could have many models for one specialized area. Specialists were seen to learn faster (in the area of their specialization) and being more productive in that area then lay people. But in this model, specialization led to isolation. Specialists had diverse skills but the specialized groups tended to not interact directly with one another; reflection of this separation is in the common expressions of 'knowledge silos' or 'towers' to describe the extensive separation of highly specialized thinkers (Bundred, 2006; Lomawaima, 2014). This is a characteristic of professionals until today as education (including higher education) is producing I-shaped graduates, or students with deep disciplinary knowledge, but limited in respect of cross-disciplinary knowledge or experience (Lomawaima, 2014; Page, 2012; University, Minesota, 2012). Page (2007), Howe (2008), Lamberson & Page (2012) and others show that modern cognitive specialization relies on direct interaction, hence the rise of team-based work, using the 'wisdom of the crowds' or 'group-think' (Bell, Koren & Volinsky 2010; Hong & Page, 2004; Howe, 2008; Lamberson & Page,

2011; Page, 2008). The 'diversity prediction theorem'[4] (Page, 2012) strengthens the case for the benefits of diversity mathematically by using a statistical approach to computing prediction accuracy. A number of documented examples show that diverse ways of thinking can contribute to the ability to make accurate predictions, create better models and arrive to solutions to complex problems (Bell, Koren & Volinsky 2010; Page, 2010a; Page, 2012; Suroweicki, 2005)

People generally make different predictions because they grew up creating different conceptual models of how the world works. There is a tendency to base one's predictions on what one knows; diverse 'crowd' includes number of individuals whose idiosyncratic errors are equally likely to be high or low; in some crowds these errors of individual allow to cancel each other leading to a 'wise crowd' (Page, 2012). Groups of people will always demonstrate diversity because each person will likely have at least one model to work with therefore the group size affects the diversity and improves collective predictions; still in too large a group problems in communication may break the possibilities to come up with solutions therefore not every diverse group will make a 'wise crowd.' When working with individuals with diverse cognitive models the diversity of the group's predictions increase. The diversity theorem shows that the ability of crowds to make accurate collective prediction (or propose good solution to a problem) depends in equal measure on the 'crowds ability' and the diversity of their predictions.

It follows that the group diversity benefits translate to individual person's benefits if he/she is able to develop a higher cognitive diversity using knowledge and patterns of thinking based on different models. The 'many-model thinker', i.e., person with a higher cognitive diversity, has a problem solving advantage to a person who understands only one big idea or one model to understand or solve problems (Lamberson & Page, 2011; Page, 2010a). People with

[4] A full examination of the implications of this theorem lies outside the scope of this dissertation, the theorem is mentioned here to illustrate support for the importance of diversity

higher individual cognitive diversity may have more sophisticated grasp of everyday life experiences, allowing them to find contextually better, more mature solutions to complex problems in their individual, professional or civic life. Reaction to the need for 'multi-model thinker' can be seen from the interest in 'interdisciplinary education' that is promoted at various schools, starting at Stanford University and spreading fast to other universities. Stanford University strongly encourages students from diverse majors to come together with the goal to become what is called 'T-shaped students'; students who have an in-depth knowledge of a particular field of study but also breadth across multiple disciplines (Auletta, 2012). The shape of the letter 'T' is meant to symbolize the depth of the specialty knowledge and the breadth of the multidisciplinary knowledge. The idea of cognitive diversity and the benefits of multi-model thinker or 'T-shaped' student is currently a popular term in Silicon Valley, a highly developed and influential technopole with huge interest in developing and attracting creative and innovative problem-solvers (T-Summit, 2015; University, Minnesota, 2012).

From the perspective of the diversity prediction theorem and through the 'many-model thinker' cognitive diversity lens, the range of students' VNOS can be seen as the reflection of their cognitive diversity in respect of their VNOS. This diversity allowed each student to approach the problem at hand within different contexts and from different points of view based on pragmatic approaches to decisions and personal experience. Within the everyday use and need for VNOS, cognitive diversity, as I explained above, may enable someone to deal with an unpredictable, chaotic world better than ability or expertise. Research indicates that development of cognitive diversity is highly desirable to increase problem-solving skills and ingenuity in individuals as well as groups translating into benefits of better function, stability, robustness and

survivability of whole societies (Acemoglu & Robinson, 2012; Diamond, 2005; Page, 2008, 2010b).

Accepting that the demonstrated range of VNOS in student's minds is a demonstration of multiple concurrent mental models called forth, created or needed within the context of filmmaking, we can conclude not only that the students displayed a diversity of their views and created sophisticated and mature approach to NOS, but also that filmmaking provided an appropriate and fruitful problem space enabling the increase of student's cognitive diversity. Taking into account that exploring the issues of NOS in high school is not intended to create professional philosophers of science, the approach of increasing the cognitive diversity of models and understandings of NOS in the minds of students constitutes a change in a favourable direction.

I have shown that our understanding of diversity and how 'identity diversity' relates to 'cognitive diversity' explains the current trend of solving complex problems by using the diversity of crowd. I have explained the diversity prediction theorem and shown that shifting the idea of diverse crowd into the sphere of a single cognitive mind highlights the benefits and importance of individual's cognitive diversity. I explained the 'many-model thinker' and showed the need to develop a 'T-shaped student' in the effort to enable an efficient and inspired problem solver. In conclusion I have shown the similarity between the cognitive diversity of the many-model thinker and the concurrent multiplicity of students' VNOS demonstrated in this research, arguing that it may be a desirable goal or outcome of an educational strategy. I will now look at the possibility of a pedagogy focused on developing or expanding cognitive diversity and the role of filmmaking in providing the contextually rich environment to enable students to generate an extensive concurrent multiplicity of diverse views.

Pedagogy.

Changes in scientific knowledge stem from discoveries that can be understood either in terms of pre-existing paradigms or require the creation of a completely new paradigm (Kuhn, 1996). The process of learning science similarly "comes in two forms: learning that can be accomplished in terms of pre-existing concepts (knowledge enrichment), and learning that requires the adoption of new concept altogether (conceptual change). Both forms of learning occur in every domain, but knowledge enrichment is far more common and far easier than conceptual change" (Shtulman, 2014, p. 47). Research into the dynamics of conceptual change (Chi, 2008; DiSessa, Sherin & Sherin, 1998; Hewson, 1992; Roschelle, 1992) attempts to characterize what we intuitively know about different domains, how such knowledge differs from scientific knowledge, and how it changes with instruction, either formal instruction in the classroom or informal instruction at home or elsewhere (Shtulman, 2014).

One of the most popular concepts in contemporary teacher education programs is constructivism (Hyslop-Margison & Strobel, 2007). Constructivism represents an intricate epistemological approach with significant implications for teaching. Hyslop & Strobel (2007) provide a good overview of constructivism:

> Constructivists such as Piaget (1954), Dewey (1929), and Vygotsky (1978) all maintain that students arrive in any learning situation with a range of prior knowledge and experience that influences how they respond to new information. … These structures are epistemologically persistent, or resistant to change, and therefore play a key role in determining how students assimilate or accommodate new learning. In other words, teachers and students do not like to change their minds—particularly if that change includes considering ideas radically different from those they presently hold. (p. 78)

From a constructivist perspective, good teaching amounts to finding out what students already know or believe and creating the mandatory cognitive dissonance or mental conflict, which enables the process of adjusting students' conceptual understanding (Camilleri, 2014; Hyslop-Margison & Strobel, 2007; Murphy, 1997). This dissonance, which prompts an extensive reconsideration of 'taken for granted' ideas, is a key component of constructivist learning and one of the theory's most significant contributions to teacher education (Hyslop-Margison & Strobel, 2007; Simonson, 1977; Windschitl, 2002). Students may deal with the discomfort of cognitive dissonance in a number of ways, particularly when the solution to this dissonance is an in-class offered theory. The structure of the educational system, including its reward system, allows an acceptance of school-offered solutions in exchange for a good mark, but such acceptance may be superficial, leading students to separate 'school knowledge' from their everyday life experiences, sometimes without realizing it (Chabrak & Craig, 2013).

The research data reported in this dissertation indicate that during the filmmaking project the participant students realized the difference between the school-based understanding of science and science as used in practical problem solving of everyday life. Students openly reacted to the 'school science versus everyday life' dichotomy as discussed in Chapter Four. Students expressed their discomfort by criticizing the realized difference between school science and science as practiced and used in everyday life as they experienced that the unified and 'problem-free' school science knowledge was not helpful in the context of the everyday-life problems simulated by the film story. Students expressed that they "should be more critical" (Layla) in respect of the information they receive at school or via media. At the same time, they seemed to understand why they learn at school a simplified and un-problematic 'school science' even though the reasons 'why' it should be so were not clearly understood. Reactions range from

"we learn text-book stuff theories" (Layla) because of "what teachers are told to teach us" (Mike) and even "of course we learn at school like that" (James) because the students consider sections of science "either true or false" (Ethan) or that "there is not really a grey area when it comes to science" (Caleb). This may be an example of the influence 'marking system' may have on student's opinion of science. The "research stage of science" e.g. kind of 'incomplete' or 'contradicting' science could not be after all tested for "true or false."

Once the discussion moves into the everyday life and problems encountered there, the data reveal a significant range of each student's VNOS (see Findings 3). If one adheres to a particular view of science, one expects it to be useful for a variety of conditions and situations. It therefore seems reasonable to expect that the need for using a significantly different VNOS in each context should create a cognitive dissonance, and with it, some expression of discomfort. However, *no such discomfort* was noted during the project. The students seemed completely unaware of the variety of their understandings of NOS as they focused on the practical everyday use of VNOS within the context of the characters in the film story, without any attempt to compare their context-bound views to those they held as science students.

How can we account for this situation? Looking at Chabrak & Craig (2013) definition of cognitive dissonance it is "a state of unpleasant interior tension due to the simultaneous presence of two cognitions that are psychologically inconsistent and discordant. Cognition is consonant (congruous) if it involves or supports the other cognition. Cognition is dissonant (incongruous) if it involves or supports the opposite of the other cognition. Dissonance leads a person to modify one of the two cognitions to restore consonance" (Chabrak & Craig, 2013, p. 93).

Considering this definition of cognitive dissonance, I could argue that no cognitive dissonance was created because no discomfort with the cognitive state of subject matter was

noted. The data clearly show that each student expressed a range, sometimes extreme, in their understanding of a particular topic of the NOS problem matter. The logical conclusion is absurd: one can hold incongruous (dissonant) cognition that does not create cognitive dissonance.

Accepting that cognitive dissonance was created but did not get represented by an uncomfortable state of mind invites questions about the necessity of such discomfort. Are there particular conditions when discomfort is or is not created? Is the action leading toward consonant cognition (and with it some level of conceptual change) *always* prompted by this discomfort? These questions demand much deeper exploration; results from this research project indicate that we may need to reconsider the understanding of cognitive dissonance and the issue of conceptual change in science education.

The current understanding of cognitive dissonance seems to be based on 'graph-like' or 'line like' views in a single dimension. A particular understanding of a phenomenon meets a different explanation or incongruent experience, and the uncomfortable cognitive battle of which is 'right' in one's mind begins. This view seems to have no place for context. We can take context into account if we move this metaphor to two dimensions and imagine a 'plane-like' simile instead of a 'line-like' one. It allows us to imagine we can have a different cognitive grasp of an issue in different contextual situations. These different cognitive representations may be in dissonance, but because the context is different, they create no discomfort. We may consider that this situation may reflect cognitive diversity.

The influence of context allows students to arriving at diverse ideas and opinions that do not necessarily clash with one another unless an external, uniform VNOS is required. On one hand, the research data suggest that when functioning within a variety of contexts, students may not be always aware of cognitive dissonance, implying that diversity is at work. On the other

hand, the difference in student's reaction to 'school science' (that is considered 'external to events' or 'without everyday life context') and the 'everyday life science' is an indication of the realized difference between what the students 'should think' (school's uniformity) and what they 'need to think' when facing an everyday life problem to solve or decide on.

Creating cognitive dissonance is a major approach of constructivist teaching, attempting to challenge the intuitive or naïve understanding of a phenomenon and replacing it with a more accurate and sophisticated one, e.g. achieving a conceptual change (Chi, 2008; DiSessa et al., 1998; Hewson, 1992). At the same time "children's prior knowledge of phenomena is an important part of how they come to understand school science. …Children's conceptions are their constructions of reality, ones that are viable in the sense that they allow a child to make sense of his/her environment" (Lorsbach & Tobin, 2005, p. 3). Research indicates these naïve ideas are not 'erased' from our minds after learning a sophisticated explanation and in some situations or contexts this prior knowledge and understanding may readily re-appear (Shtulman & Valcarcel, 2012). This confirms that people may cognitively hold a *concurrent multiplicity of ideas*, which may be extremely incongruent. These ideas firmly coexist and, as a result, 'intuitive' knowledge may be impossible to eliminate (Shtulman, 2014). Looking at cognitive dissonance and conceptual change through the lens of context-based cognitive diversity may enable us to better understand and appreciate the complex and pragmatic nature of the process of learning and using science. Cognitive diversity and its reflection in concurrent multiplicity of ideas and views of an individual should be considered not as a deficit that needs to be corrected through 'better education' but as a benefit to explore and build on as it reflects the way the mind works.

I explained how shifting of the understanding of cognitive dissonance in respect of cognitive diversity allows for multiplicity of contradictory views while removing the necessity of discomfort; but cognitive dissonance establishes that it is this discomfort that is the 'force' behind the action to explore the new concept and re-establish consonance, i.e., learning. What might act as this 'force' in the case of cognitive diversity? One possibility is the *problem solving need* within a particular context that requires creating a new view or knowledge that may or may not present a solution to the problem. The problem solving need establishes the understanding of a new experience within a particular or new context. As Pasupathi (2012) explains, learning continually happens as people encounter information in purposeful action, connect it to what they already know, and as a result, this experience changes their knowledge or ability to do certain tasks and/or solve new problems. The dynamic and complex nature of learning indicates that the present notions of learning are too mechanical and linear. This research suggests we should consider cognitive diversity to be incorporated into our understanding of learning in science education and beyond.

To consider cognitive diversity as another enabler of conceptual change, several questions come to mind. What is the relationship between cognitive diversity and conceptual change? In what ways does cognitive diversity influence the possibility of conceptual change? Answering questions like these may show another aspect in the multi-layered matter of learning and conceptual change that reflects the natural way the mind works.

Conceptual change is the process whereby concepts and relationships between them change over the course of an individual person's lifetime or over the course of history (DiSessa et al., 1998). The existence of decades of research on conceptual change speaks to the complexity of the issue (Chi, 2008), but taking into account the exploration of the ideas of cognitive

diversity and cognitive dissonance above, a multi-dimensional concept of the learning landscape and conceptual change seems to be missing.

The results of this research show that students hold concurrent contradictory views but don't seem disturbed or concerned about it; in this situation the term 'cognitive dissonance' doesn't seem to be functional or practical. The students' learning progressed along the ideas of cognitive diversity where the students' reaction to different contexts demanded to create new understandings and as a result produced deeper, more mature and more sophisticated VNOS.

