

Impact of a Youth Development Camp on Participants' Skills, Attitudes, and Views

Towards Science and Scientific Inquiry

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## **Abstract**

This mixed-methods research study sought to determine the impact of an informal science camp—the Youth Science Inquiry Development Camp (YSIDC)—on participants’ science inquiry skills, through self-assessment, as well as their views and attitudes towards science and scientific inquiry. Pre and post data were collected using quantitative surveys (SPSI, CARS), a qualitative survey (VOSI-E), interviews, and researcher’s observations. Paired sample t-tests from the quantitative surveys revealed that the YSIDC positively impacted participants’ science inquiry skills and attitudes towards science. Interviews supported these findings and provided contextual reasons for these impacts. Implications from this research would suggest that informal and formal educational institutions can increase science inquiry skills and promote positive views and attitudes towards science and scientific inquiry by using non-competitive cooperative learning strategies with a mixture of guided and open inquiry. Suggested directions for further research include measuring science inquiry skills directly and conducting longitudinal studies to determine the lasting effects of informal and formal science programs.

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## **CHAPTER ONE: INTRODUCTION TO THE PROBLEM**

This study explored the impact of a week-long Youth Science Inquiry Development Camp (YSIDC) for students ages 9 to 14 in the Niagara Region. The emphasis of this mixed-methods investigation was to discover how the intervention of an inquiry camp would impact participants' attitudes and views about science as well as their abilities in conducting open science inquiries. Data were collected in the summer of 2013 in science facilities at the camp located at a university.

### **Background of the Problem**

Major reform documents such as the *National Science Education Standards* (National Research Council [NRC], 1996), the *Common Framework of Science Learning Outcomes, K-12* (Council of Ministers of Education, Canada [CMEC], 1997), and the *Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012) have emphasized the importance of inquiry-based instruction. In this study, inquiry-based instruction refers to the active process in which learners engage and construct meaning and reflect on the nature of scientific inquiry (SI). Many experts in the field agree that an important goal of science education is to foster curiosity and interest in students, thus increasing their motivation to learn concepts (Leonard & Penick, 2009; Pintrich & Schunk, 1996; Wade, 2001). Science educational researchers have also identified the importance of attitudes towards science in science learning (Koballa & Rice, 1985; Schibeci, 1984). Just like student curiosity and interest, positive attitudes towards science can be correlated to higher student achievement (House, 1996; Lee & Burkam, 1996; Rennie & Punch, 1991).

Despite Anderson's (2007) conclusion that inquiry is a viable guiding theme for

science learning and teaching, the relationship between inquiry-based learning and attitudes toward science is not yet well established (Hung, 2010). Several studies (Berg, Bergendahl, Lunberg, & Tibell, 2003; Gibson & Chase, 2002; Lord & Orkwiszewski, 2006; Shymansky, Hedges, & Woodworth, 1990) reported a positive association between inquiry-based learning and attitudes towards science. However, others (Roth, 1992; Smith & Anderson, 1984) concluded that there was no relationship between the two. Therefore, there still is a need to explore the relationship between inquiry-based learning and attitudes towards science.

Current science curriculum documents (Ontario Ministry of Education [OME], 2007, 2008a, 2008b) in Ontario identify the use of inquiry approaches to student learning through challenging activities as the most productive way to develop students' understandings of concepts and improve their skill development. These documents also suggest that inquiry-based learning will help nurture wonderment and promote students' natural curiosity about the world around them.

Despite the will of researchers and curriculum developers, student-led inquiry remains on the periphery in Ontario's schools. Bencze and Di Giuseppe (2006) claim that in practice, school systems emphasized the products of science at the expense of developing comprehensive scientific literacy.

One possible solution to address the lack of consistent quality of open inquiry in schools is to have students take advantage of informal or out-of-school educational programs. Rennie (2007) argued that many out-of-school programs and institutions are a remedy for a dull curriculum taught in many formal school classrooms. Additionally, Rennie suggested that these alternative science programs and institutions are under-

researched and undervalued for their ability to promote science learning. This study evaluated the impacts of an out-of-school educational program that Rennie promotes.

### **Statement of Problem**

Traditional didactic teaching approaches such as reading from a textbook, answering questions, and memorizing definitions and diagrams may not engage students in science (House, 2008; Lee, Deaktor, Hart, Cuevas, & Enders, 2006). Albert Bandura (1986) wrote that the beliefs people have about themselves in specific domains are powerful predictors of subsequent attainment, even more powerful than knowledge, skill, and previous attainment. Bandura also explained that people will engage in tasks they feel competent in and avoid those in which they do not. When students fail in science, their attitudes and self-efficacy beliefs towards learning science are significantly affected (Tsai, Ho, Liang, & Lin, 2011). This has deleterious effects on student achievement and further compounds the issues of engagement (Britner & Pajares, 2001). Without positive experiences in science in school, students will shy away from taking non-compulsory science courses in secondary school (Osborne, Simon, & Collins, 2003), which will limit their options at postsecondary institutions.

### **Purpose Statement**

The purpose of this study was to explore the impacts of the YSIDC on students ages 9 to 14 in the areas of SI skill development and their attitudes and views of science and SI. This out-of-school learning opportunity had the objective to teach SI skills and improve participants' attitudes and views towards science. The YSIDC provided a best practice example for other educators to learn and adapt for their educational contexts.

## **Research Questions**

The research questions that underpin this study are:

1. What is the impact of the YSIDC on participants' self-efficacy and knowledge of SI skills?
2. What is the impact of the YSIDC on participants' attitudes and views towards science and SI?
3. How does the program of the camp facilitate student inquiry learning?

## **Rationale**

This research is intended to contribute to understandings of the impact of informal science programs on their participants. Rennie (2007) describes the research in out-of-school settings as sparse and incomplete, primarily because the context of each of these learning environments varies greatly (e.g., purpose of program, participant demographics, group size, qualifications of instructors, physical environments, etc.), potentially leading to variable impacts of their effectiveness. This study will add to the greater body of work in this area to help us better understand the effects of informal science learning.

Before entering the teaching profession, I had the opportunity to work as a research assistant in a postharvest horticultural research program for 2 years. During this time, I realized that my academic experience ill-prepared me for conducting authentic research. In all of my years in formal education, including a 4-year undergraduate science degree, I was never provided the chance to adequately develop my open inquiry skills. Most of my experience learning science was through traditional didactic teaching methods and carefully scripted closed inquiries. I cannot recall being encouraged to ask questions, create my own procedures, or choose how to organize and interpret my data (i.e., open

inquiry). My years as a research assistant opened up a new exciting world of science that I did not even know existed.

After a few early failures in teaching science to intermediate students, I began to invest more of my time in developing productive inquiry-based activities. In my fourth year of teaching, I held a science fair for over 200 students. I was impressed with the overall project quality and the students' ability to articulate how they conducted their investigations and what they learned from them. This initial positive experience with project-based learning in science sent me on a path to increasingly invest in supporting students to complete science fair projects. Soon I became heavily involved in the Niagara Regional Science and Engineering Fair (NRSEF) as a volunteer, Judge-in-Chief, Vice-Chair and Co-Chair. Through my roles on the NRSEF Committee, I had a chance to qualitatively assess students' abilities or lack thereof to communicate their understanding of their open inquiries. It was quite evident that many of the students did not have the necessary knowledge and skills to conduct their inquiries and defend their work. I came to this conclusion after interviewing many students over several regional fairs as well as listening to the feedback from a number of judges. It became apparent that the majority of students who participated in the regional fair were passionate about their projects, but needed significantly more support. One of my concerns was that these students had a narrow vision of science, not unlike my own childhood experience, and this distortion may lead to a rigid incorrect thinking about SI. Possibly even more troubling was the fact that regional fair participants were not a random sample of students from Niagara; rather they more often than not had professional parents and overwhelmingly enjoyed

tremendous academic success in school. I wondered what kind of understanding students had who did not make it to regional fair; what were the causes of this dilemma?

Such questions led me to begin supporting students outside my own school in conducting their scientific investigations. After several years of guiding young scientists through informal science programs, I wanted to know how much of an effect these types of programs could have on students' SI skills, as well as on their attitudes and views of science and SI.

### **Scientific Inquiry**

This research study is concerned with how the YSIDC intervention can affect students' SI skills. Therefore, SI will provide an analytical framework or lens to describe the data collected in the study. This section will develop an operational definition for SI after contrasting it with the scientific method (TSM).