Due to the tightly packed variety of contexts they had to face during the filmmaking process, students' understanding of NOS became enhanced with multi-layered meanings. To interpret this effect, I propose to consider *cognitive contextual expansion* as a way of understanding learning by recognizing that contexts will influence learners, who may create and hold a variety of concurrent views about a phenomenon with no apparent discomfort. Including *cognitive contextual expansion* as a way of learning captures the way we react and learn in 'not ideal' environments, in situations where information is not complete and results are uncertain. Such complexity is not possible to explore, understand or solve though uniform thinking; this is where the power of diversity shows itself most clearly (Hong & Page, 2004; Page, 2010a; Suroweicki, 2005). Science, as I explained in Chapter One, offers a way of dealing with complexity and uncertainty; therefore, uniformity of thinking is detrimental in science (Acemoglu & Robinson, 2012; Diamond, 2005; Feyerabend, 2011). The diversity of scientific approaches to is essential to finding solutions of difficult and complex problems, and it is therefore important to portrait science in school in a similar manner. Accepting that *cognitive contextual expansion* is particularly beneficial in learning and understanding of complex

problems as it nurtures diversity accedes to finding efficient pedagogical approaches to teaching such problems; filmmaking seems to be one of them.

The natural way people learn and develop their 'knowing' over the course of lifetime is that with passing time they happen to experience a large variety of situations and 'contexts'. These situations will be always burdened by uncertainty and incomplete information, but people will try to solve problems at hand by using the knowledge they have and 'tweak' their understanding according to the successes or failures they experience. This lifetime of experience, when we deliberately explore it and learn from it, amassed over a lifetime constitutes something we call 'maturity' or 'wisdom.' Can we teach wisdom?

'Teaching' has a particular feature and benefit that it assists to speed up the process of natural learning by using intelligent methods of presentation of topics and problem-solving patterns needed for successful life in society (Pasupathi, 2012). It is reasonable to consider that compacting number of contexts within which students' understanding can be tested and experienced 'speeds up' the process of gathering experience by chance during everyday life and as such it speeds up the process of 'maturing' of views and understandings. Focusing on *cognitive contextual expansion* therefore may help to 'teach' in a way that increases maturity and possibly allow for wisdom.

I have shown that current favoured approaches to teaching are connected to the ideas of achieving conceptual change though cognitive dissonance. The required feeling of discomfort when facing incongruent views of a problem or topic were not demonstrated by the students in this research even though they concurrently held a variety of views, sometimes contradictory. I explored the ideas of cognitive diversity to explain the lack of students' discomfort with the concurrent multiplicity of their ideas and discussed the need for additional 'dimension' to our

understanding of conceptual change to account for contexts. I propose considering *cognitive contextual expansion* as a way to address and support diversified group of views and understandings to particular phenomena within different contexts. *Cognitive contextual expansion* is the missing partner of cognitive dissonance that allows to address learning and teaching of complex problems with incomplete information and uncertain outcomes.

In the next section I will discuss filmmaking as a possible pedagogical approach that enlivens *cognitive contextual expansion* within a collaborative environment that thrives on diversity.

Filmmaking as a pedagogical approach.

I found no literature that would indicate that filmmaking has ever before been used in science education, either as a research method or as a learning environment. Discussing the possibilities, including the benefits and disadvantages, of filmmaking will allow us to illuminate the strength and transferability of this approach and at the same time review possible pitfalls.

Filmmaking for education.

In Chapter One I explored in depth the problems with addressing the issues of NOS in the classroom. The complexity of the topic and teacher preparation time, as well as instruction time demands, all hinder the possibility and willingness to genuinely address NOS in the classroom. Shallow adoption of school-science-based VNOS provides poor preparation for students to deal with the complexity and dynamism of scientific and technological changes within the society.

In filmmaking, the process of learning about NOS is supported by feedback-based storying and re-storying (self-similar on many different levels). Students explore NOS in a variety of contexts that increase the complexity of their VNOS, expanding their cognitive diversity and strengthening the robustness of their views as I showed in Chapter 3. Teachers who

will include filmmaking in their classroom will find that a number of overlapping learning activities can be implemented in a condensed and compressed form within an exciting and memorable project.

Using the theoretical philosophical constructs embedded in the accepted NOS tenets introduces the topics of NOS in the classroom but those topics remain in the theoretical realm with little connection to the everyday world. The VNOS in students' minds remain like an abstract mathematical concept that doesn't readily show itself, for example, as the principle behind a moving car or a falling apple, unless practically explored. Such knowledge has little use in everyday life and so the effort of school instruction on the topic can be wasted as students' 'naïve' or 'intuitive' understanding of NOS remains unexplored and without deeper understanding continues to be used in the practical everyday decision-making.

Research shows that 'naïve', intuitive knowledge can be overridden but not overwritten (Shtulman & Valcarcel, 2012). The naïve views need to emerge and be recognized by students before they can be addressed. Filmmaking creates a possibility for reflection that allows to mitigate the influence and re-emergence of the intuitive attitudes because "such intuitions are sustained and reinforced by how we talk about natural phenomena in everyday discourse and how we perceive natural phenomena in everyday situations. Much colloquial language seems to be predicated on intuitive conceptions" (Shtulman, 2014, p. 50). By repetitive examination and reflection on the different contexts in a film story, the students may realize their own naïve views and adjust them to arrive at more informed VNOS. The awareness of the coexistence of diverse VNOS and possibility for exploration of its contextual variations becomes crucial to grasping the subject of NOS with lasting effect.

Filmmaking requires the creation of a filmic reality (Mullarkey, 2009) in a variety of contexts within which the topics of NOS can be probed in a realistic way. The goal of re-creating a believable, everyday-based story brings with it the everyday language, situations, reactions and also the cultural time-framed background. The intuitive common understandings and assumptions of the social background must be considered in order to be realistically re-created in the film. At the same time the dialogues and attitudes, including the body language, have to be collaboratively defined by the creative team, allowing the creators' ideas to be compared and filtered. The filmmaking process therefore exposes the viability of the multitude of thoughts within a particular context. It enables the practical investigation of diverse sets of VNOS. Students' everyday experiences and their intuitive understanding of NOS becomes the foundation for exploring the NOS within the filmic reality. Teachers, as a part of the team, can link the tenets-based understanding of NOS to the variety of students' experiences and discuss their practical consequences.

Other educational creative approaches to addressing the topic of NOS in the classroom like theatre (Clough, 2011; Miller & Saxton, 2011; Ohler, 2008), creative writing, writing a news article (Andrews, Hull, & Donahue, 2009; Barton & Booth, 1990; Campbell, 2001), group investigations of socio-scientific issue, interviews with scientists, or even creating slow animations (G. F. Hoban et al., 2009; G. Hoban & Nielsen, 2011, 2013, 2014), can be seen as parallel methods for teaching the NOS to filmmaking. The teacher or project facilitator decides where they start their class (or classes) in the process of filmmaking. Individual teachers may opt to approach the use of filmmaking in their classroom from the very beginning and follow the full process from story development to film completion. They may let the students to select a topic,

immerse in research, create a dramatic story and write the script. They may let the students to select actors or choose to be the actors in the film in addition to being the film crew.

My research project focused only on the 'on-set' filming activities with a script and actor preparation already in place to be manageable as a research project, but there are many other options for both the individual teacher or for the whole school should a group of teachers collaborate in such a project. There is also a possibility that teachers from different schools may collaborate; only a willingness to plan and cooperate is needed. The inherent multi-disciplinary nature of a film production offers a multitude of ways to collaborate between different departments: music, art, history, writing, technology, and so on. Each provides an opportunity to consider the issues of NOS from a slightly different perspective, thus enhancing both depth and breadth of NOS education.

A filmmaking project in a school has the capacity to connect learning of many different school topics, support cooperation among teachers and provide a unifying 'reason' (other then getting the mark) for students to learn particular topics in their classes. Projects such as this also have the capacity to connect and 'unify' large portion of the student body of the school in the adventure of completing a film. For example, planning for an original film in a school would require the teachers to sit down together and set some basic initial parameters for the project; e.g., choosing the time period and subject area of the problem to be presented by the film. The more concrete definition or outline of the film topic teachers arrive to, the easier it will be for the teachers to plan their regular classes' content, flow as well as students' independent projects and home-works in order to support the film-making time-line. Science teachers may choose a scientific problem or story from history of science and review the scientific knowledge of the time including the errors of the era; history teachers then may implement classes exploring the

selected time period, its politics and societal structure, morals of the times and behavioural standards, personal stories of the time, etc., all essential to visually re-create the environment of the film story and find a realistic look and behaviours of the characters; Art teachers could draw on the knowledge of history classes to design wardrobe, plan for the needs of the set but also look at the topics of photography, framing and its psychological effects, etc.; English Language teachers may choose to cover script writing and have the students to write a script; Theatre teachers can focus on preparing students to act in the movie; Mathematics teachers may look at the topics related to budgeting and cost estimate calculations or look at the story from the point of view of history of mathematics; Technology teachers may invest time in understanding use of camera or editing software, etc.; these are just a few suggestions, but the possibilities are endless: Whatever the specializations of classes in a particular high-school there may be a task to do in order to support the film production. It may be too optimistic to expect an involvement of many teachers in such a project as teachers tend to focus on their own classes and work in relative isolation (Ganzel, 1940; Merki, 2014); using a support group of filmmakers may possibly make the difference, and all that is needed is willingness to cooperate under the guidance and coordination of one teacher.

Connecting with a filmmaking support team may also provide a connection to the community outside of the school. The practice of filmmaking may possibly simulate the environment of Dewey's progressive school model (Dewey, 1897, 1907). In his article *My Pedagogic Creed* Dewey (1897) argues that, "the only true education comes through the stimulation of the child's powers by the demands of the social situations in which he finds himself" (p.77), but "education fails because it neglects this fundamental principle of the school as a form of community life. It conceives the school as a place where certain information is to be

given, where certain lessons are to be learned, or where certain habits are to be formed" (p.79); Dewey describes that education "is a process of living and not a preparation for future living" (p.79), therefore the whole community should be reflected in the schooling process. Dewey (1907) in his work *School and Society* expands the ideas related to the school-community relationships visualizing on charts the physical structure of school that includes planned integration with the various areas of community's business, professional, technical, environmental and home life. Dewey (1907) hopes to demonstrate

> … how the school may be connected with life so that the experience gained by the child in a familiar, commonplace way is carried over and made use of there, and what the child learns in the school is carried back and applied in everyday life, making the school an organic whole, instead of a composite of isolated parts. The isolation of studies as well as of parts of the school system disappears. (p.106)

Through filmmaking the "isolation of studies" (ibid, p.106) may also disappear if the studies are planned to lead toward achieving the goal of making the film. The practical needs of producing the film can engage numerous and varied members of community's business, professional, technical, environmental as well as home life and assist the project to bring it to successful end. In this way, filmmaking could be an important pedagogical method for realizing Dewey's vision of a school-based education more integrated with community expertise. The steps needed to take on a filmmaking project are outlined in Resources Section A, *Brief Guide For Teachers* in the hope that teachers will recognize the unique value of filmmaking that seamlessly connects theoretical and practical knowledge, school and it's community as well as people of wide range of ages and backgrounds in a variety of fruitful relationships.

Regardless if one class or the whole school joins in a film-making project, the possibilities for exploration of everyday life problems and the science behind it within the context of the story and characters will dramatically expand the diversity of students' views and complexity of their NOS reflections that, as I explained in Chapter 3, allows for increasingly sophisticated and mature VNOS.

I captured only in broad and rough strokes the vast amount of research, learning, planning and fun that is incorporated into film-making; pre-production has more relaxed schedule to gather as much preparation as possible, then during production all the congregate of knowledge amassed get 'fire tested' on the set in intense, time-constrained situation where the success is measured by the result, the film. Filmmaking delivers intensity into the learning process that may be unmatched by other NOS activities, and permits a time-efficient, in-depth and comprehensive coverage of the required topic of NOS.

Filmmaking for research.

The effect of film on an audience is widely studied (R. Allen & Krebs, 2007; Bordwell, 1985; Branigan, 1992, 2006; Buckland, 2009; Davis, 2002; Metz & Guzzetti, 1976). Discourse regarding film language and its development, its understanding and effect on audience, made me realize that we only discuss the after-effects of filmmaking. Like reading a novel, we do don't think about the way the author thought writing it; we only evaluate the final product disregarding the complex preparation and thinking involved in its creation. Film delivers filmic experiences that are sometimes profound, akin to our own everyday life experiences (Bersani & Dutoit, 2004; Mullarkey, 2009), but how were they created?

If we look closely at the process of creating a film, the opposite happens. The members of the filmmaking team seem not to think about the final product in its entirety or about how it

affects the viewer. They concentrate their thinking on one very small bit of the film at a time. Even the smallest sections of film become eerily independent as they are created one by one in a jumbled time-order. Each member of the filmmaking team has an area of responsibility, and be it a flower in a vase or the facial expression of a character, someone is focusing on it, deciding if it confirms their understood meaning of the place or character expected by the film story. They know that even though the whole film is not on their mind, if the characters and situations are modelled 'right', the entire film will fall into place under the hands of the Editor.

The filmmaking team will focus on tiny details within the portraiture of the character, location or situation. Details that are not thought of in an everyday situation or even noticed by the viewer of the film get regularly discussed in depth on the film set. This unusually deep focus on detail within the big picture is what enlivens the meaning-making activities within the team and allows an access to underlying ideas and understandings.

The storying that surrounds the reasoning for these extreme details has to satisfy the description and understanding of the character within the different story settings. Despite the focus on details of the story, filmmakers need to keep the overall narrative and the characters' motivation in mind. The feedback loop I discussed in Chapter Two manifests itself as a continuous, repetitive process where character actions and motivation shown in the film are influenced by the overall narrative, which in turn is the result of the sum of the story, the plot, and the character relationships.

When using film for research, the declared reason for the research is largely overlooked or forgotten in the intense environment of filmmaking. Participants will concentrate on such a minute ideas that they reveal attitudes, feelings and understandings that they may not be completely aware of. The filmmaking activity is not directed at them and the protective wall of

their identity comes down showing hidden opinions as well as features of their personality not usually at play in the everyday environment.

Filmmaking demands efficiency. If something is not necessarily needed to support the story it is not used. Inefficiency wastes time and money so every item on the screen has some important meaning and there is a well-discussed reason for the item (person, situation, location etc.) to be in the film. This has the effect of setting up and deciding on only the essential features of the film.

The behaviour of the team resembles that of the children 'playing sisters' in Vygotsky's description of learning via games (Vygotsky, 1966), creating rules of the game that contain the meaning of 'being a sister'. The spotlight in filmmaking is on issues and items that are rarely discussed with so sharp a focus to derive the particular meaning it has in the film-story situation. This level of focus disrupts the regular way of skimming over situations and items in everyday context. It disturbs and deepens the regular way of thinking, removes barriers among the team members and brings forth hidden experiences and understandings all in the service of creating the film.

Another benefit of filmmaking for research lies in its tendency for redundancy. Researcher will gather rich source of data from multiple perspectives within a variety of contexts and under variety of conditions. This multiplicity allows getting a better grasp of the studied idea, subject or topic.

Pitfalls.

Filmmaking is not an elementary activity regardless of the perceived ease of using modern camera and film equipment. The required specializations of the filming team ensure that the translation of ideas into film is possible in a focused, planned and efficient way. To finish a

film requires a large number of tasks to be completed. In professional filmmaking, each department or position on the production team has a well-defined set of tasks and responsibilities. The division of responsibilities on the filming team makes it manageable to ensure all required support is in place at the time of filming. Omissions lead to frustration on the team, because often the entire team must wait until a solution can be found, wasting time and putting the whole project in jeopardy. It is therefore beneficial to cooperate with professional filmmakers to harness their experience and practical efficiency to bring a filming project to a successful end.

Technical know-how of filmmaking has major impact on the look of the final product. There is a large variety of equipment that can be chosen for the filming project. The nature of the film, locations, expected time of filming all dictate what equipment will be needed. The overall feel of the film is grounded in the way it is filmed, for example adventure based or escape based film might use a hand-held camera to create a feeling of authenticity, while poetic film that uses lyrical style with many extreme close-up shots could be compromised by such decision. Filming locations dictate the camera supporting equipment, type and colour of lights, etc. The choice is made based on the needs, cost, quality, capabilities and function of the required equipment. The filming team has to become very quickly familiar with the equipment used on the filming set. Inexperienced people who are not used to using similar equipment or thinking within the technical terms of this highly specialized equipment find it frustrating and very stressful to perform in such situations. On the other hand, when the responsibility for the equipment is carried by a professional and passed slowly during the filming on the trainee, the learning process becomes exciting.

Using filmmaking for either education or research will benefit from the cooperation with experienced filmmakers. Filmmaking is a greatly interconnected activity. It requires to establish a cooperation among an unusual variety of players; Technical, artistic, administrative, etc. This demand for cooperation allows large variety of everyday life ideas to make its way into the process of making film. Common, everyday life views compete and possibly merge with the ideas of the film story and thus facilitate the connection of everyday world to education as well as to research. I explained briefly how to approach a filmmaking project in Resources section that both educator and researcher may find helpful (see Resources Section A, Brief Guide For Teachers).

Unique value of the script.

The film's script is the vision of the film captured in words. Some sections will appear in the final product unchanged (words of dialogue etc.) but large portions of the script are 'translated' into images by the creative team. This 'translation' is what embeds the unique view of the team (personal and social) into the film and makes every film an original, even if based on the same story or script. Wonderful example of this effect can be seen in film re-makes.

Script is the detailed guiding document for the filmmaking process. It stands at the beginning of the planning process and changes during the pre-production stage. A variety of constrains derived from the planning choices (people, locations, timing etc.) will affect the script. It is common that the script changes several times during the production phase as the information from the creative team make its way into the script. The goal of the changes of the script is to protect the film-story while enabling the crew to create the film within the limitations of available resources. A modified and reasonably stable version of the script is used for production.

During the production, the discussions among the team members (valuations, understandings, logic etc.) are directed at the scripts portraiture of the section of film under scrutiny. The script serves as a reflection board for the discussion and 'records' the changes derived from it. The creative team on the set keeps on comparing the writer's (e.g. script's) understandings of the film-story (described by the written words of the script) to their own (described by spoken words) to bring out the possible (collective) meanings and represent them in images, sound and movement.

A researcher has the opportunity to use a script to represent the studied phenomenon, and via filmmaking, record the participants' (who act as the filmmaking team) deeper understanding of the film overall. For example, creating a film script with story from a work environment will lead the creative team toward in depth discussion of minute elements and details of the film environment and story; if allowed, they will modify the script in a way that in some way better reflects the team's views.

Within my research project the students were allowed to modify the script. Time constrains didn't allow for exploration and compilation of individual student's script modifications to arrive to 'official' changes to be reflected in new written script version; because there were no research tools implemented to capture the written script modification data the script modification data are not substantial to be a data source for this research. Students were to make a film and research data collection followed the reasoning that quizzes the students were filling in were to serve the purpose of understanding the characters to visualize them well in the film. The script modification data might allow additional comparisons, but they were not the focus of the research. Most changes to the script happened on the set while filming and making

different takes of the same section of a scene. From documented discussions on the set the students expressed their 'feel' for the characters in the context of the story.

For example Ella brings up the relationship of the mother and father in the film: "I was wondering … is there a special reason why we have mother and father talking here … they were kinda angry at each other so did they kinda find an answer?" and Layla adds, "I think if they got back together it would be too cliché and more …it would be too perfect you know?" so together with the actors the dialogue was changed. These kinds of nudges to the script affected the films' feel of the everyday life story towards a way the students felt was more natural. As I showed in Chapter Two, storying and re-storying are the basic elements of building a narrative. The script changes the students created during filmmaking are an example of a continuous narrative-building process.

There is a technical film-making disadvantage allowing such 'on the fly' modifications; as each scene is shot several times (sometimes on different days) continuity of the dialog becomes hard to manage resulting in problems for the Editor editing the film.

From the perspective of researcher using film-making as a research method following and documenting the script changes together with recording the discussions and its reflection in the final film may create rich data sets that allow a multifaceted insight into the studied issue.

For an educator, the script could replace a textbook narrative, such as the discovery of a scientific idea or a discussion on science and social values. The script presents the topic under discussion in the everyday immersion facilitated by the story. Regular textbooks are usually not questioned; rather, they are used for looking for answers or as a reference for the 'correct' information that is supposed to be learned; a script-based textbook invites, indeed demands, a focused discussion and deep reflection against the backdrop of everyday life. Script can

consciously force all information to show its domains of uncertainty and through the story the ways of dealing with it. There will be large number of topics ready to be explored in depth because the story requires complex backgrounds that anchor the conflicts that drive the story. The teacher can choose one or several of the topics or let students to explore the interplay of them.

Realizing the benefits of embedding research or educational ideas into script opens new way for research and education alike.

Limitations and critique of the research

The findings of the project are encouraging, but given that there are no previous studies on filmmaking or on dynamics of VNOS the study provides limited data. Data were collected from only twelve (initially and ten finally) students during one filmmaking project. Data collected from such a small sample size cannot be used to confidently draw conclusions about much larger population and therefore more research is needed. The broad as well as detailed results collected by this research study will prove useful for further research. Still, the sample size and diverse quality of respondents advocates the prospective transfer of this research approach to a regular classroom.

This study employed a mixed method research design. By combining the quantitative and qualitative approach, both a broad overview of the students' views of NOS and context specific picture of their understanding and application of VNOS were revealed.

Quantitative methods, even though it can detect general trends, can also impose a polarity on the data that is collected as it attempts to create the contrast between the factors tested. That approach tends to artificially represent the phenomena studied as being opposed or entirely different. This can prove rather challenging in educational research where changes in students'

knowledge, attitudes and actions are not easily separated but instead emerge to form a continuum over time. In this study we implemented a measurable continuum based slider bar along which data were collected and compared. The results show large variability that would be difficult to understand without the support of the findings of qualitative approach.

The project used established and tested SUSSI instrument for measuring and evaluating the level of students' understanding of NOS (Chen et al., 2006; Golabek & Amrane-Cooper, 2011; Liang et al., 2008, 2009; M. C. D. Miller, Montplaisir, Offerdahl, Cheng, & Ketterling, 2010). As noted in chapters three and four, the instrument's brevity and ease of delivery and analysis made it a better fit for the project over other, much longer and demanding NOS instruments (Abd-El-Khalick, Bell, & Lederman, 1998; Bell & Lederman, 2003; Lederman et al., 2002).

The SUSSI instrument collected student's 'school-like' NOS answers a week before the filming project commenced. Comparing these results with answers to the modified continuum-based quiz at the beginning of the first day of the filming project revealed large discrepancies in students VNOS with very limited correlation. These discrepancies could indicate students' miscomprehension of the statements of either of the questionnaires, but the qualitative data helped to reveal a rough pattern centred on an NOS idea that permeated the rest of questionnaires. Still, I find that it is unsettling that so little correlation in students' VNOS was found just by using somewhat different questionnaire: one with a rough scale and other with smooth continuum based slider bar. The meaning of this discrepancy deserves further exploration.

One factor included in the questionnaires that was problematic was the allowance for the value 'undecided.' The definition of 'undecided' proved difficult, leading to large amount of data

assigned to this unclear category. Students seemed to choose that option even if their descriptions of the studied situation suggested they do have a clear opinion that makes their choice of 'undecided' contradictory. 'Undecided' came to mean many different things such as; undecided due to lack of understanding the NOS issue, undecided due to the lack of understanding the character, undecided due to discomfort with judgment, undecided because no opinion was formed yet, etc. Modifying the scale and adding a clear meaning to the 'undecided' option may allow better use of the collected data.

There is always the possibility to remove the "undecided" option altogether, and allow students to provide worded answer to elaborate their view if none of the options in the questionnaire can be used. This would improve the researcher's understanding of the possible misunderstandings of the statements in the questionnaires. In future research I would favour this approach.

The mixed methods research also brings into focus the interaction between the quantitative and qualitative results. In this study the quantitative results, if viewed in isolation, could be considered limiting, as the patterns revealed are fuzzy and contradictory. However, when read through a lens inclusive of the qualitative findings, the meaning of the quantitative analysis is expanded and is actually complementary to the qualitative data. From this interaction the research questions are further illuminated and the significance of the research emerges. Here the quantitative data from the questionnaires regarding the VNOS disturbed by inconsistencies (and limited correlation) draw attention to the fact that the changes were specific to the filmic context; this may be unique to filmmaking because it demands deep reflections to varied contexts, but compresses them to a relatively short period of time of production.

Further research.

This study is exploratory in its nature as no similar approach can be found in research literature. In order to grasp the interplay of the studied environment, the research project addressed several comprehensive issues; to explore students VNOS, find out if it tends toward dynamism, clarify the role played by context and to look at the possibilities brought forth by filmmaking for education as well as for research. The data collected revealed striking discrepancies leading us to suggest that we need to redefine or rethink each of these areas; but that requires additional research focused on each area separately.

At the same time, it would be beneficial to recreate this inquiry with new teams of students and see if the patterns suggested hold for different students and different scripts. Research would greatly benefit if it can utilize the efforts of any teacher who takes on filming project in their classroom.

Summary

Science has become an essential part of modern life permeating nearly every aspect of functioning western society. Looking forward, it is difficult to imagine a future where science and technology do not play a fundamental role in maintaining and improving people's lives around the world (Van Woensel & Archer, 2015). This presents a challenge; if we rely on science and technology so much, how do we make sure that this dependency works *for us*, rather than *against us*? Preparation of our young generation for these challenges is monumentally important.

Science and technology is part of our history for few millennia, but in the past, the rate of science discovery and technology advances was not so high as today and it has allowed us to adapt to the changes they bring about. The 21st century, the so-called 'information age', is

marked by science and technology that transforms so fast that we are under pressure to adapt to one set of breakthroughs before the next comes along and the rate of this 'progress' is accelerating. It is impossible to plan to teach our students 'all' the 'current' science and we still have to keep in mind that some ideas may be obsolete by the time they finish school. Understanding how science works and how it deals with uncertainty becomes the only way we can assure students have attitude toward science that can help them navigate the future successfully.

Indeed it can be disputed that 'progress' in science and technology always leads to more successful societies and people having healthier, happier and more fulfilled lives, a greater 'quality of life'; but when scientific or technological implementations bring un-desirable effects (sometimes due to unintended consequences) the 'blame' is directed at science (or scientists), as the society's role and responsibility for implementing science and technology innovations is often overlooked or denied. We need to teach students to explore and be aware of their VNOS; they need to comprehend the responsibilities they have as citizens of the world for the decisions they make using science realizing the that there is uncertainty embedded in any scientific enterprise and problems are always based on incomplete information. Only then can they appreciate how can science and technology provide the means to protect the environment, alleviate suffering, improve health and well-being, but also how it unavoidably and irreversibly defines who we are.

Students with simplistic, superficial or unexplored set of VNOS will not be well equipped for the challenges of 21st century, they may become citizens ill prepared to steer or supervise how we develop and use science and technology within society (Kolstø, 2000, 2007; Priest, 2013; Roth & Désautels, 2002; Ryder, 2002; Wellington, 2002). We need to radically re-think

how we approach the subject of NOS in school. The past research that I explored in Chapter One indicates that it seems utterly naïve to believe that how we've done things in the past will serve us well in the future. The research reported in this dissertation argues that encouraging widely diverse VNOS may enable students, as citizens and members of a global society, to engage in the conversations around how to ensure science and technology might improve our lives and protect the world for future generations.

The educational institutions struggle to find ways to ensure that students learn in the classroom today what they may use or need in everyday life tomorrow (Bybee & McCrae, 2011; Kim, Yoon, Ji, & Song, 2012; Krapp & Prenzel, 2011; Lin, Hong, & Huang, 2012; Yore, Kottová, & Jagger, 2010). This research project provides evidence that the challenge of realistically connecting these four directions, knowledge and practice, present and future, so prevalent in education, can be successfully addressed by using filmmaking. As Stephen Hawking reminds us, "Science is not only a disciple of reason but, also, one of romance and passion" (Hawking, quoted in Wall, 2010); filmmaking appears to be one way to encourage students to break open their simplistic understanding of science, experience all facets of science including uncertainty, and learn personal responsibility for action.

In my experience I found filmmaking to be an extremely powerful educational environment for determining students' VNOS. This research project is also one of the first attempts to identify filmmaking as a potentially useful educational method for exploring the NOS with students. I described how the film's rich context generating power influences the process of expanding and deepening students' NOS knowledge as well as testing it in a filmic reality of number of everyday life contexts. Filmmaking brought the opportunity for students to reflect on the 'school knowledge' and how it helps (or not) to solve a variety of everyday life

situations; it forced them to face uncertainty and decide on behaviours and actions despite of it. Filmmaking requires the team to be highly imaginative, resourceful and open-minded. Artistic and technical know-how is intertwined through 'for camera' problem solving utilizing the understanding of vision, light, psychology, as well as its technological representations via camera, lenses, colour and time.

In addition the collaborative nature of filmmaking nurtures cooperation, communication and keen management skills for anyone involved. The complex environment of film production demands hard work, responsibility and dependability that are strengthened by the cooperation with a professional team.

This project makes it evident that filmmaking provides an incomparable educational method that allows compact, high-speed and intense learning that proceeds in a naturally controlled, complex environment deepening students' knowledge, enhancing maturity of their VNOS and nurturing skills and attitudes necessary for citizens of the 21st century.

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TEACHER RESOURCES

A: Brief Guide For Teachers: Re-creating filmmaking inquiry in a classroom

Transporting learning out of the classroom into the everyday life is always challenging. This film project was purposefully designed to use environments that might be readily accessible within a regular high school building; large common room, hall, school outdoor area, school parking lot. It attempted to simulate a school environment with the goal of encouraging teachers to become filmmakers along with their students. Filmmaking reaches beyond the classroom "turning the intangible into the tangible" (Theodosakis, 2001, p. 29) and could allow teachers to empower their students by letting them to demonstrate their learning in a media rich and innovative manner. Teachers that venture into film might agree with Susan Crichton's experience that: "Filmmaking in the classroom does have the ability to change learners' lives (I have witnessed it first hand in my teaching practice)" (Crichton, 2002, p. 2).

Filmmaking from scratch.

Our project focused only on the production; including the full filmmaking process could bring additional learning benefits but expands the needed time and planning demands as well. Filmmaking activities are divided into phases that have a similar type of tasks necessary to complete for the next phase to begin. The pre-production phase is dedicated to creation and planning. During this phase a script is written, funds allocated, cast and crew selected, locations found and secured, time frame for production decided and detailed production plan completed. The production phase is focused on the filming; it is the most intense and time constrained phase where the footage of the film is generated. The post-production phase is dedicated to editing and

completion of the project including the planning for viewing and distribution. There is a number of practical books that provide details regarding the full filmmaking process for independent filmmakers (Bettman, 2003; Donelan, 2007; Katz, 1991, 1992; Rabiger, 1998; Stanley & Monta, 2008). I found that teacher oriented and classroom bound description of the filming process helps to overcome the fear of stepping into a complex professional world. Nikos Theodosakis, a Canadian filmmaker in his book "The Director in the Classroom: How Filmmaking Inspires Learning" provides good support for a teacher. Susan Crichton's (2002) in her review of the book finds that "while it recognizes the audience is new to film, it doesn't talk down to the reader but, instead, is inclusive, supportive and instructive" (Crichton, 2002, p. 3). It informs and supports the teacher/s to take on filmmaking project. It helps with understanding the roles everyone on the team will play and helps with choosing a good support team for their class or classes.