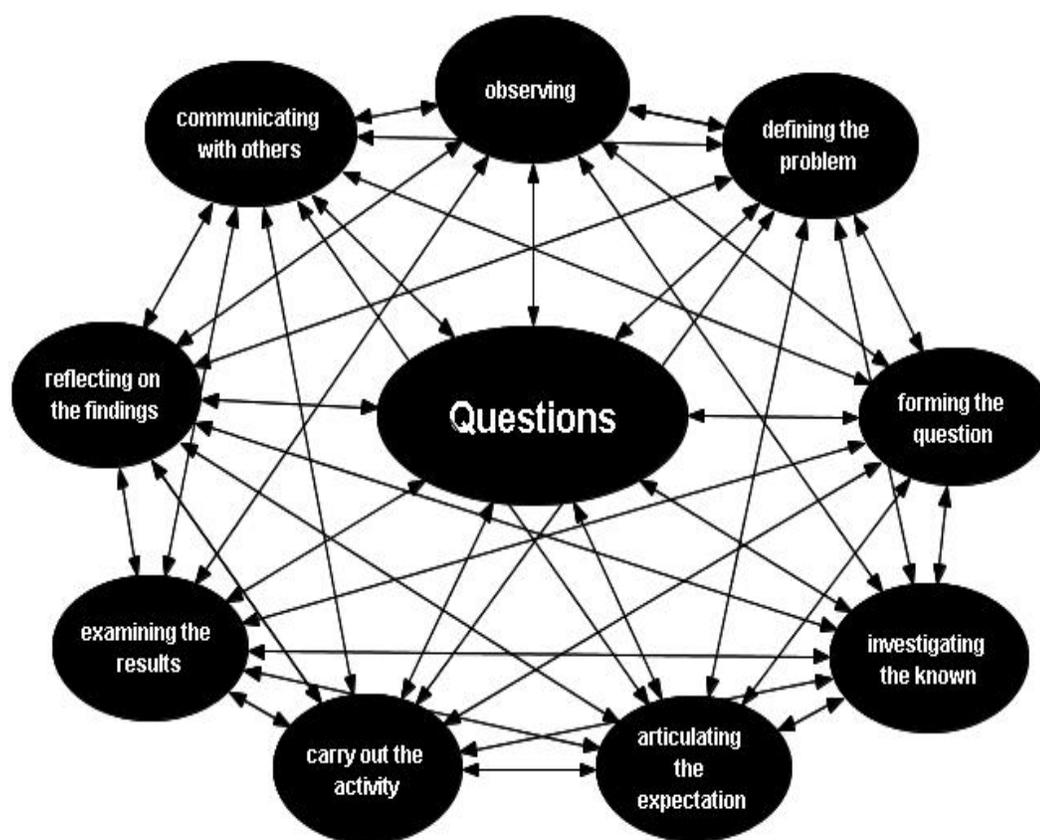
Llewellyn (2007) describes TSM as a series of prescribed steps or procedures that begins with a problem or question. This limiting, linear approach to investigation usually includes generating a hypothesis or a prediction, rigorously collecting data by an experimental design to test the hypothesis or reflect on the prediction. Llewellyn and others (Harwood, 2004; Windschitl, Thompson, & Braaten, 2008) claim that there really is no singular scientific method, but rather a variety of ways that scientists and researchers conduct their investigations.

Inquiry is a complex term with at least three nuanced distinctive meanings. Anderson (2007) contrasts the meanings of SI, inquiry learning, and inquiry teaching, which were shaped by the *National Science Education Standards* (NRC, 1996). He describes *scientific inquiry* as the work and nature of scientists' investigations as well

as their abilities and understandings to do their work. Anderson defines *inquiry as learning* as the active process of learning which is deeply connected to constructivism and John Dewey's (1902) belief that individuals construct meaning themselves and are dependent on prior conceptions they already have. Finally, *inquiry teaching* encompasses many forms of teaching that promote inquiry learning. The YSIDC uses the tenets of inquiry teaching to promote inquiry learning. However, since this research is focused on measuring the effect of the intervention on participants' SI skills, this is the most important construct for this study and will be further elaborated upon in chapter 2.

To address the limitations of TSM, Harwood (2004) developed the activity model of the process of SI that was meant to be used by teachers. However, it was developed out of research of the activities that scientists engage in. This activity model (see Figure 1) included 10 activities that scientists engage in (generate questions, observe, define the problem, form the question, investigate the known, articulate the expectation, carry out the study, examine the results, reflect on the findings, and communicate with others). However, unlike the prescribed steps of TSM, the activity model does not require the activities to be done in order, or only once in an inquiry. All of the activities are interconnected and it is suggested that scientists would weave in and out of these activities as they see fit.

For the purpose of this research, SI will be defined as a process through which students answer their own questions, like scientists, using the activity model of inquiry described by Harwood (2004).



*Figure 1.* SI Activity Model adapted from Harwood (2004). This model identifies 10 activities that scientists and students can engage in during the course of a SI.

## **Attitudes and Views**

An attitude is “a general and enduring positive or negative feeling about some person, object or issue” (Petty & Cacioppo, 1981, p. 7). Koballa and Glynn (2007) suggest that attitudes are distinct from beliefs, values, and opinions. Attitudes are rooted in a behavioural orientation in social psychology and educational psychology. Student attitudes about science will have a significant effect on student learning (Duschl, Shouse, & Schweingruber, 2007). Additionally, according to Dusch et al. (2007), some students have a rigid negative view of themselves as science learners and do not bother to put forth effort to improve. Therefore, the key factor for participants to persist in finding solutions to scientific problems and concepts is connected to the students’ expectations on their ability to do such things. Participants with positive attitudes will also have the confidence to ask good questions and make mistakes.

Unlike attitudes that come from a behavioural orientation, beliefs emerge from cognitive perspective in social psychology (Koballa & Glynn, 2007). They can also be described as the cognitive basis for attitudes. This study will not directly measure changes in beliefs, but instead will document potential changes in views. Fazio and Melville (2008) identified views as a combination of beliefs and knowledge.

## **Theoretical Framework**

Although the study did not test an existing theory, the YSIDC program development was informed by social development theory. Lev Vygotsky’s (1978) seminal work on social development theory explained that people develop skills from the culture they are immersed in; essentially, they are unconsciously learning. Inquiry skill and knowledge development can be accomplished by creating social learning situations that participants enjoy and can implicitly learn from one another. Participants in this study

learned in a social context and because of the relatively small numbers, individuals received targeted instruction based on their own inquiries. Therefore, the YSIDC instructors modelled and appropriately scaffolded learning for individuals.

### **Scope and Limitations of the Study**

One cohort of 30 participants ranging in ages from 9 to 14 were in the study in the summer of 2013. The inquiry development camp took place over 5 consecutive days at a university in southern Ontario. Participants were residents within the Niagara Region and paid a registration fee to attend the camp. Since the camp was not mandatory, the sample of convenience (Creswell, 2008) cannot be assumed to reflect the larger population from which it was taken. Furthermore, information was not collected from a control group to compare the effect of the intervention on the sample group.

Survey, questionnaire, and interviewing data were collected from participants at the beginning, during, and immediately after the intervention. A longer study that obtained data at several points after the intervention could provide additional insight on how long potential effects last. Since the intervention took place over a short time period, it may not have been long enough to produce significant effects. The program was unique and thus results may not be adequately generalized to other contexts.

A further limitation to this mixed-methods study (Creswell, 2008) is that the interpretation and analysis of the qualitative data are limited to the depth and scope of the lens of the researcher. Despite my intimate connection to the development of the camp program, attempts were made to remain objective while collecting and interpreting the data.

### **Outline of the Remainder of the Study**

Chapter 2 of this study presents literature that is relevant to several areas of research that need to be explored to answer my research questions. The review of the

literature is organized into eight distinct domains. The review begins by contrasting TSM with SI. The second section presents research on the benefits of student-led inquiry in science. This section is followed by a review of the current challenges facing science education. The fourth section focuses on the benefits and challenges of an out-of-school or informal science education. This is followed by how the constructs of attitudes and views in science are used in this research. Next, the role of self-efficacy in science and SI is explored. The seventh section of the literature review elaborates on the role on the role of student questioning in SI. Finally the last section positions the YSIDC in the social development and communities of practice theories. This literature review makes the case for the need for further study aligned with the research questions.

Chapter 3 outlines the research methodology and procedures used to collect and analyze the data for this study. Included in this chapter is a description of both the quantitative and qualitative instruments that were used and the field procedures on how data were collected. The limitations of this study and the strategies for establishing credibility are also outlined in this chapter. Chapter 3 concludes with a restatement of the problem.

In chapter 4, I present the results of this study by identifying major themes that emerged from the analysis of the data. Initially, data from each instrument are reported and summarized. Themes that emerged when the qualitative and quantitative data were triangulated are presented at the end of chapter 4.

Finally, chapter 5 contains a brief discussion of the study followed by a discussion of the research findings and connections that I make between the study and the existing body of research. This section provides implications for practice, theory, and future research.

## **CHAPTER TWO: REVIEW OF THE LITERATURE**

This section provides an overview of the literature that is relevant to the goals of this study. The review begins with a critical examination of SI. The goal of this first section is to clarify the intentions of the study. The review continues by highlighting the benefits of student-led inquiries in science. Next, the purpose of the research is explored by providing current challenges to increasing the amount of inquiry in science education. This is followed by models of other informal science camps and ends by examining researched-based components of successful SI programs. This chapter continues with an examination of the literature about student attitudes and views in science. The sixth and seventh parts of the literature review explore student self-efficacy in science and SI as well as the role of student questioning in SI. The literature review ends with the camp being positioned under the social development and communities of practice theories.