Planning your project.

A movie begins with an idea. Be it a teacher's idea of what to teach, a researcher's idea what to research or a student's ideas of what's cool to explore, the idea evokes in the mind of the filmmaker an image of the final film. "When the idea becomes a script, the challenge for directors is to hold a clear picture in their minds of what they want to communicate and then to guide their crew towards that vision. The goal of the filmmaking process and all involved is to put that vision on the screen" (Theodosakis, 2001, p. 29).

Now the script is finalized and your project is ready to be prepared for filming. It is essential to develop a complete plan for your filming project. Firstly, the teacher has to decide when they wish to include the students in the work on the film. The teacher can plan the whole

project and invite the class for the production, similarly as our research project proceeded, or they can include the students in the planning stage. Students will be able to use their planning skills and make crucial choices that influence the film. Secondly, the teacher has to decide how they wish to use the skills of external filmmakers to support the whole process.

Using filmmaking support team will have impact on the time-line of the production; experienced crew will guide the students in efficient manner so the production of the project is under control. This is possibly vital benefit for the time-stretched teacher; the need to have good grasp of the time necessary for the production of a film. In addition, the supporting crew will lend to the project an air of professionalism; I found the students react well to cooperation with experts and feel recognized as colleagues making their own attitudes and behaviour on the set more professional then on 'school only' project. The crew will keep the consistency of the production across team as they easily pass their knowledge to the student team; the teacher can let students to experience more areas of filmmaking instead of 'specializing' them for one role on the production team. The cons might include some difficulties with scheduling the crew and possibly budget. Again, a good plan well ahead of time will outline possible obstacles to successful production in your classroom and provides the opportunity to solve them.

Find filmmaking support for your project.

Filmmaking enthusiasts are looking for an opportunity to practice their skills and usually enjoy having a chance to join a film project. Find a filmmaking community in your town, contact a filmmaking school or you may know someone involved in filmmaking; advertise your need for filming support in educational setting and select a fitting contact for your class. Finding a person with production experience is very helpful as producers and assistant producers may already

have contacts to other specialized filmmakers making it easier to build the filming team for your project. I recommend to establish such relationship very early in the process. Don't be afraid to ask questions and ask for help. Outline your vision for the project and let the enthusiasts to join in. The type and structure of the support team will help you to see what you need to plan for in respect of your classroom – time, activities, budget, cooperation with other teachers etc.

Create production breakdown.

Your chosen script guides all planning stages. Script is analyzed in detail by breakdown sheets (see Resources Section C). Creating film breakdown sheets is a great activity to involve students in. Every scene of the film requires one breakdown sheet that records everything that is needed to film that particular scene. Reading the script in detail and filling in all applicable boxes on the sheet will prepare the base for the planning of production. Collect and organize information from breakdown sheets. Number of characters, number of locations, number of interior and/or exterior scenes, the length of the scene, and lighting conditions for the scene (day/night) – this information will guide next planning steps and decisions about which tasks can the students fulfil.

Select a cast – choose actors for each character.

Create a rough description of each character in the film; identify if the character is male or female, note expected age, include a short life story and personality of the character. This list includes main characters as well as all other characters and people appearing in the film even if only for a moment or in the background. This understanding guides the actor selection process during auditions for the roles. The description is used to inform prospective actors to select a

particular role that would best suit them. This is possibly a way for your students to start their involvement with the pre-production. They have to understand the story and its background to decide on the types of characters in the story and choose fitting people to present them; after all they will work with them to create the film. The development of the understanding of what kind of personality and what types of views that personality should have to best present the film character allows to fully immerse in the particular context of the character and think about the character in connection to everyday life person – the actor.

You can look for actors outside of the classroom or choose to have students in your school to be featured in your film. In either case, set up auditions. Choose a team of students (including possibly a support filmmaker) to serve as the casting directors. Book a room and set the audition times. It is better to have at least two auditions to allow more actors to show interest and not to overwhelm the casting team. Auditions are often recorded for later reference.

During the audition the prospective actor says their full name and the character they are auditioning for. The casting team chooses a part of the script appropriate for the character and let the prospective actor to read and act a small section of the script. The casting team makes notes to help them to collectively decide later which actor would suit which role the best.

The casting team can also ask the actor to act a different character than the one they chose to audition for. It is helpful to create more options for the casting team to find actors for all characters. For example, an actor wanting to play Kayla can audition for the role of a Kayla's friend as well etc.

Find locations.

There are number of locations where the film story is happening. Breakdown sheets record all the locations required by the script. Locations are hard to find and may be costly therefore it is important to minimize the number of locations necessary for the film.

Our film project *Shadow of Hope* physically required one large room, a hall and an outdoor space. All film locations were re-created in those areas. Using different parts of the same room allowed us to create three different locations in the film story. Our project simulated the options that may be readily available at most high school buildings. Review your chosen script and find out if the number of locations can be reduced without affecting the story. Be very conservative in respect of locations. The creative team of the art department can create on-film believable spaces with few ingenious ideas. Allow that challenge and support reductionism – only the most necessary items are in the shot.

Set production time-line – Create production board strips.

Selecting the cast and choosing the number of locations guides the decisions that create the filming schedule. It is important to be prepared for modifications of the schedule because during the filming not everything works out exactly as planned; for example an actor may get ill or an exterior scene can't be shot because of weather. Regardless of what is the problem, issues have to be solved quickly, efficiently and without overlooking any details (for example a scarf prop missing etc.). A production board allows this flexibility and easily tracks in one place all work that need to be completed. A production board is made of production (filming) strips. Each strip records essential information from the breakdown sheets and refers to a particular breakdown sheet for additional details (see Resources Section D). The strip allows the filmmaker

to put together scenes happening in the same location. The location is the number one guide for the filming schedule, followed by availability of actors. The strip is aligned according to those preferences and therefore puts scenes out of order (in respect of the film story flow); this method allows to use the time and locations most efficiently, limiting the cost (in money and time) of the production.

Organizing the strips on production board shows the possibilities for daily schedule (see Resources Section E). A production day tends to be longer then eight hours, so define the 'day' appropriately for your educational project. Consider about three to four hours to shoot one page of a script. The daily shooting goal should not exceed three script pages a day. Without a filming support team, plan for even fewer pages. To guide the filming estimates, script pages are divided into eight sections. Each dialog will then take one or more eights of the page. Each eight (1/8) of a script page can take between 30 - 45 min to shoot (not including the set up time), so plan accordingly. Your production board shows the required eights for each scene giving you quick overview if the scene can be completed in the allocated time.

The production board will show clearly the amount of time (days) you will need to complete the filming of the script. You will have to make choices to fit all work into the schedule. You might need to either extend the number of hours in the production day or extend the number of production days. The worst-case scenario includes modifying and shortening the script.

Our project *The Shadows of Hope* was originally designed for one week (five days) long production. With the help of the support team, we were able to complete the project during four days (two weekends) of eight hours each for the students and ten hours each for the support team who took care of the set-up and takedown each day.

Create a storyboard.

Having a storyboard is a great help for the directing team. It shows the film in a form similar to a comic strip. This is an excellent opportunity for the students to plan the shots and explore the film language. One doesn't need to be an experienced artist to sketch the basic look of the screen for a particular scene. The purpose of storyboard is communication, not aesthetics – it attempts to lead the selection of shots for a particular section of the film. Having an experienced support team allows your students to cover all the appropriate shots easily with educated guidance. Not using a support team will require your students to do additional research and learn basics of film language on their own or with the teachers support.

Create a film Art Department.

During filmmaking, the students involved in creating the film's look and feel are organized in the Art Department. High schools usually have art section or departments including specialized rooms and teachers that may be an excellent resource, help and may be possibly excited to join your filmmaking project. The film Art Department crew members review the script and decide of the clothing (costumes) for each character in each scene; they are also responsible to find or create the clothing for all characters. The Art Department team needs to evaluate the locations and find out what areas will be used, what will they represent and what needs to be done to complete the look of each of the scenes. Members of the team will have to discuss the location needs and find out what will have to be added or re-created (scene dress-up) in order to satisfy the scene. Our project *Shadow of hope* presents a story in today's world therefore the demands on the art department were reduced. Imagine creating a period piece – that would require much more involved costume and location preparation. Based on breakdown

sheets, the film production Art Department crew puts together all props that are used during the film and keeps control and care of them. It is essential to manage that clothing and props as well as scene set-up use exactly the same items in the same locations for all pertinent shots. Since filming proceeds not in order of the film story, there must be a person responsible to keep track of all on-set decisions and recreate them next time when a logically continuing shot is done. This responsibility of the film production's Art Department falls to the continuity supervisor.

The film production Art Department usually requires larger team (in comparison to others, like Camera Department) and that need may support creating an inter-departmental cooperation in the school. It may serve as an excellent connection between the schools art department and science department.

Set up the technical production team – filming crew.

During the production days the filming crew takes the required footage of the scenes that will be later combined in the correct order to create the film. The crew consists of five main areas (see Table 2) to take care of the production during the filming days - directing, sound, camera, lights and art department that includes on-set make-up artist. If you plan using filmmaker's support you will need a team of four to five people to guide your students' crew. Without such help the teacher has to assign the team roles early in the process to allow students to explore and learn the basics of the particular production department's tasks and responsibilities. This includes the responsibility of finding the appropriate equipment. Many high schools have a media department and with it a teacher knowledgeable in the area of media production that can be an enormous help in many ways, including finding and securing the equipment. Today's need of understanding media in varied areas of curriculum may present a

possibility to involve other school departments and teachers in setting up the technical team. Looking for support in your school and finding out the teachers willing and happy to join the project will greatly benefit the project's reach and ease the work necessary to put together the team.

The filming team must be aware of the necessity to take multiple takes of the same shots, and multiple shots of the same scene to create enough source footage for the film. It is only later, after they look at all of this information, that they decide which film footage best illustrates what they are trying to communicate or what they want to explore. Contacting filmmaking groups in your area can prove to be most helpful particularly in the technical area of filmmaking as many groups can provide the knowledge and equipment for your project.

Budget.

Independent filmmaking projects tend to require substantial funds to proceed to completion. At the same time there is usually a willingness to donate work, equipment, locations or food to filmmaking community in exchange for recognition of cooperation and credits. An educational project might enjoy a strong community support and allow the school and the community to come together in a valuable and memorable project. It is therefore important to plan for and put in place a process that will inform and promote this unique school project. Plan for enough time to distribute information about the project. The more people know about the project, the more involvement and help comes in support of it and the more excitement, pride and celebration gets generated.

Plan for the expenses as well as for the donations (see Resources Section F). Do not hesitate to ask for in-kind donations. As you create the budget overview you will be able to identify what to ask for in respect of funds and donation support.

An educator should also be cautious in respect of the amount of time that is possible to invest in a filming project. The amount of students' time that can be spent on such activity depends on the number of learning outcomes that will be fulfilled with the project. The complexity of the filming project allows, indeed invites, cooperation of teachers within different departments of the school and in a variety of subjects. I am confident that efficient planning allows to connect a number of teachers to cooperate on the project, cover wide range of learning outcomes across curricula and all within a reasonable amount of time to successfully complete the film.

Some of the challenges in education today are related to attempting to stretch already tight budgets and share limited resources. Filmmaking accommodates multiple objectives within limited time, and provides a great opportunity to take advantage of cooperation with the community outside of the school. It provides a pedagogical method that, if well applied, generates large amount of completed learning outcomes in varied areas of curriculum through exciting and memorable activity for the students. Though no exact measurements are available I believe that to venture into a film making project is well worth doing as the cost (in time and money) considered in respect of achieved results may be in the end relatively low.

Ready, set, go.

The process of filmmaking lets students see how ideas can be transformed into action. It teaches them that if they can envision it, they can do it. It gives them the confidence that if you

want something, you can reach for it and you do not need to be alone. They honed their planning and management skills immersed themselves in research, their logic, analytical and problem solving skills were used to solve many problems on the way toward completing the film.

The more preparation is done in pre-production the smoother the production runs. Still, filmmaking is a perpetual exercise in problem solving and I all heartedly agree with Theodosakis (2001) that "… as students set out to create their films and discover obstacles of time, equipment and other resources, they learn to identify and solve their own problems, and to own the process for finding solutions. It is then that these multiple, real world filmmaking challenges have become a great opportunity to experience real world problem solving" (Theodosakis, 2001, p. 32).

When all is *ready*, *set* the team to work and *go* with confidence and courage for the filming. Regardless of the quality of final film, your students will learn on multiple levels, they will have fun and create many memorable experiences; in the end they will be proud of their achievement.

The filming days are very demanding and tiring. Many things are happening at the same time, everyone has to trust everyone else to do their job. Full day production is the best way to complete your film. The artistic and technical set up of the filming set and actors is very time consuming so it is best to get as much footage out of that preparation as possible. Planning for a full day production, consider arranging food for the entire production team (it might be possibly donated by a local provider). It saves time, allows more rest for the team and creates better interpersonal connections within the team. A food service will be expected in the case your team includes external filmmakers, particularly if they are volunteering. At the end of the production, when the last shots were taken and they 'are in the can', filmmakers celebrate the 'wrap'. These

expressions link us to the ‘old times’ when film was shot on strips of celluloid and kept protected and wrapped in light-proof cans. At this time cake, hugs, team picture taking, laughter etc. - all mark the end of the intensive filmmaking time when new friendships were made, new ideas learned and an exciting film made. Celebrate.

Post-production.

When filming is completed, equipment cleaned and returned, filming set dismantled the post-production can start. Post-production is mainly concerned with editing and completing the film. There will be hours of footage that needs to be reviewed, shots selected and combined in a way that best tell the story.

Editing can be done either by one person or by a team of people. The teacher decides if editing the film is left in the hands of students or if an editor can be used (volunteer may be available). Both solutions will have its benefits. Having students to edit the final version of the film provides the opportunity to re-think and re-create the film. There will be additional discussions and decisions that will deepen the learning and influence the final product.

An experienced editor will be able to choose footage that provides the best flow of the story. A visual flow that doesn’t ‘jump’ due to bad cuts is as important for the viewer as is a good sound. These types of technical problems push the viewer out of the filmic reality experience, disturbing the enjoyment and full immersion into the film story.

It is beneficial for the first cut of the film to be reviewed by the students. They can discuss how to best complete the film and suggest corrections to the draft cut. Many ideas come out of such discussion and the teacher will see how much information the students retain. They will bring our forgotten shots or the ideas behind them, discuss the usability of particular shots

and remember many problem solving situations on the set (particularly the funny ones). A first cut review is very exciting for all involved. It is the first opportunity to see the full film and it is again a good reason to celebrate.

Finishing a film and viewing it first few times – with the filming crew, 'first friends viewing', first 'public viewing' – all call for a celebration. Celebrate, celebrate, and celebrate. The students and their teachers deserve the recognition, the pride and enjoyment of their achievement.

Celebrate.

In my experience I found filmmaking to be an extremely powerful educational environment. This research project provided one of the first attempts to identify the strengths of filmmaking as an educational method and find out where its main learning power lies. I described how the film's rich context generating power influences the process of expanding and deepening students' knowledge as well as testing it in a filmic reality of everyday life context. Filmmaking brought the opportunity for students to reflect on the school knowledge and how it satisfies or helps to solve a variety of everyday life situations; it forced them to face uncertainty and decide on behaviours and actions despite of it. Filmmaking requires the team to be highly imaginative, resourceful and open-minded. Artistic and technical know-how is intertwined through 'for camera' problem solving utilizing the understanding of vision, light, psychology, as well as its technological representations via camera, lenses, colour and time.