### **The Scientific Method Versus Scientific Inquiry**

Several researchers (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Windschitl et al., 2008) specifically criticize TSM for having a narrow view of scientific investigations that distort what the full scope of science is. They present four reasons for their discontent with TSM. First, questions are typically provided by the teacher which prevent students from sense-making contexts by not allowing them to access resources or personal experiences. Secondly, TSM generally encourages controlled experimental design as the sole method of gathering data at the expense of other accepted designs (e.g., correlational studies). Thirdly, TSM usually limits students by encouraging them to look for simple patterns instead of developing and reflecting on models and explanations of scientific constructs. Ultimately this trade-off prevents students from constructing deeper

understanding of their work and the underlying scientific concepts involved in their investigations.

Finally, Lederman et al. (2002) add that TSM's easy, linear dimension helps teachers keep investigations simple and procedural, rather than as way of promoting thinking among students. In fact, much more problem solving goes into developing the investigations than there is during their execution. Students can easily conclude that science is just a series of predetermined steps that are drawn up by someone else.

SI is not defined by the same rigid linear view of TSM. However, because of the broader scope of SI, it is challenging to define, not unlike the term literacy. Rutherford and Ahlgren (1990) state that "Scientific inquiry is not easily described apart from the context of particular investigations. There simply is no fixed set of steps that scientists always follow, no one path that leads them unerringly to scientific knowledge" (p. 5). Llewellyn (2007) adds that each science educator has his or her own nuanced understanding of SI. To answer the research question, an operational definition of SI is required.

A complicating factor in understanding inquiry is that the usage of the word *inquiry* can fall into the three broad categories: scientific inquiry, inquiry learning, and inquiry teaching (Anderson, 2007). These three distinctive inquiry usages were defined in the *National Science Educational Standards* (NRC, 1996). Scientific inquiry refers to how scientists study and understand the natural world and propose explanations using collected evidence. Inquiry as learning is part of an active process in which learners engage to construct meaning. This type of inquiry should reflect the nature of scientific inquiry. Finally, inquiry teaching is a broad concept of a desired teaching approach as

well as the processes that teachers create in their classrooms. For the purpose of this thesis, SI will be used as Anderson's inquiry as learning.

Bell, Smetana, and Binns (2005) define inquiry as "an active learning process in which students answer research questions through data analysis" (p. 31). Educational researchers have further distinguished different levels of SI on a continuum (Liang & Richardson, 2009; Rezba, Auldridge, & Rhea 1999). Specifically, Rezba et al. (1999) separated SI into four levels. The first level of inquiry is confirmation whereby students are provided with a question, a method, and the solution. Structured inquiry, the second level, is when the question and procedure are provided, but students generate meaning from their collected data. Most prescribed labs in textbooks fall under the first two levels. During the third level of guided inquiry, students are only given a question to investigate by the teacher and need to design an investigation to present a solution to the question. The highest level of inquiry, open inquiry, has students generating and answering their own questions. Students should not be expected to independently perform open inquiry without scaffolding (Bell et al., 2005).

Llewellyn (2007) argued that the concept of inquiry-based instruction is not a fad, but dates back to Socratic methods of questioning, discovery, and learning. At the beginning of the 20th century, Dewey (1902) proposed the idea that learning requires a student to engage in a problematic situation. He believed in the importance of discovery and inquiry. Schwab (1962) also had a significant influence on promoting inquiry-based learning. He believed that teachers needed to provide students with opportunities to perform inquiries in similar fashion to scientists. This type of student exploration needed to take place in advance of any formal explanation of scientific concepts. It was during this

time that inquiry learning was integrated into science classrooms and science process skills were promoted. SI has a long history and is widely regarded as beneficial to student learning (Bell et al., 2005; Harwood, 2004; Hermann & Miranda, 2010; Leonard & Penick, 2009).

### **Benefits of Student-Led SI**

The benefits of SI instruction have been well documented. Anderson (2007) argued that student learning through SI was synonymous with constructivist learning and is a requirement for an optimal educational experience. When students engage in SI they are encouraged to be self-directed learners. Kohn (2011) argued that educators need to promote student self-directed learning and allow them choice to maximize their motivation to perform educational tasks and, thus, improve their overall learning.

A meta-analysis of 138 SI studies done by Minner, Levy, and Century (2009) concluded there was a positive correlation between SI instruction and content learning and retention. The most beneficial activities were when students were asked to draw conclusions from data and inquiries that promoted student active thinking. The researchers could not sufficiently conclude that student-led inquiry alone would result in the highest rates of student learning. Although the meta-analysis addressed the quality of the data collected in the individual studies, it did not factor in the quality of the instruction in the studies.

Fogleman, McNeil, and Krajcik (2011) found in their study that inquiry teaching had a considerable impact on student learning. Specifically, they concluded that students who completed activities themselves had more positive gains than those who were in classes in which the teachers performed the activities and demonstrations. Additionally, Anders et al. (2003) reported that students in university experienced significantly more

positive outcomes when performing an open inquiry lab in contrast to the expository version. Students in the open inquiry treatment group demonstrated more learning, spent more time in the laboratory, and had a more positive perception of the experiment. They also found that students who began with a lower attitude position of inquiry benefited from the open-inquiry experience, but needed additional supports of a clear explanation of the aims and feedback from instructors halfway through the investigation.

### **Current Challenges to Teaching Science as Inquiry**

Despite the documented advantages of having students perform SI, there are definite barriers of implementation. Fogleman et al. (2011) reported the benefits of an inquiry-oriented curriculum, but discovered a wide variation in student achievement based on how the curriculum was being delivered by teachers. Most significantly, they found that teacher experience with the curriculum materials impacted the quality of instruction, indicating the necessity to support teachers' understanding of teaching science as inquiry. Without adequate support or sufficient science background, teachers' anxiety around enacting an inquiry-based program could result in partial implementation, or a reduction in teacher self-efficacy.

Anderson (2007) describes the anxiety that teachers face as they shift their pedagogical practices towards integrating more inquiry into their classrooms. Anxiety largely is a result of teachers challenging their personal beliefs and values about science education. Anderson argued that moving towards a program of open inquiry is more about reassessing one's ideas about education as much as learning the new strategies and techniques. Without adequate professional development, such a change will likely be unsuccessful. Anderson advocated for teachers to engage in collaborative dissonance to

challenge their existing equilibrium. Teachers would also need to learn with their own students in their own contexts as well as having the appropriate amount of time and support. Such an undertaking would require systemic support both from local boards of education as well as from policy makers. However, with a defined focus on literacy and numeracy in Ontario through EQAO testing, a coordinated effort to advance SI will likely not be championed.

In addition to the previous barriers of integrating increasing amounts of SI in classrooms, Anderson (2007) outlined five other dilemmas that teachers will face. First, teachers will see a lack of time available to understand and deliver a program based on open inquiry. Secondly, teachers will see SI as an idealistic situation and one that will be in conflict with the reality they face. Next, the change towards inquiry learning will require a change in the role of a teacher. This change is often extremely difficult and time consuming. His fourth dilemma was that teachers are often preoccupied with preparing students for the next level. Teachers may see abandoning their old practices and programming as detrimental to the future success of their students. Finally, teachers may believe that inquiry learning will disproportionately benefit stronger students at the expense of those who currently struggle in science.

With all of the aforementioned barriers at implementing an increasing amount of SI in classrooms, it is unrealistic to believe that the necessary structures and culture that Anderson (2007) believes are required to nurture real change will be implemented in publicly funded schools. An alternative agent to promote SI in our communities may lie in informal educational experiences.

### **Informal SI Experiences**

Informal SI experiences are educational experiences that occur outside of school contexts. Rennie (2007) challenged the usage of informal science learning because it insinuates a qualitative difference from traditional formal science learning. Instead she described informal learning as outside of school learning. Regardless of the term, Rennie concluded that science can be effectively taught and learned in alternative environments. She also argued that learning is a personal experience in which the learner needs to engage in some mental, physical, or social activity. In addition, Rennie believes that learning takes time and is contextual. Although these out-of school science experiences are invaluable sources of learning, they currently are not well linked to formal science learning in schools. The focus of this study's program is to augment scientific process skills outlined in the Ontario Curriculum.

Even though there is a relative lack of research on informal science learning (Rennie, 2007), several studies demonstrate that there are significant benefits to learning science outside of schools (Bhattacharyya, Mead, & Nathaniel, 2011; Gibson & Chase, 2002; Jarvis & Pell, 2004). Specifically, Gibson and Chase (2002) examined the positive long-term impact of the Summer Science Exploration Program that ran for 2 weeks. They concluded that the camp intervention had a positive impact on participants' attitudes towards science and also increased their interest in careers over a control group. Jarvis and Pell (2004) studied the impact of students attending the U.K. National Space Centre. Their study reported an immediate benefit to the 1-day program on students' interest in space and a moderate increase in their views about the value of science in society. Another study done by Bhattacharyya et al. (2011) found a week-long camp

changed African-American high school students' perceptions of science and had a favourable impact on their views about science careers. However, none of these studies looked at the impact of informal science experiences on SI. The research suggests a positive effect of learning science outside of school.

Fields (2009) presented two models of informal science camps for students. The first model focuses on student-led inquiry using authentic laboratory equipment and technologies (Gibson & Chase, 2002; Hay & Barab, 2001). These camps emphasize inquiry and generally expect participants to defend their work to the peer group. The second model connects participants individually or in small groups with scientific mentors (Bell, Blair, Crawford, & Lederman, 2003; Hay & Barab, 2001). The first model is better at nurturing inquiry skills and creativity and providing ownership of work while the second is more effective at connecting participants to a community of scientists and digging deeper into their work. The YSIDC falls under the first constructivist model of informal science camp.