In addition the collaborative nature of filmmaking nurtures cooperation, communication and keen management skills for anyone involved. The complex environment of film production demands hard work, responsibility and dependability that are strengthened by the cooperation

with a professional team. These are just few to mention as each film production is unique and each will bring additional variety of learning benefits.

In this guide I focused on the steps a regular teacher in a high school needs to take so he/she can use filmmaking as a pedagogical approach and implement it well. I am certain that they will find filmmaking provides an incomparable educational method that allows learning to proceed in a naturally controlled, complex environment deepening students knowledge, enhancing maturity and nurturing skills and attitudes necessary for citizens of the 21st century.

B: Script: The Shadows of Hope

The Shadows of Hope

by
Alena Kottova
Jerry Kott

Jerry Kott

250-891-5828

1 EXT. PARK - DAY 1

KAYLA, a lively teenager, walking through a park with her friend LUCY. Kayla suddenly stops - she sees two people, sitting on a bench in romantic mood. Lucy notices a moment later.

KAYLA
Dad???

The man turns toward them, somewhat startled. He jumps from the bench. It's Kayla's FATHER with his girlfriend JESSICA. They feel awkward.

FATHER
Oh - hi, sweetheart! ... Hello Lucy.
(awkward pause, looks at the watch)
What are you doing here?

Kayla makes a dismissive gesture, suggesting she should be somewhere else but doesn't want to. She looks at Jessica - who is that?

FATHER (CONTD)
Oh... right... mmmm. Jessica?

Jessica gets up, walks over.

FATHER (CONTD)
This is Kayla, my daughter. This is... my... friend, Jessica.

JESSICA
Hello, very nice to meet you.
(looks at father, back to Kayla)
I've heard so much about you.

KAYLA
Really?
(quick glance at father)
I haven't heard about you.

Awkward silence is interrupted by father.

JESSICA
Well... we should go now.

KAYLA
Yeah, we too.

1 CONTINUED: 1

She goes to dad, gives him a tight hug. As he holds her, she whispers to him

KAYLA (CONTD)
You should have told me.

FATHER
Alright. I'll see you soon.
(to Lucy)
Keep her out of trouble!

The two pairs walk away in opposite directions.

2 EXT. PARK - MOMENTS LATER 2

Kayla and Lucy continue their walk, Kayla glances over her shoulder toward the couple.

LUCY
Hey... are you okay?

Kayla silently acknowledges her, continues to walk, thinking about what just happened.

LUCY (CONTD)
Does it bother you?

Kayla stops abruptly, after a moment:

KAYLA
What bothers me is that he left.
(pause)
It only surprises me that it took him so long to find someone. You've met my mother, didn't you?

Kayla turns away, leaves the area rather upset.

As the OPENING CREDITS start, we see Kayla alone in the park.

FADE TO:

3 INT. KAYLA'S ROOM - DAY 3

A montage of shots reveals a messy teenager's room with Kayla, standing in front of a mirror, 'dancing' to the sound of some hip-hop music, getting ready for school. A torn photograph at the edge of a computer screen shows her dad, a half of the picture is missing.

MOTHER (O.S.)
Kayla!

3 CONTINUED: 3

Kayla rolls her eyes, sighs.

MOTHER (O.S.) (CONT'D) (CONTD)
Kayla, let's go!

Kayla starts lip-synching the "late for school" routine while

MOTHER (O.S.) (CONT'D) (CONTD)
Kayla, you will miss the bus again!
You'll be late for school!
(pause)
Do you hear me? Hurry up!

Kayla sighs angrily, picks up her school bag, leaves the room.

4 INT. KITCHEN - DAY 4

Mother is preparing breakfast as Kayla walks in.

MOTHER
What's taking you so long?

Kayla sits at the empty table. She looks at her mother, gesturing: "where is food?".

KAYLA
What's taking YOU so long?

Mother stops, two plates in her hands, in a brief staring contest with Kayla.

MOTHER
Why don't you make your food? You should take responsibility for yourself! What else do you want me to do? I go to work every day, pay the bills, take care of the household...

KAYLA
(interrupts)
...and keep talking about it!
That's why dad could not stand you!

Mother puts the plate in front of Kayla and sits down across from her.

MOTHER
(irritated)
Enough! Grow up! I'll be quiet when you start doing all the work!

4 CONTINUED: 4

Kayla is eating her breakfast, answering with full mouth.

KAYLA
Or I could live with dad...

MOTHER
Now THAT would be something! Two children home alone... One day you'll see, it's not that simple.

KAYLA
(mumbling)
Of course, you know ... you know everything, right?

Mother pauses for a moment in frustration. She slowly continues her breakfast

MOTHER
If you think you know more than me then you should get better marks! ... I ran into your science teacher. He told me about your last quiz ...

Kayla interrupts her mother impatiently.

KAYLA
You teachers are all the same, just keep on bugging me!... "you can do better than that" ... "take responsibility" "blah blah blah"
(pause)
Besides... science is boring!

Kayla angrily pushes off her plate, grabs her lunch and gets up while mother continues.

MOTHER
Kayla, you are smart, and you will need science in your life...

As Kayla is about to leave the kitchen, suddenly

CUT TO:

KAYLA'S P.O.V.

her vision becomes blurred, followed by a dizzying motion. We see the fuzzy view of the room, mother ...

4 CONTINUED: (2) 4

MOTHER'S P.O.V.

Kayla makes few disoriented steps, stumbles side to side, gets hold of something, then collapses back into her chair.

MOTHER (CONT'D) (CONTD)
Kayla! What's the matter?

She runs to Kayla.

KAYLA'S P.O.V.

In a blurred and dizzying motion, mother is looking into Kayla's eyes as she keeps calling her name.

5 EXT. STREET - DAY 5

Sounds of emergency vehicles, sirens, an ambulance rushing through the street.

AMBULANCE ENTERING EMERGENCY ENTRANCE TO A HOSPITAL

6 INT. HOSPITAL - DAY 6

Montage of shots establishing we are in a hospital.

WIDE SHOT FROM AFAR

Mother sitting in a hospital hallway. DR. PETERSON walks toward her. Mother jumps off her seat, full of anticipation as Dr. Peterson approaches her. They face each other in a conversation as camera slowly creeps toward them. We don't hear the conversation, until...

E.C.U. OF MOTHER'S FACE, HER EYES FILLED WITH QUESTIONS AND SHOCK

MOTHER
Multiple Sclerosis?

DR. PETERSON
I am afraid so. I will ask for a second opinion, but I doubt the diagnosis will be different.
(beat)
In any case, Kayla is not ready to go home. She will have to stay for observation and some preventive treatment. If it's not progressive, she could be home in a week or so. That's the best case ...

6 CONTINUED: 6

MOTHER
And in the worst case?

Dr. Peterson's serious face is his response.

DR. PETERSON
Progressive MS can put her to wheelchair in a few months... or worse.

Camera pushes in to show mother's shock.

7 INT. KAYLA'S ROOM - DAY 7
TWO WEEKS LATER

Kayla sitting at the computer, searching info re: Multiple Sclerosis. Her fingers franticly typing, pictures and article titles scroll on the screen. Some disturbing videos appear. Kayla stops, puts her head down, starts crying. Mother steps in and attempts to comfort Kayla, she pushes her away. Mother comes behind her and looks at screen. We HEAR the phone - mother leaves, fighting tears.

8 INT. KITCHEN - DAY 8

The phone rings. Mother picks it up - it's her friend SANDRA.

SANDRA
Hi Nancy, how is she?

Mother lowers her voice. She doesn't want Kayla to hear the conversation.

MOTHER
Not good. She's hardly left the room since she's come home.

SANDRA
Poor girl...
(beat)
Hey, a friend of mine's husband was diagnosed with MS about six years ago. He had went through some procedure, and three months later, he was practically symptom-free.

MOTHER
That must be it! I've been trying to find out more. Dr. Peterson says there is no cure, but I read an article recently that claimed that a cure for MS may have been found!

8 CONTINUED: 8

SANDRA
I don't know if it is the same thing, but it sounds promising. I would like you to meet her, she is a doctor, too, so she has a lot of information.
(pause)
What about Peter? He has that hot shot doctor friend, was he able to find anything?

KAYLA (O.S.)
Mom!

MOTHER
Dr. Robinson? I don't know. Peter and I don't really talk. I hear he is seeing someone now... Last thing I need is to deal with that.

SANDRA
Nonsense! It's his daughter too! Call him. Have him invite Dr. Robinson, and we can all talk about it at your place?

KAYLA (O.S.)
Mom!

MOTHER
(to Kayla)
Just a sec, honey!
(to Sandra)
I have to go. I'll think about it.

SANDRA
OK, we'll talk later.

9 INT. LIVING ROOM - NIGHT 9

Kayla, SANDRA and her friend DR. TERRI WILLIAMS sitting around a coffee table with some refreshments: coffee, tea, biscuits. Mother is running around, being a hostess.

TERRI
(speaking to Kayla)
I am so sorry you have to go through this... my husband has MS too.

KAYLA
(quiet, weak)
How did it happened to him?

9 CONTINUED: 9

TERRI
He was driving to work one day, suddenly he became disoriented and confused. The right half of his face got numb - just like that
(snaps her fingers)
- it was literally like someone flipped a switch...

MOTHER
(from distance?)
Similar with Kayla, it was very quick - she suddenly fainted...

KAYLA
Mom! I can still speak for myself!

TERRI
(pauses to take in Kayla's response)
After my husband was diagnosed I did a lot of research. I learned about a procedure that was proposed by a doctor in Italy. He used venoplasty to release blocked veins in the neck leading to the patient's brain.

The door bell rings. Mother leaves to answer the door.

TERRI (CONT'D) (CONTD)
It is not a cure, but the procedure showed a great improvement in some MS patients.

SANDRA
Here we go! That's good news! Maybe Kayla could have the same procedure...

TERRI
It is not so simple. Bob - my husband - went through it in 2007. He was one of the first five patients treated in Canada. Four of them improved - including Bob, but one did not. They all became the advocates for the procedure.

Mother returns with two more guests - Kayla's father Peter, and his friend DR. ROBINSON.

9 CONTINUED: (2) 9

MOTHER
Everybody, this is Peter, Kayla's dad, and his friend Dr. Robinson. He works at the City Medical Centre.
(gestures around the room)
My friend Sandra, Dr. Williams. She is a family doctor.

KAYLA
Daddy!

Kayla starts running to her dad but she loses her balance and he has to catch her. Her mother moves to help but Kayla's dad ignores her and helps Kayla back to her seat, sitting beside her.

Everybody arranges themselves around the coffee table as Mother makes half-hearted introductions.

FATHER
(worried)
How are you doing, honey?

Father helps weak Kayla back to her seat, sits beside her.

FATHER (CONT'D) (CONTD)
You'll be alright! We will beat this monster, I promise!

TERRI
I was just telling them about a MS procedure my husband went through.

DR. ROBINSON
I hope you don't mean the Liberation Therapy nonsense? It's been all over the news lately.

Silent tension fills the room. Nobody knows how to respond. People exchange puzzled looks.

SANDRA
What makes you say it's nonsense?

DR. ROBINSON
For one thing, it has not been properly clinically tested, so it can't actually be called a "therapy". It's very risky... and the results aren't that great... all it does is raise false hopes in people...
(MORE)

9 CONTINUED: (3) 9

DR. ROBINSON (CONTD)
And the advocacy for the procedure might have done more harm then good.

TERRI
(interrupts)
Well... some of the more advanced cases didn't improve. But the procedure itself is hardly risky. It's routinely used on non-MS patients.

DR. ROBINSON
The positive results are just an anecdotal evidence. You wouldn't take aspirin to cure a broken leg, would you? - still some people might feel better if you did...

TERRI
But until venoplasty, Bob was getting worse and worse, and since the procedure the progression stopped.

SANDRA
That's right! He is not his old self, but he walks without a cane... What's anecdotal about that?

DR. ROBINSON
(murmurs to himself)
Placebo effect?...

Kayla is puzzled and helpless. Father comforts her.

TERRI
And the truth is - it's not been clinically tested in Canada because since then, the procedure has been banned here.

MOTHER
What?

SANDRA
Are you serious? Why?

9 CONTINUED: (4) 9

DR. ROBINSON
Well - the medical community concluded it is an unproven procedure for MS. It can harm patients!

TERRI
I am not so sure. The technique is similar to angioplasty, which is a routine, low risk procedure for a wide variety of conditions, but for some reason, for MS patients it was classified as "highly experimental".

KAYLA
There we go again. As long as it is playing with rats in the lab, or doing disgusting stuff to animals, scientists can experiment what they want, but to actually help sick people? Noooo... Nerds...

DR. ROBINSON
That's a rather simplistic view.

Kayla makes a dismissive face.

DR. ROBINSON (CONT'D) (CONTD)
Scientists must follow certain protocols - they can't just declare something a cure and release it into the wide medical community. The health care system isn't here to provide experimental therapies. Those must be done in a rigourous, scientific, ethically approved research!

FATHER
I think everybody understands that, but why to ban it outright?

DR. ROBINSON
The hypothesis didn't seem to fit with a lot of other observations and data we had... that's why it was dismissed ... but the buzz outside the medical community just...!

Dr. Robinson makes an explosive gesture.

9 CONTINUED: (5) 9

SANDRA
I am not surprised, any good news about MS would make a splash - and now with the internet...

DR. ROBINSON
Journalists paid no attention to the weaknesses of the theory AND the level of evidence - they were just screaming "A revolutionary treatment for the most debilitating disease!" They just want a sensation.

MOTHER
I've read some of the articles... a very different story from what Dr. Peterson has been saying!

FATHER
Aren't there are clinical trials going on now?

DR. ROBINSON
Yes, but they are still a long way from proving that this is even the right concept, so these are experiments with randomized control groups, are performed over long periods of time...

KAYLA
(interrupts)
Time... I don't have time! Haven't you heard? I have MS! That's what I HAVE! What people like me don't have is time...

Kayla breaks down in tears. Her father comforts her. Silence fills the room again. Everyone is thinking what to say.

MOTHER
So what do people do?

TERRI
Some go to clinics overseas ... but there are always concerns what kind of treatment one would get there, or back home in case of complications.

9 CONTINUED: (6) 9

SANDRA
OK, but even if it's not a "cure" - if it helps, I don't understand why they can't include it as a legitimate procedure.
(turns to Terri)
It's safe, right?

TERRI
It depends. Doctors are caught in the middle. We want the best for our patients - but Dr. Robinson is right - we are not used to the idea of advising unproven treatments ... our medical licenses are on the line.

FATHER
You must understand that science has its rules. It cannot cut corners, but produce evidence in certain ways.

SANDRA
Does it? Lots of scientific discoveries were made by a total fluke! How do you know this is not the case?

Father raises his hands in resignation.

TERRI
I always refer my patients to doctors I know for procedures I am familiar with. There are different treatments, some more effective than others... To support patients to go to Costa-Rica or India or some place else - where I do not know the doctors or the facilities - that is simply unacceptable.

DR. ROBINSON
That's right. This so-called 'Liberation Therapy' is done in some pretty shady places.
(sarcastic)
You might as well go see a psychic or a healer...

MOTHER
And why not? There are things science doesn't understand.

9 CONTINUED: (7) 9

FATHER
Really? ... I hope you are not serious!

KAYLA
(annoyed, under her breath)
... what's the difference? Since the "medical community" is just a bunch of bureaucrats!

FATHER
(disapproving)
Kayla!?

DR. ROBINSON
(to Kayla)
You shouldn't take any unnecessary risk. This Liberation Therapy thing... it's had problems. People get hung up on their hopes and don't see all the dangers...

FATHER
(Annoyed, to mother)
You must be mad! A healer? ... That wouldn't help anything!