### **Attitudes and Views of Science**

There have been concerns from developed countries with a lack of motivation in students towards science learning and pursuing science careers (Sjøberg & Schreiner, 2005). Toplis (2011) reported that studies in student attitudes towards school science is actually quite limited. However, attitudes have been demonstrated to be a predictor of achievement in science (Webster & Fisher, 2000). Nonetheless, studies (Butler, 1999; Shrigley, 1990) concluded that the achievement gains from positive attitudes were improved if the attitude was specifically, not only generally, linked to the outcome. For example, if one needed to predict the future benefits of conducting independent research,

specifically asking students about their attitudes towards conducting research would be more useful than finding out their attitudes about science in general. Several studies (Gibson & Chase, 2002; Haussler & Hoffman, 2002; Perrier & Nsengiyumva, 2003; Siegel & Ranney, 2003) all found that summer science camps or informal after-school programs that promoted active inquiry learning and issue-based experiences improved attitudes in those areas.

Despite a body of research that supports an inquiry approach to teaching science, Gautreau and Binns (2012) did not find a clear relationship between a play-based inquiry curricula and improved student attitudes towards science. Potential issues with an inquiry approach could be that students need to be scaffolded into higher order inquiry instruction (Wilson, Taylor, Kowalski, & Carlson, 2010).

Since current research has not yet clearly concluded that informal inquiry learning will directly improve student attitudes in science and SI, it is worthwhile to investigate the relationship between this teaching approach and its effects on student attitudes. Moreover, each informal science program provides a unique experience that could potentially impact student attitudes towards science and SI in different ways, so investigation of this context needs to be conducted.

Fazio and Melville (2008) defined views as a combination of knowledge and beliefs. Studies concerning the views of science have focused their efforts on the views of the nature of science (VNOS). Many recent reform efforts have emphasized the development of students' VNOS and studies have found that students generally lack an adequate understanding of the nature of science (Lederman, 1992; McComas, 2008). The nature of science is defined as the epistemology of science, characteristics of

scientific knowledge, and the values and beliefs inherent to scientific knowledge and its development (Lederman, 1992). Many goals of developing students' VNOS are not emphasized in traditional science classrooms, resulting in students learning inaccurate or incomplete notions about how science is conducted (Abd-El-Khalick & Lederman, 2000).

Driver, Leach, Millar, and Scott (1996) described the benefits of students having a sophisticated VNOS including being aware of the norms of science, learning science content with more depth, understanding the process of science, and better connecting science to the sociocultural context in which it operates. Lederman (2007) reviewed research on the assessment and evaluation of VNOS. Lederman concluded that elementary and secondary students did not possess "adequate" VNOS. Student misconceptions could be attributed to teachers' inadequate VNOS as well as instructional approaches and decisions made in the classroom.

Deng, Chen, Tsai, and Chai (2011) reviewed 105 empirical studies that investigated students' VNOS. Deng et al.'s findings revealed that students' VNOS by and large positively related to learning in science and that effective interventions usually included inquiry, discussion, reflection, and/or debating activities.

The YSIDC program assessed participants' views on SI and science in general. Although it might be difficult to have a significant impact on beliefs, the intent was that participants' views about SI and science would develop throughout the YSIDC.

### **Self-Efficacy in Science and SI**

One manner to assess the impact of the YSIDC is to look at the effect the intervention has on self-efficacy within the domain of study. Self-efficacy is the belief "in one's capabilities to organize and execute the courses of action required to produce

given attainments” (Bandura, 1997, p. 2). Self-efficacy affects behaviour by impacting goals, outcome expectations, affective states, and perceptions of sociostructural impediments and opportunities (Bandura, 1997). Therefore, individuals with higher self-efficacy will be more successful on tasks because they will persist longer, exert more effort, set higher goals, and believe they can be successful (Bruce & Ross, 2008).

Previous research in science education has demonstrated that science self-efficacy is associated with science achievement and future decisions in engaging in science related activities across age levels (Britner & Pajares, 2006). Britner and Pajares (2001) also concluded that science self-efficacy in elementary students can predict future science achievement.

Because of the influence of self-efficacy on future engagement and achievement in a variety of areas, researchers have been interested in understanding the sources of improving self-efficacy. Bandura (1997) believed that students develop their self-efficacy beliefs from four sources: mastery experience, vicarious experience, social persuasion, and physiological states. In general, he explains that experiencing success at a task can generally positively impact one’s confidence, whereas being unsuccessful can lower one’s self-efficacy.

Other factors that can impact the outcome on self-efficacy via mastery experiences are: the perceived challenge of the task, the perceived effort during the task, the amount of assistance provided, and other personal and environmental factors (Bandura, 1997). Nevertheless, mastery experiences are considered the most powerful source of improving self-efficacy. Bandura defined vicarious experiences as those in which an individual observes others perform tasks. Although less effective than mastery

experiences, vicarious experiences provide models on how to perform a task and give individuals information about their potential ability to complete tasks successfully. Social persuasion, the third source of self-efficacy by Bandura, is cultivated by having peers encourage individuals through positive appraisals. However, peers have an even more powerful outcome on decreasing self-efficacy by communicating negative appraisals. Social persuasion in isolation will not independently produce significant positive impacts on self-efficacy, but can work with the other sources to affect self-confidence. Finally, physiological states such as anxiety, stress, and contentment during an experience can either positively or negatively affect self-efficacy. Similar to the previous sources of self-efficacy, the individual's interpretation of the physiological state will impact the contribution of this source.

Britner and Pajares's (2006) study supported all four of Bandura's (1997) sources of self-efficacy in science. Specifically, their work highlighted the strong influence of mastery experiences with middle school aged students in developing their self-efficacy in science. Educators need to facilitate students being successful with science activities and minimize failures that will reduce confidence, but at the same time provide challenging work that will be perceived as meaningful.

Just as with student attitudes, research suggests self-efficacy is context dependent (Smith & Fouad, 1999). Therefore, it is important to use instruments that can measure specific self-efficacy domains. Ketelhut (2007) interestingly found at the onset that students with lower self-efficacy at collecting data in fact gathered less data in a multi-user virtual environment than their peers with higher self-efficacy. However, after spending time in the virtual environment, the two groups' data gathering behaviours

converged. Ketelhut explained this contrary finding could perhaps be the result of the students with low self-efficacy initially responding to their previous difficult experiences with data collection; however, as they were successful in the new inquiry virtual environment, they gained mastery experience and expressed a higher level of self-efficacy in a novel context, thus increasing their self-efficacy in a specific domain.

Sasson (2014) studied the role of an informal science experience—participating in activities at a science centre—on students' self-efficacy. While self-efficacy scores increased, gains were not significant. Sasson argued that perhaps the length of the intervention (50 hours) was too short to have more of an effect. Research in student self-efficacy in inquiry activities during informal science experiences is an under-researched area that was only related to constructs that were directly investigated in this study.

### **Role of Student Questioning in SI**

Learning science and SI depends on a complex web of interrelated experiences, including the opportunity to ask meaningful questions (NRC, 2012). Gillies (2011) concluded that teaching questioning skills is essential for participants to reason effectively in inquiry-based science. A complicating factor is that not all questions are of equal value. Some questions are easy to frame and answer while others require more imagination and require reflection and understanding to develop a response. Science classrooms should aspire to have students ask more cognitively challenging questions that promote learning (Chin & Osborne, 2008). Unfortunately, the literature suggests that children do not initiate thought-provoking questioning during their inquiries (Meloth & Deering, 1999; Zuckerman, Chudinova, & Khavin, 1998). One effective instructional strategy to improve the quantity and quality of student questioning is for teachers to

consistently use a high degree of constructivist teaching practices in their classrooms (Erdogan & Campbell, 2008). Erdogan and Campbell suggest these practices lead to students having more opportunities to practice forming and testing their questions in the context of them learning science.

### **Social Development Theory and Communities of Practice**

The YSIDC was purposefully intended to impact students' SI skills as well as their attitudes, beliefs, and self-efficacy about science. To achieve a positive effect, the camp needed to create conditions that the participants enjoyed, but also challenged their current beliefs about science and effectively provided experiences that deepened their knowledge about SI. As a result, the camp was constructed to include significant social interaction among the participants and the camp leaders.

Vygotsky (1978) proposed that social interaction profoundly influences cognitive development. Central to Vygotsky's theory is his belief that biological and cultural development do not occur in isolation. He stressed the importance of social interaction and mentorship on the development of higher-level thinking (as cited in McCown et al., 1999). Vygotsky was more interested in a child's potential for intellectual growth than he was in their intellectual abilities at a particular point (as cited in Seng, 1997). He thus proposed the concept of zone of proximal development. Vygotsky (1978) defined the zone as the difference between the child's "actual development level as determined by independent problem solving and the potential development as through problem solving under adult guidance or in collaboration with more capable peers" (p. 86). Thus, a child's potential development can be shaped by scaffolding tasks by more knowledgeable others in social situations.