Situation is heating up. It's a faux pax for the broken family. Others feel awkward.

MOTHER
What do you know? People aren't machines!
(sarcastically)
Where is YOUR "proper evidence"?

FATHER
Proper evidence? You need proper evidence? I think everyone ...

MOTHER
Everyone? Or you? You've always wanted everyone think what you do!

The situation is getting heated, Kayla jumps out of her seat, shaking.

KAYLA
Stop! Stop it you two! Can't you pretend for a moment to be normal?

Father and mother look around the room, embarrassed.

9 CONTINUED: (8) 9

SANDRA
(toward the couple, calming mother)
Hey, ... everybody is doing their best! You don't have to argue... it's not about who is right, it's about helping Kayla.

Kayla wants to leave fighting her tears, but as she gets up, she loses her balance again, and all weak, falls into a chair. She's got a relapse.

KAYLA'S BLURRED P.O.V.

People rushing toward Kayla, Terri checking her vitals, mother in shock.

MOTHER
Kayla!!!

SOMEONE'S HAND DIALING 9-1-1

CUT TO BLACK.

FADE IN:

10 INT. HOSPITAL 10

Mother sitting in the hospital hall, stirs her coffee in quiet contemplation. Her friend Sandra enters, walks toward her and quietly sits beside her.

MOTHER
(Blank stare into the space in front of her)
It's... the progressive type ... the worst.

She breaks down crying. Sandra comforts her.

SANDRA
Shhh... I am so sorry.
(pause)
What will we do?

MOTHER
I've talked to a healer. I have an appointment next week.

SANDRA
Are you sure you want to do that?

10 CONTINUED: 10

MOTHER
What else can I do?

Sandra is determined to be there for her friend. She nods her head in understanding.

11 EXT. PSYCHIC HEALER GARDEN - DAY 11

WIDE SHOT

We see Mother shaking hands with the HEALER, followed by unclear conversation. Mother is visibly distressed, the Healer calms her down.

CUT TO:

MOTHER
Doctors do not have any cure...

HEALER
Yes, I know ...

MOTHER
... and the cause is unknown, too

HEALER
Hmmm ... well, in holistic medicine, we don't believe in a single cause. That's a band-aid fix approach of conventional medicine, and we try to avoid it. A lot depends on the person who is sick.

MOTHER
You said you could help! Please ...

HEALER
We look beyond their symptomps and make a complete view of their state of body and mind, send energy to the ailing areas, strengthening and speeding up their healing response.
(pause)
It's too bad your daughter couldn't come today. Let me try to send her positive energy. Can you wait here, please?

The healer walks into a grassy/bushy area, slowly "getting into a trance" and sending energy to Kayla. Mother watches from distance when her cell phone rings.

11 CONTINUED: 11

FATHER (O.S.)
Hey, where are you? I thought I can see you in the hospital before we pick up Kayla.

MOTHER
What time? I am... with the healer.

Father takes time to take it in.

FATHER
Are you crazy? I hope you don't pay him! You know we should save every penny! We will need it to help Kayla!

MOTHER
(with tears in her eyes)
But I believe this IS helping her!

FATHER
You and your beliefs... nobody gets cured by a belief! Even if science can't always get a straight answer, it's the only way! Believe...

Mother sees the healer coming out of his retreat.

MOTHER
(interrupts)
At five at the hospital then?

FATHER
(frustrated)
Fine.

12 INT. HOSPITAL - DAY 12

Mother & Father waiting to pick up Kayla.

FATHER
I can't believe you went through with the voodoo stuff...
(pause)
I've been thinking about the Therapy thing for her... I guess if Kayla wants it, I couldn't say NO... but you know it would go against my beliefs.

MOTHER
It's expensive. Your friend was right.
(MORE)

12 CONTINUED: 12

MOTHER (CONTD)
The clinics we could afford are in very questionable places. But I've found one in Poland - that's a reasonably civilized country, no?

Kayla appears from around the corner on a wheelchair pushed by a nurse. Mother takes over the chair.

FATHER
(Attempting up beat voice)
Looking good

KAYLA
Hardly.
(toward Mother)
Wait, I can walk on my own!

Kayla has hard time getting up, is losing balance, but finally, slowly regains her posture and carefully walks out, supported by her parents. (more dialogue?)

13 INT. KAYLA'S ROOM - NIGHT 13
SEVERAL WEEKS LATER

Kayla sitting at her computer, searching the internet, watching "successful MS story" videos. Mother looks in, unnoticed by Kayla. Mother turns back, swallows her tears.

MOTHER
(tries to sound optimistic)
Wanna go out? Its a nice day!

KAYLA
(with resignation)
Whatever ...

14 EXT. PARK - DAY 14

KAYLA'S P.O.V. PEOPLE WALKING, KIDS PLAYING, TREES, BIRDS.

C.U. of Kayla, taking pictures. Camera pulls out to reveal Kayla in a wheel chair, contemplating her future. Slow pull out, we see father and mother in the background, engaged in a conversation. Kayla looks at them, turns the wheelchair away.

MONTAGE: SHOTS OF BIRDS, WAVES, TREES, ROCKS, ALTERNATED WITH KAYLA FROM VARIOUS ANGLES.

FADE TO BLACK.

Before the CREDIT SCROLL, a short description of Multiple Sclerosis, it's symptoms, how it's treated, and the controversies.

C: Breakdown Sheet Sample

CODE-BREAKDOWN SHEETS/STRIPS
Day Ext. -Yellow
Night Ext. - Green
Day Int. - White
Night Int. - Blue
Numbers reffer to
budget categories

SCRIPT BREAKDOWN SHEET

DATE

PRODUCTION COMPANY | PRODUCTION TITLE | BREAKDOWN PAGE NUMBER

SCENE NO. | SCENE NAME | INT. OR EXT.

DAY OR NIGHT

DESCRIPTION | PAGE COUNT

CAST
Red (1301-2-3)

EXTRAS/ATMOSPHERE
Green (2120)

LOCATION

EXTRAS/SILENT BITS
Yellow (2120)

STUNTS
Orange (1304-5)

SPECIAL EFFECTS
Blue (2700)

PROPS
Violet (2500)

VEHICLES/ANIMALS
Pink (2600/4500)

WARDROBE
Circle (3400)
hooded Tracksuit
Tear off pants

MAKEUP/HAIR
Asterix (3500)

SOUND EFFECTS
Brown (5100,5300,5400)

SPECIAL EQUIPMENT
Box

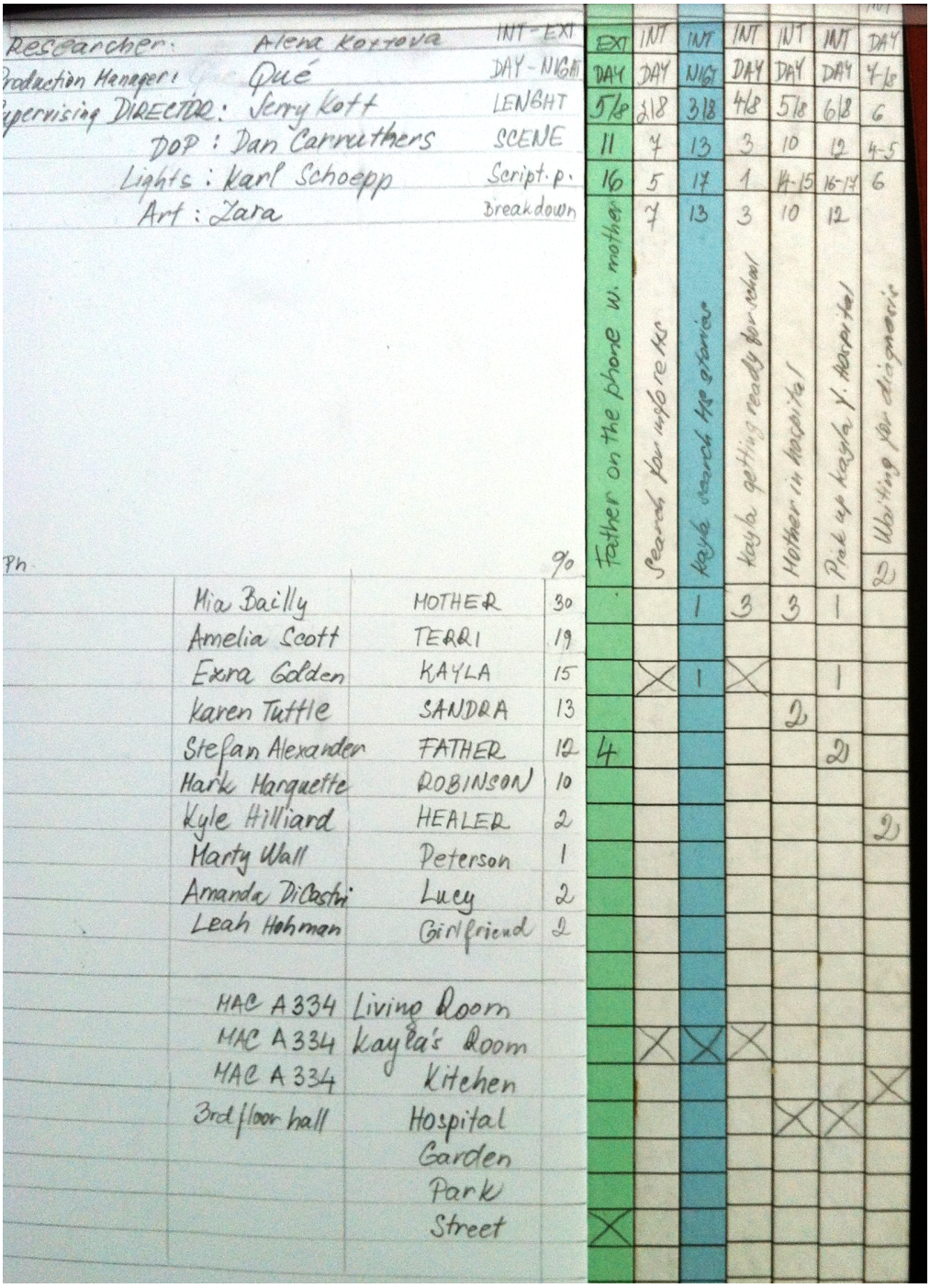
PRODUCTION NOTES

D: Production Strips Guide

Individual strips to cut independently and fill in

PRODUCTION BOARD: Heading Column											
Film Title:	*The Shadows of Hope*		INT/EXT		EXT		INT				
Production:	*Zue*		DAY/NIGHT		DAY		DAY				
Director:	*Jerry Kott*		Scene LENGHT		5/8		2/8				
DOP:	*Dan Caruthers*		Script PAGE		11		7				
			BREAKDOWN pg.		16		5				
Brief Scene Description *This is an example of filling in the strips (see picture)* *1. Create this heading column first:* *2. Fill in the strips in story order– i.e. scene 1,2,3,4 etc.* *3. Cut strips apart* *4. Organize them according to availability of* *a) locations* *b) actors* *Characters & Actors:*					Father on the phone with Mother		Kayla searches info about MS				
Phone #	Total scenes	Actor:	Character:								
	30%	*Mia*	**MOTHER**								
	19%	*Amelia*	**TERRI**								
	15%	*Ezra*	**KAYLA**				X				
	13%	*Karen*	**SANDRA**								
	12%	*Stefan*	**FATHER**		4x						
	10%	*Mark*	**ROBINSON**								
	2%	*Kyle*	**HEALER**								
		LOCATIONS:	Living Room								
			Kitchen				X				
			Hospital								
			Street		X						

E: Production Board Sample



F: Budget Template

FILM Budget: TITLE .....

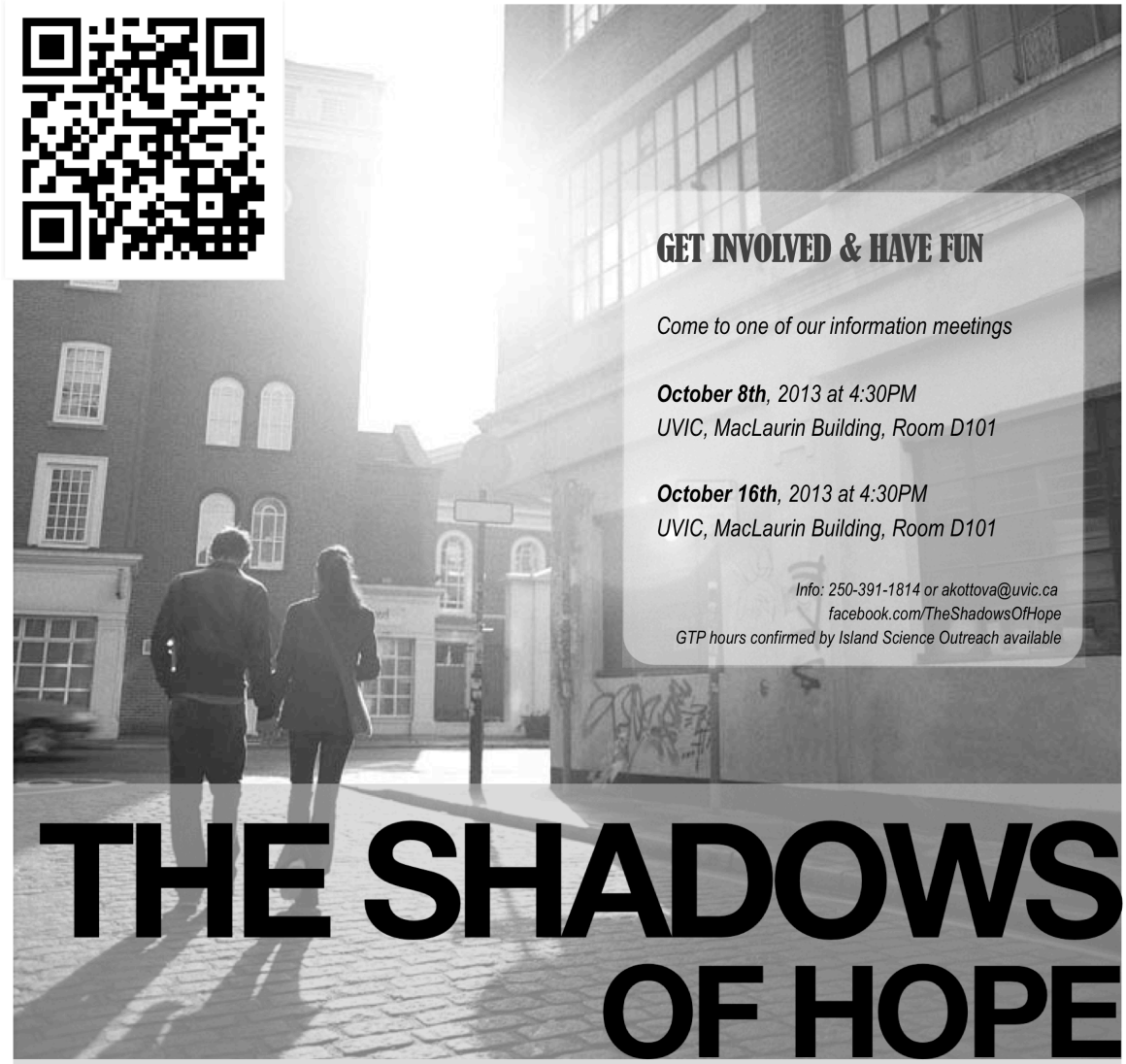
		CASH	*notes*	DONATED	TOTAL
1	Writer		script fee:		0.00
2	Producer				0.00
3	Director - Film Consultant				0.00
4	DOP - Film Consultant				0.00
5	Camera - Film Consultant				0.00
6	Sound - Film Consultant				0.00
7	Art Director- Film Consultant				0.00
8	Make-up Director- Film Consultant				0.00
8	Performers -main				0.00
9	- extras				0.00
10	Rights				0.00
	SUBTOTAL A	**0.00**		**0.00**	**0.00**
11	Choreographer				0.00
12	Set Design/Construction/Misc				0.00
13	Rehearsal Space				0.00
14	Location Space				0.00
15	Sound Studio				0.00
16	Special Effects				0.00
17	Wardrobe labour				0.00
18	Wardrobe supplies/rental				0.00
19	Makeup/hair Labour				0.00
20	Makeup/hair supplies				0.00
21	Lighting Labour				0.00
22	Camera Labour				0.00
23	Grip LABOUR				0.00
24	Sound Person				0.00
25	PA				0.00
27	Craft Service		$10/person/day		0.00
28	Travel expenses				0.00
29	Art Supplies				0.00
30	Props				0.00
31	Lighting Package				0.00
32	Camera Package				0.00
33	Grip Package				0.00
34	Sound Equipment				0.00
	SUBTOTAL B	**0.00**		**0.00**	**0.00**
38	Editor				0.00
40	Video post (sound)				0.00
41	Music - composition fees				0.00
44	Computer animation				0.00
	SUBTOTAL C	**0.00**		**0.00**	**0.00**
46	Legal/ Insurance.				0.00
	SUBTOTAL D	**0.00**		**0.00**	**0.00**
	SUBTOTAL A+B+C+D	0.00		0.00	0.00
	TOTAL PRODUCTION COSTS				0.00
	AMOUNT REQUESTED			**0.00**	
		participants	cost per week		

G: Film The Shadows of Hope

https://vimeo.com/124070922

APPENDIX

APPENDIX A: Promotion School Flyer



APPENDIX B: Student Application

This is an application to take part in a Filmmaking Workshop that is offered free of charge. Participants will be part of a research that will proceed during the film production.