In the community of practice perspective, knowledge is relational and dynamic and, as a result, learning takes place in a social context (Lave & Wenger, 1991). Wenger (2006) defines communities of practice as “groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly” (p. 1). Wenger’s model of community of practice includes the characteristics of domain, community, and practice. The domain characteristic refers to the community having a shared domain of interest. The community characteristic means that members must interact and learn from one another. Finally the practice characteristic refers to the members solving problems by sharing resources, stories, experiences, and tools on a sustained basis. A group must effectively combine and develop these three characteristics to be considered a community of practice.

### **Summary of Literature Review**

TSM has been widely used as the framework to teach science investigations in school. Research has identified issues with TSM. Its narrow view of how “to do” science results in limiting students’ involvement in experimentation and presents an oversimplified model of scientific work. Inquiry is a complex construct that has three broad categories of meaning. In this study, SI is defined as an active process in which learners engage to construct meaning and is consistent with Anderson’s (2007) inquiry as learning definition. SI is much more flexible than TSM and recognizes that there are a multitude of methods or approaches to answering questions and making meaning of evidence. The benefits of SI instruction that include improved student achievement and attitudes in science are well documented and supported by research. Despite the

advantages of encouraging SI in classrooms, research has documented the challenges that teachers face in integrating this learning approach in their programs.

The literature also supports the benefits of informal science learning that takes place in many environments including but not limited to science centres and camps. Studies have demonstrated informal science learning can have positive impacts on participants' attitudes, views of science, and their SI skills. However, informal science learning is still an under-researched area in science education.

With the current concern in research about student motivation and achievement in science, researchers have been investigating the constructs of students' attitudes and views on science to gain an insight into the issue. Additionally, SI skills have been a focus of research, including students' self-efficacy in this domain.

The purpose of this study was to explore the impacts of an informal science camp on participants' attitudes and views towards science as well as developing their SI skills. To achieve this goal, the program purposefully was designed to broaden participants' view of SI and provide ample opportunities to collaborate and learn from each other.

The following chapter will detail the study's methodology and procedures. The chapter will justify the choice of a mixed-methods design and will describe the site and participant selection as well as the how the data were collected and analyzed. Finally, the chapter will outline limitations and ethical considerations.

## **CHAPTER THREE: METHODOLOGY AND PROCEDURES**

The process of conducting research is a complex endeavour that involves interrelated activities (Creswell, 2008). Nonetheless, educational research is still a process that follows procedures and utilizes specific data collection techniques. The purpose of this study was to evaluate the impact of the YSIDC on participants' SI skills as well as their attitudes and views about science and used a triangulated mixed-methods design. This chapter will present the methodological decisions for the research design, and sections describing the YSIDC intervention, site and participant selection, and data collection and analysis. The chapter will conclude with limitations in the methodologies and a discussion of the ethical considerations of the research.

### **Research Methodology and Design**

A triangulated mixed-methods design is one in which the researcher collects, analyzes, and mixes both qualitative and quantitative data simultaneously in a study to help answer research questions (Creswell, 2008). Creswell (2008) also states that the benefit of this design is that it can use the strengths of quantitative and qualitative data. Quantitative data sets can be statistically analyzed and are effective at understanding trends and generalizing findings. However, qualitative data sets can offer different perspectives and describe complex situations with depth. In advance of the study, the researcher has to also describe the rationale for choosing this design and decide if one type of data is given priority as well as how the data will be analyzed and interpreted (Creswell, 2008). In this study, a triangulated mixed-methods design was used so that the qualitative data could provide context and a richer description of the impacts suggested by the quantitative findings. Both data sets were given equal priority in the triangulation

design that collected the quantitative and qualitative data simultaneously. Creswell describes this interpretive procedure as *qualifying quantitative data*.

Both types of data were collected to assess the potential impacts of an out-of-school science inquiry camp (YSIDC). Specifically, quantitative data was used to assess participants' SI skills and attitudes towards science and SI. Qualitative data were used to support or refute the quantitative findings and provide insight into participants' views of science and SI.

### **YSIDC Intervention**

The intervention that was investigated was the YSIDC, a week-long science inquiry camp for students age 9 to 14. The camp ran for 7 hours for five days during a week in the summer of 2013. The YSIDC is one of three programs offered throughout the year by the local Regional Science Fair Committee. Participants could also have their specific science fair projects supported in the fall to early winter with small group coaching. The third program had participants learn scientific topics and concepts in informal settings with experts in the local region. The intent was to build long-term relationships with participants and have them build skills over a period of several years. However, this study only investigated the impact of one part of the overall program. This was the fourth year the camp was offered. It was developed by the researcher with assistance from the three program instructors and input from previous participants and professors at three different postsecondary institutions.

The purpose of this intervention was to promote open SI as well as prepare participants to complete high-quality science and engineering fair projects. The program was fully developed by the end of April 2013. Many elements used the Smarter Science

Framework (Smarter Science, 2010). However, the YSIDC gradually released instructor support throughout the week to prepare students to complete a student-led open inquiry. The three instructors who led the YSIDC were qualified elementary teachers. In addition, two students in secondary school who had already completed the intermediate program and had demonstrated exceptional inquiry skills in their science fair projects volunteered to assist children in the camp.

Adhering to Vygotsky's social development theory, the YSIDC was structured into two levels (i.e., novice and experienced) based on participants' age as well as previous experience attending the program and conducting science fair projects. The program was differentiated for each level, but included several common experiences that both groups did together. This study assessed the intervention with both novice and experienced level participants (see Appendix A for a Novice Program Schedule and Appendix B for an Experienced Program Schedule).

The program was also informed by the social development theory by focusing on problematic situations in which participants worked in pairs to complete tasks and receive support from knowledgeable others (i.e., the three instructors and expert peer volunteers). In addition, participants had some choice in the complexity of the investigations that they undertook. This provided several opportunities for them to receive targeted instruction that addressed their particular zone of proximal development. Participants shared and defended their work to the community of learners.

The YSIDC also satisfied the three characteristics of community of practice: domain, practice and community. Participants who selected the camp had a common interest in learning (domain) about how to improve their SI skills. Furthermore, students

were paired up on the basis of identifying shared interests and worked to solve problems together. The YSIDC is only the first pillar of the Niagara Regional Science and Engineering Fair's Development Program. Participants were also encouraged to receive assistance in completing science fair projects through a 5-month small-group coaching program. The structure of the program as a whole provided the necessary experiences to satisfy the practice component of the theory. Finally, these same children were invited to participate in monthly science café sessions that were developed to foster community and scientific knowledge on specific topics in informal settings. In isolation, the YSIDC did not nurture community over a sustained period of time. However, it was intended that participants enrol in the program in several subsequent summers and engage in the other programs that ran throughout the year.

A secondary goal of the YSIDC was to have participants challenge the acceptance of TSM. Topics covered at the YSIDC and assessed in the research included: investigating the work of real scientists, how to frame research questions, learning about data collection and analysis by using an assortment of probeware, how to locate and summarize previous research, and how best to present and discuss scientific results. Participants also worked in pairs to develop and conduct an open inquiry with probeware. The intent of this larger project was to promote problem solving by having participants solve the issues that arise from the challenges of their studies. The program instructor's role was to encourage persistence and provide some guidance at the zone of proximal development through the use of targeted questions and specific support. At the end of the YSIDC, participants were expected to defend their work to the community of learners.

### **Site and Participant Selection**

The site selection of this study was predetermined by my role as the designer of the YSIDC. The YSIDC was previously held at a university in southern Ontario and was again going to be used for the camp location, and therefore was selected as the site for this research study. This university had suitable facilities to accommodate the YSIDC requirements. In addition, the participants had a chance to be exposed to an academic research setting.

Potential participants were identified by registering for the summer camp through the community outreach initiative of the local regional science fair. Individuals were required to be between the ages of 9 to 14. Convenience sampling was required because participants were identified by signing up for the summer 2013 YSIDC. The participants accepted into the YSIDC were asked to participate in this research. Registration for the week-long camp was capped at 30 students. This was a pay-per-attendance camp, but families unable to pay for the camp were subsidized. Therefore, the sample was not random.

Of the 30 participants in this study, 20 were in novice programming which was designed for individuals who had completed up to one science fair project in the past and had a maximum of one previous YSIDC experience. These students were in grades 5 to 7. The study also included 10 participants in the experienced program. These individuals either completed two science fair projects at the regional level, or previously attended at least one inquiry summer camp program. Experienced participants were in grades 7 to 9. The YSIDC had both groups complete some of the same activities together, but often separated them to provide a differentiated experience for the two cohorts to respect their

previous background and skill level. For example, the part of the camp that dealt with data analysis was much more advanced for the experienced students. Furthermore, they conducted their main inquiries separately from the novice participants. Novice students used probeware to design a controlled scientific experiment, whereas the experienced participants worked on design projects with open-sourced computer hardware and software. Since these two groups had different backgrounds, data were not only pooled but also analyzed separately for each group to assess if the YSIDC potentially impacted the two groups differently.

Six students were purposefully selected to be interviewed before and after the YSIDC for the stratified factors of experience level and gender. Purposeful selection was used to provide a diverse subset of those in the study so that multiple perspectives could be explored. Of the six interviewed participants in the study, four were novices and two (participants 5 and 6) were in the experienced program, three were female and three were male.