Do you agree to participate in the research project? YES NO *(circle one)*

Contact Information:

First and Last Name:
Address:
City & Postal code:
Phone:
E-mail:
School: Grade:
How did you hear about the project?

Please answer the following questions as completely and honestly as you can.

Why do you want to get involved in filmmaking?

Do you have any prior experience with film or drama.

What are your favourite subjects at school?

What are your hobbies/interests?

What scientific subjects you like (if any)?

What are your future plans?

What would others consider your greatest strengths?

What would others consider to be areas where you need improvement?

We will be making film about science. Following questions will focus on the subject area of the film. There are no right or wrong answers. Answer the questions with ease, your opinion matters.
Please read each statement carefully, and then indicate the degree to which you agree or disagree with EACH statement by circling the appropriate letters to the right of each statement:

(SD= Strongly Disagree; D = Disagree More Than Agree; U = Uncertain or Not Sure; A = Agree More Than Disagree; SA = Strongly Agree).

SUSSI Questionnaire

APPENDIX C: SUSSI Questionnaire

1. Observations and Inferences

A. Scientists' observations of the same event may be different because the scientists' prior knowledge may affect their observations.
SD D U A SA

B. Scientists' observations of the same event will be the same because scientists are objective.
SD D U A SA

C. Scientists' observations of the same event will be the same because observations are facts.
SD D U A SA

D. Scientists may make different interpretations based on the same observations.
SD D U A SA

With examples, explain why you think scientists' observations and interpretations are the same OR different.*

2. Change of Scientific Theories

A. Scientific theories are subject to on-going testing and revision.
SD D U A SA

B. Scientific theories may be completely replaced by new theories in light of new evidence.
SD D U A SA

C. Scientific theories may be changed because scientists reinterpret existing observations.
SD D U A SA

D. Scientific theories based on accurate experimentation will not be changed.
SD D U A SA

With examples, explain why you think scientific theories do not change OR how (in what ways) scientific theories may be changed.

3. Scientific Laws vs. Theories

A. Scientific theories exist in the natural world and are uncovered through scientific investigations.
SD D U A SA

B. Unlike theories, scientific laws are not subject to change.
SD D U A SA

C. Scientific laws are theories that have been proven.
SD D U A SA

D. Scientific theories explain scientific laws**.
SD D U A SA

With examples, explain the difference between scientific theories and scientific laws.

4. Social and Cultural Influence on Science

A. Scientific research is not influenced by society and culture because scientists are trained to conduct "pure", unbiased studies.
SD D U A SA

B. Cultural values and expectations determine what science is conducted and accepted.
SD D U A SA

C. Cultural values and expectations determine how science is conducted and accepted.
SD D U A SA

D. All cultures conduct scientific research the same way because science is universal and independent of society and culture.
SD D U A SA

With examples, explain how society and culture affect OR do not affect scientific research.

5. Imagination and Creativity in Scientific Investigations

A. Scientists use their imagination and creativity when they collect data.
SD D U A SA

B. Scientists use their imagination and creativity when they analyze and interpret data.
SD D U A SA

C. Scientists do **not** use their imagination and creativity because these conflict with their logical reasoning.
SD D U A SA

D. Scientists do **not** use their imagination and creativity because these can interfere with objectivity.
SD D U A SA

*With examples, explain how and when scientists use imagination and creativity **OR** do not use imagination and creativity.*

6. Methodology of Scientific Investigation

A. Scientists use different types of methods to conduct scientific investigations.
SD D U A SA

B. Scientists follow the same step-by-step scientific method.
SD D U A SA

C. When scientists use the scientific method correctly, their results are true and accurate.
SD D U A SA

D. Experiments are not the only means used in the development of scientific knowledge**.
SD D U A SA

*With examples, explain whether scientists follow a single, universal scientific method **OR** use different types of methods.*

APPENDIX D: Character Questionnaire

……

Your Name

CHARACTER'S EVALUATION FORM

Guide:
Think about the character identified at the top of following page. What do you think is his/her perspective and understanding of science? Place an **x** (or arrow) on the 'ticker-tape' below to indicate your opinion about the character's view of science. Each end of the 'ticker-tape' is identified by the described attitude.

Example:

Mother (Nancy)…… *in my opinion thinks that what we know in science …*

(name of the character)

Scientific knowledge is

⇓

↑ it is transmitted from authority figures (e.g., scientists, textbooks, teachers)

↑ it is created/constructed by each individual separately

In the second section, please indicate how much the character's view matches your own e.g. your level of agreement with this character. Colour in or circle the appropriate box.
In the space provided please explain why you agree or disagree with this character's attitude and include suggestion of what attitude this character should demonstrate

Do you agree with this character's perspective? (colour in the appropriate box)

Strongly disagree	Disagree	Undecided	Agree	Strongly Agree

Explain why?
I think that she should be looking into…..

Character: **SANDRA**

What do you think is her understanding of:

1) *Source of scientific knowledge*

Scientific knowledge is

↑ ↑

it is created or transmitted from authority figures (e.g., scientists, textbooks, teachers)

it is created/constructed by each individual separately

Your level of agreement with this character?

Strongly disagree	Disagree	Undecided	Agree	Strongly Agree

Explain why?

If you do not have enough space here, continue on the back of this page ➡ ➡ ➡

2) *The imaginative/creative nature of science*

Scientific knowledge is

↑ ↑

completely free of human imagination or creativity

a product of imagination and creativity similar to poetry or painting

Your level of agreement with this character?

Strongly disagree	Disagree	Undecided	Agree	Strongly Agree

Explain why?

If you do not have enough space here, continue on the back of this page ➡ ➡ ➡

3) *The theory-laden nature of science*

Scientific knowledge is

↑ ↑

completely unaffected by scientists' personal backgrounds — influenced by scientists' existing theories and biases

Your level of agreement with this character?

Strongly disagree	Disagree	Undecided	Agree	Strongly Agree

Explain why?

If you do not have enough space here, continue on the back of this page ➡ ➡ ➡

4) Empirical nature of scientific knowledge

Scientific knowledge is

↑ ↑

completely based on pure logic or faith — derived only from observations and data.

Your level of agreement with this character?

Strongly disagree	Disagree	Undecided	Agree	Strongly Agree

Explain why?

If you do not have enough space here, continue on the back of this page ➡ ➡ ➡

5) The nature of scientific method

Scientific knowledge is

↑ ↑

based on single, universal step-by-step scientific method — derived by using multiple methods for solving scientific problems

Your level of agreement with this character?

Strongly disagree	Disagree	Undecided	Agree	Strongly Agree

Explain why?

If you do not have enough space here, continue on the back of this page ➡ ➡ ➡

6) The changing nature of scientific knowledge

Scientific knowledge is

↑ ↑

unchanged, once the information is discovered it will be always true

tentative, changing with new discoveries, but relatively stable

Your level of agreement with this character?

Strongly disagree	Disagree	Undecided	Agree	Strongly Agree

Explain why?

If you do not have enough space here, continue on the back of this page ➡ ➡ ➡

7) The coherent nature of scientific knowledge

Scientific knowledge is

↑ ↑

a collection of isolated pieces of information or discoveries

unified system of interrelated ideas, concepts and principles

Your level of agreement with this character?

Strongly disagree	Disagree	Undecided	Agree	Strongly Agree

Explain why?

If you do not have enough space here, continue on the back of this page ➡ ➡ ➡

8) The socially and culturally embedded nature of science

Scientific knowledge is

↑ ↑

unaffected by society and culture, it develops independently of culture

affected by social and cultural factors, and influenced by the particular society's norms and beliefs.

Your level of agreement with this character?

Strongly disagree	Disagree	Undecided	Agree	Strongly Agree

Explain why?

If you do not have enough space here, continue on the back of this page ➡ ➡ ➡

APPENDIX E: SUSSI Taxonomy

Taxonomy of Views about Nature of Science and Scientific Inquiry
Aspect Explanation/Description Items

1. Observations and Inferences
Science is based on both observations and inferences.
Observations are descriptive statements about natural phenomena that are directly accessible to human senses (or extensions of those senses) and about which observers can reach consensus with relative ease. Inferences are interpretations of those observations. Perspectives of current science and the scientist guide both observations and inferences. Multiple perspectives contribute to valid multiple interpretations of observations.
1A (+); 1B (-); 1C (-); 1D (+)

2. Tentativeness
Scientific knowledge is both tentative and durable. Having confidence in scientific knowledge is reasonable while realizing that such knowledge may be abandoned or modified in light of new
evidence or reconceptualization of prior evidence and knowledge. The history of science reveals both evolutionary and revolutionary changes.
2A (+); 2B (+); 2C(+); 2D (-)

3. Scientific theories and laws
Both scientific laws and theories are subject to change. Scientific laws describe generalized relationships, observed or perceived, of natural phenomena under certain conditions. Scientific Theories are well-substantiated explanations of some aspect of the natural world. Theories do not become laws even with additional evidence; they explain laws. However, not all scientific laws have accompanying explanatory theories.
3A (-); 3B (-); 3C (-); 3D (+)

4. Social and cultural embeddedness
Scientific knowledge aims to be general and universal. As a human endeavour, science is influenced by the society and culture in which it is practiced. Cultural values and expectations determine what and how science is conducted, interpreted, and accepted.
4A (-); 4B(+); 4C(+); 4D(-)

5. Creativity and Imagination
Science is a blend of logic and imagination. Scientific concepts do not emerge automatically from data or from any amount of analysis alone. Inventing hypotheses or theories to imagine how the world works and then figuring out how they can be put to the test of reality is as creative as writing poetry, composing music, or designing skyscrapers. Scientists use their imagination and creativity throughout their scientific investigations.
5A(+); 5B(+); 5C (-); 5D (-)

6. Scientific methods
Scientists conduct investigations for a wide variety of reasons. Different kinds of questions suggest different kinds of scientific investigations. Different scientific domains employ different
methods, core theories, and standards to advance scientific knowledge and understanding. There is no single universal step-by- step scientific method that all scientists follow. Scientists investigate research questions with prior knowledge, perseverance, and creativity. Scientific knowledge is gained in a variety of ways including observation, analysis, speculation, library investigation and experimentation.
4A (-); 4B(+); 4C(+); 4D(-)
6A (+); 6B (-); 6C (-); 6D (+)

Source:
Chen, X., Adams, A. D., & Macklin, M. (2006). SUSSI: Revision and further validation of an assessment instrument. *Student Understanding of Science and Scientific Inquiry*. San Francisco, CA.

APPENDIX F: Interview Questions

Please mark your preference for 3-5 questions from the list below

Q SET: Enjoyment & Involvement

❒ Q: How does it feel to be on film set?
❒ Q: What is the most interesting thing you learned?
❒ Q: What would you have done differently?

Q SET: Team and cooperation

❒ Q: How does the team cooperate?
❒ Q: What would you change on the team?
❒ Q: How would you do a similar project at school?

Q SET: Film Story

❒ Q: What is the main issue in the film?
❒ Q: How does the story relate to real life?
❒ Q: How do you think the story ends?

Q SET: Characters

❒ Q: What character did you like the most?
❒ Q: Do the characters remind you of anybody in your life and who?
❒ Q: Can you imagine yourself in the situation of the main character?

Q SET: Evaluation of the final film

❒ Q: How much does the film agree with your understanding of the character?
❒ Q: How do you think your friends will react to the film?
❒ Q: What do you like/dislike on the final film?

Q SET: Anything else

❒ Q: What crossed your mind as really new and interesting?
❒ Q: Anything else you want to add?
❒ Q: Do you think you will make another film in the future?

APPENDIX G: Sample Data tables

Table 1

Comparison SUSSI & Self Character Quiz: (examples)

		Q	SUSSI	self	difference	**Range**		**Calculate:**
Naomi		1	94.5	55	39.5		24%	**Min/Max**
		2	63	112	49		29%	19%
		3	52.5	122	69.5		41%	52%
		4	94.5	138	43.5		26%	**Median**
*		5	115.5	148	32.5		19%	28%
		6	94.5	138	43.5		26%	**Average**
		7	73.5	137	63.5		38%	32%
x		8	52.5	140	87.5		52%	
Mina	x	1	105	37	68		40%	**Min/Max**
		2	84	44	40		24%	5%
		3	84	150	66		39%	40%
		4	105	137	32		19%	**Median**
*		5	73.5	82	8.5		5%	26%
		6	73.5	135	61.5		37%	**Average**
		7	52.5	36	16.5		10%	25%
		8	84	133	49		29%	

Table 2

Comparison SUSSI & Self Character Quiz; Overview of minimum and maximum range

	MINIMUM/MAXIMUM range										
		Ethan	Layla	Mina	Emma	Caleb	Aubrey	James	Jack	Ryan	Lucas	Alex
1	source			MAX						MAX		
2	imagination				MAX	min		MAX				
3	theory-laden	MAX			min			min	MAX	min		
4	empirical	min										
5	method		min	min					min		MAX	
6	change						min					min
7	system						MAX				min	MAX
8	culture		MAX			MAX						

Table 3

Sample Character Quizzes data set

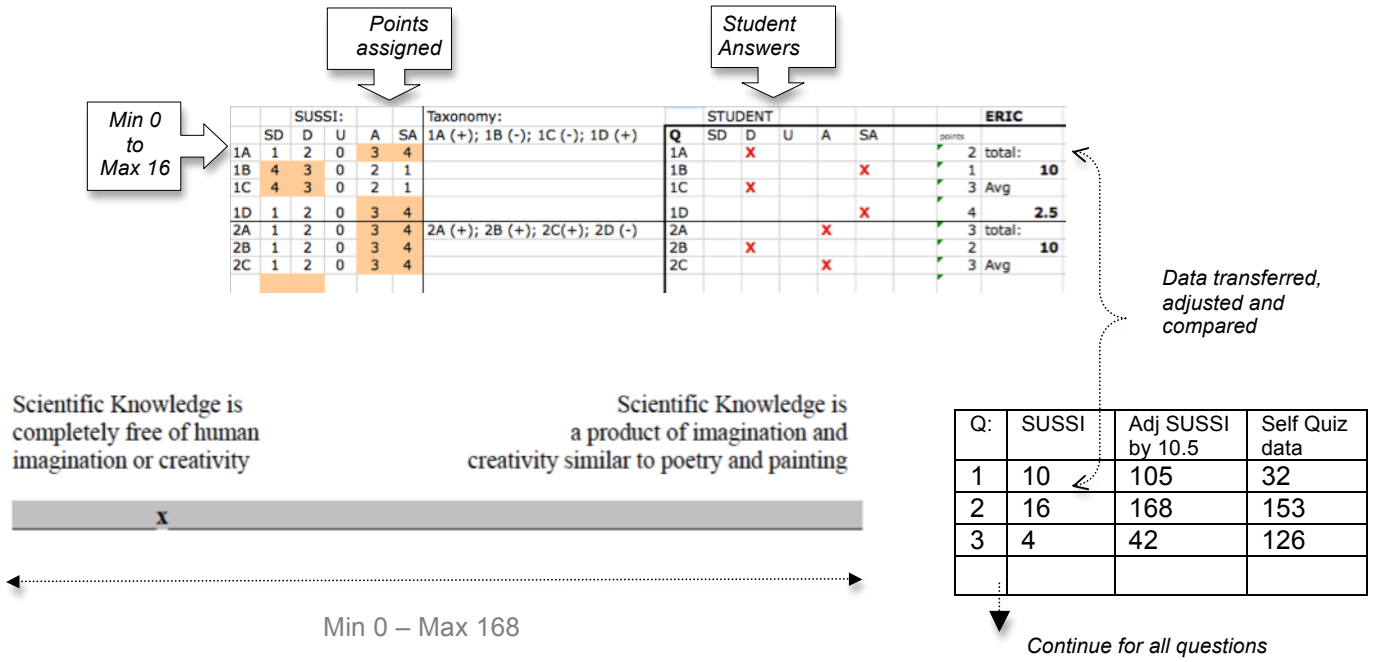
Student # 25																
	Q1		Q2		Q3		Q4		Q5		Q6		Q7		Q8	
self	**55**		**112**		**122**		**30**		**148**		**138**		**31**		**140**	
Kayla	24	D	56	D	131	A	122	D	94	A	112	A	105	D	132	A
Healer	150	D	145	D	140	A	53	A	154	A	140	A	42	A	24	D
Mother	133	U	94	U	63	D	34	A	124	A	125	A	54	A	37	D
Sandra	122	U	118	A	125	A	57	A	71	D	115	A	100	D	99	A
Dr.Williams	114	D	32	D	113	A	85	U	61	D	128	A	120	D	48	D
Father	34	D	25	D	58	D	130	D	60	D	66	D	82	D	93	U
Dr.Robinson	16	D	6	D	114	A	156	D	29	D	20	D	110	D	125	A

APPENDIX H: Questionnaires mapping

SUSSI questionnaire data mapping procedure

Assigning evaluative positive points ranging from 1 point to 4 points to each SUSSI answer students provided followed SUSSI evaluation scheme (Chen, Adams, & Macklin, 2006); incorrect, i.e., (-) received from 1 to 2 points, correct, i.e., (+) received from 3 to 4 points. Each SUSSI domain consisted of four answers, therefore the maximum points for each domain was 16 points. The Character Quiz self-assessment answers for each domain returned a number between 0 and 168 reflecting the actual length of the continuum scale in millimetres. The maximum of 16 points in SUSSI was mapped on the continuum scale of 168 points by adjusting each SUSSI point by 10.5 and creating a comparable set of data. Comparison of data from Character quizzes filled for each character-context were collected in the same scale and therefore could be compared without change.

Example: SUSSI data table & continuum scale mapping



Q:	SUSSI	Adj SUSSI by 10.5	Self Quiz data
1	10	105	32
2	16	168	153
3	4	42	126

APPENDIX I: Sample worded responses

Illustrative examples of students' worded responses in respect to a sample of code assignments

Code "FACT"	Code "LOGICAL STUDY"	Code "NOT AFFECTED, OBJECTIVE, TRUE"	Code "TESTED, JUSTIFIED, PROPER, VALID"	Code "PROOF, EVIDENCE"
I think he gets his facts based more out of pure knowledge and conventional relevance, not creativity. (24-2-8)	science is a logical study rather than perspective. It is dealt with logical reasoning. (26-4-S)-	science needs to be completely unaffected by personal backgrounds because it needs to be unbiased. (31-3-8)	science happens through proper observations and data. (31-2-5)	In science you have to prove your theory is true. Fate can't prove that. (32-4-1)
laws like the "law of mass" have been proven and are fact. (29-3-S)	science is logical thinking, and typically is logic. (32-2-1)	scientists should use logic and reasoning to uncover the truth. (30-5-S)	science should follow specific procedures in order to get proper or proven information. (31-5-7)	The knowledge has to be created from proper evidence and examination. (26-2-1)
scientific knowledge is fact, not objective opinion. (30-1-1)	it is a rather logical thought process. I believe science is mostly free of imagination. (32-2-8)	it is important to be objective when collecting data. (26-5-S)	if scientists do not follow a universal method, it is not considered valid. (35-6-S)	science regularly follows a process to prove the theory. (32-5-1)
scientific knowledge is fact, so it can't be constructed without prior knowledge. (29-1-1)	science is a logical study. Imagination can start an experiment that leads to a new invention, but it cannot produce scientific knowledge. (26-2-1)	science can start out from your imagination but after that a scientist will try to make it true. (34-2-1)	scientists must have their theories tested many times in order for them to be considered valid. (35-1-6)	A theory has evidence to support it but may not be entirely proven. A law must be completely proven and unquestionable. (30-3-S)
science is a picture based on true facts and no imagination (31-2-7) it's fact, so there's not enough room for imaginative processes. (29-2-1)	he logically proves multiple points in his thesis, so there's more than one structure of facts. (24-7-8).	You need imagination to attempt to find science. (28-2-3) scientific laws are proving to be true and cannot be broken. (35-3-S)	if scientists do not follow the scientific method, the results will not be considered valid. (35-5-1)	scientific knowledge is created or transmitted from people who have tested and proven it to the scientific community. (32-1-3)

APPENDIX J: Questionnaire comparison

Character Quiz and SUSSI questions: Content Comparison

Item	Quiz scale	Item	SUSSI	
1	**Source of scientific Knowledge** -it is created or transmitted from authority figures (e.g., scientists, textbooks, teachers) -it is created/constructed by each individual separately	1	**Observations and Inferences** - Scientists' observations of the same event will be the same because scientists are objective. - Scientists' observations of the same event will be the same because observations are facts. - Scientists may make different interpretations based on the same observations. - Scientists' observations of the same event may be different because the scientists' prior knowledge may affect their observations.	
2	**The imaginative/creative nature of science** - completely free of human imagination or creativity - a product of imagination and creativity similar to poetry or painting	5	**Creativity and Imagination** - Scientists do not use their imagination and creativity because these conflict with their logical reasoning - Scientists do not use their imagination and creativity because these can interfere with objectivity. - Scientists use their imagination and creativity when they collect data. - Scientists use their imagination and creativity when they analyze and interpret data.	
3	**The theory-laden nature of science** - completely unaffected by scientists' personal backgrounds - influenced by scientists' existing theories and biases	4	**Social and cultural embeddedness** - Scientific research is not influenced by society and culture because scientists are trained to conduct "pure", unbiased studies - All cultures conduct scientific research the same way because science is universal and independent of society and culture. - Cultural values and expectations determine what science is conducted and accepted. - Cultural values and expectations determine how science is conducted and accepted.	
4	**Empirical nature of scientific knowledge** - completely based on pure logic or fait - derived only from observations and data.	1	**Observations and Inferences** - Scientists' observations of the same event will be the same because scientists are objective. - Scientists' observations of the same event will be the same because observations are facts. - Scientists may make different interpretations based on the same observations. - Scientists' observations of the same event may be different because the scientists' prior knowledge may affect their observations.	

5	**The nature of scientific method** - based on single, universal step-by-step scientific method - derived by using multiple methods for solving scientific problems	6	**Scientific methods** - Scientists follow the same step-by-step scientific method. - When scientists use the scientific method correctly, their results are true and accurate. - Experiments are not the only means used in the development of scientific knowledge - Scientists use different types of methods to conduct scientific investigations.	
6	**The changing nature of scientific knowledge** - unchanged, once the information is discovered it will be always true - tentative, changing with new discoveries, but relatively stable	2	**Change of Scientific Theories** - Scientific theories based on accurate experimentation will not be changed. - Scientific theories are subject to on-going testing and revision. - Scientific theories may be completely replaced by new theories in light of new evidence. - Scientific theories may be changed because scientists reinterpret existing observations.	
7	**The coherent nature of scientific knowledge** - unified system of interrelated ideas, concepts and principles - a collection of isolated pieces of information or discoveries	3	**Scientific theories and laws** - Unlike theories, scientific laws are not subject to change. - Scientific laws are theories that have been proven. - Scientific theories explain scientific laws - Scientific theories exist in the natural world and are uncovered through scientific investigations.	
8	**The socially and culturally embedded nature of science** - unaffected by society and culture, it develops independently of culture - affected by social and cultural factors, and influenced by the particular society's norms and beliefs.	4	**Social and cultural embeddedness** - Scientific research is not influenced by society and culture because scientists are trained to conduct "pure", unbiased studies - All cultures conduct scientific research the same way because science is universal and independent of society and culture. - Cultural values and expectations determine what science is conducted and accepted. - Cultural values and expectations determine how science is conducted and accepted.	

Note: Additional correspondence explanation can be found in SUSSI taxonomy Appendix E

Deng, F., Chen, D.-T., Tsai, C.-C., & Chai, C. S. (2011). Students' views of the nature of science: A critical review of research. Science Education, 95(6), 961–999.
Chen, X., Adams, A. D., & Macklin, M. (2006). SUSSI: Revision and further validation of an assessment instrument. Student Understanding of Science and Scientific Inquiry. San Francisco, CA.

APPENDIX K: Ethics Approval

University of Victoria

Human Research Ethics Board
Office of Research Services
Administrative Services Building
PO Box 1700 STN CSC
Victoria British Columbia V8W 2Y2 Canada
Tel 250-472-4545, Fax 250-721-8960
Email ethics@uvic.ca Web www.research.uvic.ca

Certificate of Approval

PRINCIPAL INVESTIGATOR:	**Alena Kottova**	**ETHICS PROTOCOL NUMBER** Minimal Risk - Delegated	**13-180**
UVic STATUS:	**Ph.D. Student**	ORIGINAL APPROVAL DATE:	11-Jun-13
UVic DEPARTMENT:	**EDCI**	RENEWED ON:	11-Jun-13
SUPERVISOR:	**Dr. David Blades**	APPROVAL EXPIRY DATE:	10-Jun-14

PROJECT TITLE: **Filmmaking as a Transformative Pedagogical Method for Secondary Student Engagement with Science: A mixed method study of the dynamics of high school students' views of the nature of**

RESEARCH TEAM MEMBERS: None

DECLARED PROJECT FUNDING: **None**

CONDITIONS OF APPROVAL

This Certificate of Approval is valid for the above term provided there is no change in the protocol.

Modifications
To make any changes to the approved research procedures in your study, please submit a "Request for Modification" form. You must receive ethics approval before proceeding with your modified protocol.

Renewals
Your ethics approval must be current for the period during which you are recruiting participants or collecting data. To renew your protocol, please submit a "Request for Renewal" form before the expiry date on your certificate. You will be sent an emailed reminder prompting you to renew your protocol about six weeks before your expiry date.

Project Closures
When you have completed all data collection activities and will have no further contact with participants, please notify the Human Research Ethics Board by submitting a "Notice of Project Completion" form.

Certification

This certifies that the UVic Human Research Ethics Board has examined this research protocol and concluded that, in all respects, the proposed research meets the appropriate standards of ethics as outlined by the University of Victoria Research Regulations Involving Human Participants.

REDACTED SIGNATURE

Dr. Rachael Scarth
Associate Vice-President Research Operations

Certificate Issued On: 11-Jun-13

13-180 Kottova, Alena

University of Victoria
Human Research Ethics Board
Office of Research Services
Administrative Services Building
PO Box 1700 STN CSC
Victoria British Columbia V8W 2Y2 Canada
Tel 250-472-4545, Fax 250-721-8960
Email ethics@uvic.ca Web www.research.uvic.ca

Certificate of Renewed Approval

PRINCIPAL INVESTIGATOR:	**Alena Kottova**
UVic STATUS:	**Ph.D. Student**
UVic DEPARTMENT:	**EDCI**
SUPERVISOR:	**Dr. David Blades**

ETHICS PROTOCOL NUMBER Minimal Risk - Delegated	**13-180**
ORIGINAL APPROVAL DATE:	11-Jun-13
RENEWED ON:	03-Jun-14
APPROVAL EXPIRY DATE:	10-Jun-15

PROJECT TITLE: **Filmmaking as a Transformative Pedagogical Method for Secondary Student Engagement with Science: A mixed method study of the dynamics of high school students' views of the nature of**

RESEARCH TEAM MEMBERS: None

DECLARED PROJECT FUNDING: **None**

CONDITIONS OF APPROVAL

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REDACTED SIGNATURE

Dr. Rachael Scarth
Associate Vice-President Research Operations

Certificate Issued On: 03-Jun-14

13-180 Kottova, Alena

University of Victoria | Office of Research Services | Human Research Ethics Board
Administrative Services Building Rm B202 PO Box 1700 STN CSC Victoria BC V8W 2Y2 Canada
T 250-472-4545 | F 250-721-8960 | uvic.ca/research | ethics@uvic.ca

Certificate of Renewed Approval

PRINCIPAL INVESTIGATOR:	**Alena Kottova**	**ETHICS PROTOCOL NUMBER** Minimal Risk Review - Delegated	**13-180**
UVic STATUS:	**Ph.D. Student**	ORIGINAL APPROVAL DATE:	11-Jun-13
UVic DEPARTMENT:	**EDCI**	RENEWED ON:	08-Jun-15
SUPERVISOR:	**Dr. David Blades**	APPROVAL EXPIRY DATE:	10-Jun-16

PROJECT TITLE: **Filmmaking as a Transformative Pedagogical Method for Secondary Student Engagement with Science: A mixed method study of the dynamics of high school students' views of the nature of**

RESEARCH TEAM MEMBERS: None

DECLARED PROJECT FUNDING: **None**

CONDITIONS OF APPROVAL

This Certificate of Approval is valid for the above term provided there is no change in the protocol.

Modifications
To make any changes to the approved research procedures in your study, please submit a "Request for Modification" form. You must receive ethics approval before proceeding with your modified protocol.

Renewals
Your ethics approval must be current for the period during which you are recruiting participants or collecting data. To renew your protocol, please submit a "Request for Renewal" form before the expiry date on your certificate. You will be sent an emailed reminder prompting you to renew your protocol about six weeks before your expiry date.

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Certification

This certifies that the UVic Human Research Ethics Board has examined this research protocol and concluded that, in all respects, the proposed research meets the appropriate standards of ethics as outlined by the University of Victoria Research Regulations Involving Human Participants.

REDACTED SIGNATURE

Dr. Rachael Scarth
Acting Associate Vice-President, Research

Certificate Issued On: 08-Jun-15

13-180 Kottova, Alena