Registration for the summer camp began in April 2013. The first 30 registrations were accepted. During the registration process the participants' parents and guardians were asked if they would be willing to have their children participate in the study. Before the camp began, participants in the study were asked to complete the pre-intervention instruments. Six participants were selected and interviewed prior to the commencement of the camp. Interviews lasted between 6 and 25 minutes.

### **Data Collection**

Quantitative data for the study were collected using a pre–post design (Creswell, 2008). When only one group is used in a study, pre-intervention data are compared to

post-intervention data to determine whether there was an effect of the intervention on the dependent variable(s) investigated in this study: participants' SI skills and attitudes and views of SI and science.

Specifically, self-efficacy for SI skills were individually assessed using the *Science Process Skills Inventory* (SPSI; Bourdeau & Arnold, 2009), attitudes towards science were measured using the *Changes in Attitudes about the Relevance of Science* (CARS) instrument (Siegel & Ranney, 2003), and the views about science were collected using the *Views of Science Inquiry—Elementary Version* (VOSI-E; Ko & Lederman, 2005; Schwartz, Lederman, & Lederman, 2008). The SPSI, CARS, and VOSI-E instruments (see Appendices B, C, and D, respectively) were modified to meet the specific needs of this study and administered immediately before the initial intervention. Demographic information was collected before the YSIDC began. Participants also completed all three of the instruments both at the beginning and at the end of the YSIDC.

The SPSI Instrument (see Appendix C) has 11 questions that participants answer using a 5-point Likert scale (i.e., strongly disagree, somewhat disagree, neutral, somewhat agree, and strongly agree). The CARS instrument has 26 items about participants' attitudes of science and uses the same 5-point Likert scale as the SPSI tool. The last survey used was the VOSI-E survey, a qualitative survey used to assess participants' views of science. The VOSI-E has six short-response questions, some of which have related sub-questions.

In addition, qualitative data were collected through observations and interviews (see Appendix F for interview protocol) of six purposefully selected participants based on stratified factors (e.g., gender and experience) enrolled in the YSIDC. Six were chosen

for interviewing because that number was manageable. Individuals were selected to represent the diversity of the group in terms of age, gender, and level attending the camp. Data collected from the interviews were triangulated with the other data collected in the research. The researcher completed tracking sheets (see Appendix G for sample tracking sheet) on observed behaviour of the six selected participants during the camp. The initial interviews were conducted immediately after the first surveys were completed. The post-interviews took place within the 2 weeks after the YSIDC concluded. Interviews expanded upon the participants' survey responses (see Table 1 for the schedule of data collection instruments).

During the camp, the researcher maintained a daily journal reflecting on observations about the progress of the participants. Students also maintained a daily journal that they were prompted to reflect on what they learned each day.

### **Data Analysis**

As a mixed-methods study, both quantitative (i.e., SPSI and CARS instruments) and qualitative (i.e., VOSI-E instrument and interviews) forms of data required separate and distinct data analysis.

#### **Quantitative Data Analysis of the SPSI and CARS Instruments**

Inferential statistics are used in research when comparing groups (Creswell, 2008). In this study, the quantitative data analysis was used to determine if the YSIDC intervention had an impact on its participants' SI skills and attitudes towards science and SI. Pre and post data for each item in the SPSI and CARS instruments were compared using a two-tailed paired-sample *t*-test. Individual items were compared to find potential specific impacts that could later be triangulated with the qualitative data.

Table 1

*Schedule of Data Collection Instruments, Observations, and Interviews*

Type of assessment	Before intervention	During intervention	End of intervention	After intervention
Background demographic information	√			
Science Process Skills Inventory (SPSI)	√		√	
Changes in Attitudes about the Relevance of Science (CARS)	√		√	
Views of Science Inquiry – Elementary Version (VOSI-E)	√		√	
Interviews*	√ <sup>1</sup>			√ <sup>1</sup>
Tracking sheets of observed behaviour*		√		
Student daily journal		√		

\* Indicates that only six selected students were interviewed and observed in detail.

<sup>1</sup> Indicates that interviews only took place after all of the instruments had been completed. This happened for both before and after the intervention.

Data collected by the SPSI survey instrument (Bourdeau & Arnold, 2009) were used to demonstrate participants' self-assessment of their SI skills. The SPSI instrument used a 5-point Likert scale. Participant responses were converted to a numerical value using the following conversion scheme: 1 = strongly disagree; 2 = somewhat disagree; 3 = neutral; 4 = somewhat agree; 5 = strongly agree. The results of the pre- and post-survey were then entered into Microsoft Excel for each item. Mean values for each of the 11 items were calculated using Excel. Mean pre- and post-test scores were compared using a two-tailed paired-sample *t*-test in Microsoft Excel. Significance was set at a value of  $p < 0.05$ . Afterwards, means were determined separately for each item for both the novice and experienced participant cohorts to investigate if the YSIDC had a different impact on those two different groups. The calculations were completed using the exact same method as the one for the complete data set.

The CARS instrument's 26 items (Siegel & Ranney, 2003) were used to assess participants' attitudes towards science and SI. This instrument used the same 5-point Likert scale as the SPSI instrument. Data were treated and analyzed the same way as the SPSI instrument data.

### **Qualitative Data Analysis of the VOSI-E Instrument and the Interview Data**

After the quantitative findings were determined, the qualitative data were analyzed to help better understand the quantitative data. Qualitative research allows for individuals' thoughts, feelings, and theories about given situations to be compared with those of others experiencing similar phenomena. Creswell (2008) states that the analysis of qualitative data requires the researcher to make sense of text to form answers to research questions. Creswell suggests that after collecting qualitative data, the researcher

should organize, explore, and then code the data to find and describe themes that can be validated. This process of qualitative data analysis was used.

The VOSI-E instrument is a short-answer survey with six questions, four of which have multiple parts. All participants' responses for both the pre- and post-survey were transcribed into Microsoft Excel. Once the data were organized in Excel, each question and sub-question was inductively coded. Creswell (2008) describes coding as a process of segmenting and labelling text to form descriptions and broad themes of the data. After the questions and sub-questions for the VOSI-E were initially coded, the codes were then compared and connected to codes across the items in the instrument to produce reoccurring themes for this data source.

Six participants from the study were purposefully chosen to be interviewed based on stratified factors (e.g., gender, age and experience). Interviews were audiotaped and then later transcribed into Microsoft Word. Interview data were initially coded for each question and then inductively analyzed across pre- and post-responses to uncover emergent themes.

### **Triangulation**

The triangulation mixed-methods design simultaneously collects quantitative and qualitative data and then merges the results to better understand the research problem (Creswell, 2008). A sequential data analysis procedure (Creswell, 2008) was used in which the quantitative data were analyzed before the qualitative data. In this study, the qualitative data were primarily used to provide context and depth to the relationships discovered in the quantitative data. Despite the overlap of findings across data sources, the results are presented separately in chapter 4 and synthesized together in chapter 5.

## Limitations

Limitations are potential weaknesses or problems outside of the researcher's control that may affect data collection and analysis (Creswell, 2008). It is obviously very difficult to avoid limitations when conducting research. However, every effort was made to minimize the impact of limitations during this study. The rest of this section will identify limitations that might have affected the results of this study.

First, participants were given the same instruments before and after the intervention. This procedure potentially led to a testing effect impact on the results. Future studies might use instruments with different versions to avoid this threat to internal validity. Having unique items in two different versions would reduce the testing effect even further.

To minimize the influence of the researcher, another threat to internal validity, a scripted protocol was used each time an instrument was administered. The interview protocol (see Appendix F) helped the researcher stay focused on the questions in the protocol and follow-up clarifying questions. This helped to avoid leading questions for favourable responses and minimize the researcher effect.

In addition, there were two threats to external validity. First, participants in the YSIDC were not representative of the larger population. Instead, they most likely had a stronger affinity to science compared to the general student population and could possibly be more receptive to the intervention. In addition, there is an interaction of setting (Creswell, 2008) because the specific context of the intervention prevents the results to be generalized to other situations. The YSIDC is a specific program in a specific community with specialized instructors. However, the results of this research will be

useful in the context of a larger body of work in this area.

### **Establishing Credibility**

One method to increase the credibility of the study is to triangulate the data. Creswell (2008) notes that “triangulation ensures that the study will be accurate because the information draws on multiple sources of information, individuals, or processes” (p. 266). Using three surveys, interviews, and observation field notes ensured that data were collected from multiple sources and types. Triangulation was achieved by overlapping the various qualitative and quantitative data sources and conducting interviews with six individuals with a variety of backgrounds and perspectives. The two quantitative surveys used in this study have previously been validated by the authors of the instruments (Bourdeau & Arnold, 2009; Siegel & Ranney, 2003).

### **Ethical Considerations**

Brock University’s Research Ethics Board (REB) must provide ethical clearance before any research with human participants can be initiated. Since all participants in this study were below the age of 18, parental or guardian permission was required. In addition, participants themselves were asked to provide their assent to participate in the research. Furthermore, confidentiality of all participants was maintained and only pseudonyms appear in this thesis. The study obtained clearance from Brock University’s REB on June 5, 2013 (file no. FAZIO REB 12-245).

### **Restatement of the Area of Study**

The focus of this study is to investigate the effects of an informal science camp (YSIDC). Specifically, participants’ SI skills and their attitudes and views about science and SI was assessed and reported upon.

## **CHAPTER FOUR: PRESENTATION OF RESULTS**

The purpose of this study was to explore the impact of the YSIDC on the participants' inquiry skill development as well as attitudes and views towards science. The results contained in this chapter were obtained through a mixed-methods design. Both quantitative and qualitative data were collected from a variety of sources. The researcher collected descriptive field notes along with three surveys completed by students both before and after the YSIDC intervention. Interview data were also obtained from six specific participants before and after the intervention.

Participants attended the week-long camp engaged in activities that were designed to promote SI process skills and knowledge. Two levels of programming were offered; beginner novice and intermediate experienced. Much of the time, these two groups performed the same activities; however, experienced participants were separated to expand on their current understanding of inquiry and instead of performing an open inquiry with a controlled experimental design, they solved a technological problem.

This chapter presents the findings from each survey instrument (SPSI, CARS, VOSI-E) separately, and highlights significant differences between beginner novice and intermediate experienced students. This is followed by a presentation of the interview data in which themes emerged that support the data from the surveys. The chapter concludes with a synthesis of all of the data sources. The major themes identified in this chapter provide context for the discussion in chapter 5.

### **Self-Assessment of Knowledge in Respect to SI—Findings From SPSI Instrument**

One of the research questions for this thesis was: What is the impact of the YSIDC on participants' self-efficacy and knowledge of scientific inquiry skills? SI skills

and self-efficacy were not directly assessed, but participants completed a self-assessment of their SI skills using a modified SPSI Instrument (see Appendix C). This was completed both before and after the intervention. Since self-efficacy has been demonstrated to be a powerful indicator of individuals' attitude towards a domain of learning, it is a useful framework to use in regards to how participants perceive their SI abilities that can impact their future behaviours in relation to learning and doing science. For each item on the SPSI instrument, a numerical value was assigned to each selected response (i.e., 1 = strongly disagree; 2 = somewhat disagree; 3 = neutral; 4 = somewhat agree; 5 = strongly agree). Mean pre- and post-test scores for individual items were compared using a two-tailed paired-sample *t*-test. Individual items were analyzed so that the quantitative findings could be triangulated with the qualitative data sources.

### **Results From SPSI Instrument for All Participants**

Participants demonstrated some significant growth in self-efficacy of scientific process skills as a result of their participation in the YSIDC. When the 30 participant data were pooled together, eight of the 11 items in the SPSI instrument significantly improved after the intervention, seven of which were significant at a level of  $p < .01$ . The other three items' means did increase in the post-test, but were not significant. Table 2 shows a summary of the pre and post-test paired *t*-test scores as well as the means, standard deviations, and degrees of freedom for all 30 participants' responses for the SPSI instrument. Overall, the pre-test mean values for all 30 participants were fairly high, ranging from 3.83 to 4.53 out of a possible score of 5.0. The post-test mean values shifted higher and ranged from 4.33 to 4.80.

Table 2

*Paired Sample T-tests of Pre- and Post-Test of SPSI Instrument (N=30)*

SPSI item	Pre-test values		Post-test values		<i>df</i>	<i>t</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
I can use scientific knowledge to form a question	4.10	0.662	4.73	0.521	29	-5.64**
I can ask a question that can be answered by collecting data	4.17	1.02	4.80	0.484	29	-4.29**
I can design a scientific procedure to answer a question	4.20	0.887	4.67	0.661	29	-3.50**
I can communicate a scientific procedure to others	4.17	0.699	4.53	0.629	29	-3.00**
I can record data accurately	4.10	0.995	4.50	0.861	29	-2.69*
I can use data to create a graph for presentations	4.37	0.999	4.77	0.568	29	-2.84**
I can create a display to communicate my data and observations	4.23	0.971	4.43	0.728	29	-1.24
I can analyze the results of a scientific investigation	3.97	0.928	4.40	0.770	29	-3.26**
I can use science terms to share my results	3.83	0.913	4.37	0.809	29	-4.00**
I can use models to explain my results	4.07	0.907	4.33	1.03	29	-1.21
I can use the results of my investigation to answer the question that I asked	4.53	0.860	4.70	0.596	29	-1.31

\* =  $p < .05$ , \*\* =  $p < .01$

Questions 1 and 2 on the SPSI instrument dealt with participants' self-assessment of their abilities to ask questions. These two items (1 and 2) had the highest t-values and were both significant ( $p < .01$ ). The practice participants had at generating questions from experiences, interests, or looking up scientific knowledge gave them opportunities to ask questions throughout the week. The instructors emphasized the importance of scientists and engineers in asking questions.

The last item (11) was about participants' ability to answer questions based on the results of an experiment. The initial pre-test mean ( $M = 4.53$ ) was the highest value for the instrument before the YSIDC; however, it did improve in the post-test ( $M = 4.70$ ), but was not statistically significant. It is interesting to note that students began the camp with a higher mean score of answering questions than asking them, but after the intervention, mean scores were higher for asking questions than answering them.

Questions 3 and 4 dealt with designing and communicating procedures to others. Both means significantly rose ( $p < .01$ ). All participants were expected to design their own inquiries or structures and were responsible to communicate their work to others which might explain the increase.

Items 5, 6, 7, and 8 were concerned with data manipulation. The questions about producing a graph and analyzing the data both significantly rose ( $p < .01$ ), while the item about being able to record data was significantly higher in the post-test ( $p < .05$ ). However, the participants did not improve their self-assessment in their abilities to create visual displays for their SI results by the end of the camp.

Question 9 asked participants about how comfortable they were with using scientific terms. This item had the lowest pre-test mean, but was significantly higher in

the post-test ( $p < .01$ ). The instructors specifically used correct scientific terms, especially scientific process skills terminology. Participants incorporated proper vocabulary into their final presentations. This exposure and practice might have contributed to the significant difference.

Finally, item 10 that assessed participants' self-efficacy of using models to explain their results did not significantly rise after the intervention. Instructors did not emphasize using models throughout the camp and only alluded to the benefits of them once.

### **SPSI Data for Novice Participants**

SPSI pre- and post-test scores were also separated to investigate how the YSIDC impacted the novice participants. Twenty of the 30 participants in the study were in the novice program. The summary of results for the paired two-tailed paired t-test including pre- and post-test means, standard deviations, and the degrees of freedom are presented in Table 3. Ten of the 11 item means increased in the post-test. The only exception was the question addressing using models to explain results. That mean score did not change after the YSIDC.

Most of the other measures were consistent with the aggregate novice and experienced cohort scores. Five of the measures rose significantly at a level of  $p < .01$ . These included the two items about questions, two others about procedures, and the one that assessed self-efficacy of scientific vocabulary. Three more questions were significant at  $p < .05$ . They were all items that investigated the self-efficacy of data, including the recording, graphing, and analyzing of data.

Table 3

*Paired Sample T-tests of Pre- and Post-Test of SPSI Instrument for Novice Participants (N=20)*

SPSI item	Pre-test values		Post-test values		<i>df</i>	<i>t</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
I can use scientific knowledge to form a question	3.95	0.686	4.65	0.587	19	-5.48**
I can ask a question that can be answered by collecting data	4.20	1.06	4.75	0.550	19	-2.98**
I can design a scientific procedure to answer a question	4.00	0.918	4.60	0.754	19	-3.27**
I can communicate a scientific procedure to others	4.00	0.725	4.45	0.686	19	-2.93**
I can record data accurately	3.85	1.09	4.30	0.979	19	-2.27*
I can use data to create a graph for presentations	4.20	1.11	4.65	0.671	19	-2.44*
I can create a display to communicate my data and observations	4.20	1.01	4.40	0.754	19	-1.16
I can analyze the results of a scientific investigation	3.70	0.979	4.15	0.813	19	-2.44*
I can use science terms to share my results	3.65	0.933	4.25	0.910	19	-3.94**
I can use models to explain my results	4.20	0.696	4.20	1.15	19	0.00
I can use the results of my investigation to answer the question that I asked	4.45	0.999	4.55	0.686	19	-0.57

\* =  $p < .05$ , \*\* =  $p < .01$

### **SPSI Data for Experienced Participants**

Ten of the 30 participants were in the experienced cohort. A two-tailed paired t-test was used to determine the impact of the YSIDC on this cohort. The summary of this data is found in Table 4. Overall all of the mean scores increased in the post-test; however, only three items (2, 8, and 10) were significant at  $p < .05$ : “asking questions that can be answered by data,” “analyzing results of investigations,” and “using models to explain results,” respectively. Item 10 is of particular interest because it was the only item in the novice cohort data whose mean did not increase though it did significantly with the experienced group. The pre-test mean for the experienced cohort was the only one below 4.0 and might indicate that these students felt less knowledgeable about models before the camp, but it appears that even limited discussion of them was enough to connect to previous schema about models the novice students did not have, thus resulting in a significant improvement in their self-assessment of models in SI.

Overall nine of the 11 pre-test mean scores were higher in the experienced students over the novice students. The only ones that were lower were the items about asking questions that can be answered by data and using models to explain results. All items were higher for the experienced students on the post-test.

### **Attitudes Towards Science—Findings From CARS Instrument**

The second research question was: What is the impact of the YSIDC on participants' attitudes, and views towards science and scientific inquiry? The impact of the YSIDC on participants' attitudes about science was assessed by using the CARS Instrument (see Appendix D). It was administered before the YSIDC began and at the very end of the camp. The instrument has 25 questions and uses the same Likert scale as the SPSI tool. Responses were converted to numerical values and

analyzed using a two-tailed paired t-test, just like the SPSI data. This section will first present the findings for the entire population of 30 participants that attended the camp and followed by the results for novice and experienced participants.

### **CARS Results for All Participants**

The level of impact of the YSIDC on attitudes towards science was much less than on participants' inquiry skills and knowledge of SI skills as reflected by data from the CARS instrument. Nonetheless, there were some significant findings that will be explored. The summary of data for the paired t-test comparing the pre-test and post-test mean scores for all of the participants is found in Table 5. Unlike the SPSI instrument, some of the items were reverse worded in a way that lower scores reflected a more positive attitude towards science (e.g., see item 9). Out of the 25 items, 21 had post-test scores with mean values suggesting more positive attitudes towards science, two did not change (items 9 and 12) and only two (items 17 and 22) went in a direction associated with a less positive attitude towards science.

Item 9's mean did not change and the scores were consistently low suggesting the positive attitude that science is connected to their lives. The initial low mean score seems to indicate that the participants already came to the YSIDC with this attitude. Item 12's results indicate that the camp had no impact on participants' attitudes towards how science is related to sports.

Items 17 and 22 had means scores associated with poorer attitudes towards science; however, neither was significant. Item 22 was particularly interesting considering item 8 was similar and significantly improved. The original mean for this item was the lowest on the instrument and it was worded in the negative; perhaps these two observations can explain this anomaly.

Table 4

*Paired Sample T-tests of Pre- and Post-Test of SPSI Instrument for Experienced**Participants (N=10)*

SPSI item	Pre-test values		Post-test values		<i>df</i>	<i>t</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
I can use scientific knowledge to form a question	4.40	0.504	4.90	0.316	9	-2.24
I can ask a question that can be answered by collecting data	4.10	0.982	4.90	0.316	9	-3.21*
I can design a scientific procedure to answer a question	4.60	0.674	4.80	0.422	9	-1.50
I can communicate a scientific procedure to others	4.50	0.674	4.70	0.483	9	-1.00
I can record data accurately	4.60	0.505	4.90	0.316	9	-1.41
I can use data to create a graph for presentations	4.70	0.647	5.00	0.000	9	-1.41
I can create a display to communicate my data and observations	4.30	0.924	4.50	0.707	9	-0.56
I can analyze the results of a scientific investigation	4.50	0.522	4.90	0.316	9	-2.45*
I can use science terms to share my results	4.20	0.786	4.60	0.516	9	-1.50
I can use models to explain my results	3.80	0.1.17	4.60	0.699	9	-2.75*
I can use the results of my investigation to answer the question that I asked	4.70	0.467	5.00	0.000	9	-1.96

\* =  $p < .05$ , \*\* =  $p < .01$

Table 5

*Paired Sample T-tests of Pre- and Post-Test of CARS Instrument (N=30)*

CARS item	Pre-test values		Post-test values		<i>df</i>	<i>t</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
My parents encourage me to continue with science	4.73	0.691	4.83	0.461	29	-1.36
I plan to take science classes in high school	4.67	0.758	4.73	0.640	29	-1.00
Science helps me to work with others to find answers	3.97	0.928	4.53	0.730	29	-3.32**
Learning science helps me to evaluate my own work	3.90	0.923	4.43	0.774	29	-3.76**
Learning science helps me understand the environment	4.50	0.682	4.70	0.535	29	-1.65
Emotion has no place in science	2.50	1.14	2.23	1.25	29	1.11
Learning science helps me to judge other's people's point of view	3.73	0.980	4.03	0.964	29	-1.66
Science will help me understand more about world-wide problems	4.27	0.785	4.60	0.675	29	-2.41*
Science has nothing to do with my life out of school	1.33	0.661	1.33	0.959	29	0.00
Experiments in science help me to learn with a group	3.97	0.850	4.34	0.850	29	-2.11*
Science teaches me to help others make decisions	3.60	0.968	3.90	0.923	29	-1.51

\* =  $p < .05$ , \*\* =  $p < .01$

Table 5 (cont'd)

CARS item	Pre-test values		Post-test values		<i>df</i>	<i>t</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Knowing science will not help me in sports	2.53	1.36	2.53	1.46	29	0.00
Science has nothing to do with buying things, such as food and cars	2.07	1.17	1.50	0.861	29	2.98**
Knowledge of science could make it easier to fix a bicycle	4.10	1.03	4.40	1.00	29	-1.25
Science teaches me to think less clearly than I already do	1.70	1.15	1.33	0.661	29	1.61
Making a good decision is a scientific process	3.83	1.09	3.97	1.10	29	-0.680
Learning science at school and other places will help prepare me for college or university	4.77	0.430	4.73	0.450	29	0.373
Much of what I learn in science classes is useful in my everyday life today	4.07	0.868	4.40	0.932	29	-1.98
Learning science can help me when I pick food to buy	3.87	0.900	4.43	0.774	29	-4.01**
Caring about people is part of making scientific choice, such as whether to use pesticides on plants	3.80	0.887	4.07	1.34	29	-1.11
Science helps me to make sensible decisions	4.03	0.890	4.37	0.850	29	-2.41*

\* =  $p < .05$ , \*\* =  $p < .01$

Table 5 (cont'd)

CARS item	Pre-test values		Post-test values		<i>df</i>	<i>t</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
The things I do in science have nothing to do with the real world	1.17	0.379	1.43	1.04	29	-1.61
Science helps me to make decisions that could affect my body	4.20	0.997	4.50	0.682	29	-1.43
Learning science will have an effect on the way I vote in elections	3.17	1.23	3.70	0.988	29	-1.84
Making decisions can be difficult without the reliable evidence	4.53	0.730	4.67	0.711	29	-1.16

\* =  $p < .05$ , \*\* =  $p < .01$

Many of the items on the CARS survey asked the respondents questions about connecting science to their lives in many ways. Although many of these did not significantly change after the YSIDC intervention, two significantly improved (i.e.,  $p < 0.01$ ). The two items were: “science has nothing to do with buying things, such as food and cars” and “learning science can help me when I pick food to buy.” It is interesting that the food-related ones were significant because a few of the open inquiries by participants explored the impacts of food on humans (e.g., heart rate or taste preference). Perhaps the individual content and context of inquiries, including being involved in others’ studies can impact attitudes of science. The item “science will help me understand more about world-wide problems” also was significant at  $p < 0.05$  level. Instructors showed several videos of scientists working in several areas and presented the importance of science and engineering fields to solve real problems. The survey results seem to indicate that this has an impact on their abilities.

Another domain that significantly increased after the YSIDC was participants’ attitudes towards working with others. The item “science helps me to work with others to find answers” had a mean score significantly increased from 3.97 to 4.53 at a level of  $p < 0.01$ . In addition, item 9, “experiments in science help me to learn with a group” also significantly increased at a level of  $p < 0.01$ . These results seem reasonable since all of the experiences and activities in the camp were done in groups and participants needed to collaborate.

### **Comparing CARS Data for Novice and Experienced Participants**

The summary data for the CARS survey is found in Table 6 for novice students and Table 7 for experienced students. The trends in the change of pre-test and post-test

data for both groups were similar. The largest difference was on item 24. This item stated that “learning science will have an effect on the way I vote in elections.” The novice students’ mean increased from 2.95 to 3.80 ( $p < 0.05$ ), whereas, the experienced students’ mean slightly fell from 3.6 to 3.5; this change was not significant.

The novice student cohort had six items (3, 4, 13, 18, 19, and 24) that were significantly different whereas the experienced group had only two (4 and 11). This result could be due to sample size differences and the experienced cohort having more positive mean scores in the pre-test resulting in statistical variance. The experienced cohort had only one item that increased significantly ( $p < 0.05$ ) that the novice group did not. This was item 11, “science teaches me to help others make decisions.” Throughout the camp, there were opportunities for the older experienced students to work and mentor the younger participants. Perhaps this experience had an impact on how they felt about using their knowledge and skills in science to help others out.

Two items directly asked about the role of emotions in science. Item 6 stated: “emotion has no place in science.” Although the mean values in the pre- and post-test were not significant, both novice and experienced cohorts had lower mean values on the post-test, indicating emotion should not be in science. However, both groups’ mean scores increased, but not significantly, on item 20: “caring about people is part of making a scientific choice, such as whether to use pesticides on plants.” The final item on the SPSI instrument that came out significant was about the ability to use science terms. Although not a major theme in the interview data, participants’ responses used more technical terms; this was also true in the VOSI-E qualitative survey.

Table 6

*Paired Sample T-tests of Pre- and Post-Test of CARS Instrument for Novice Participants*

*(N=20)*

CARS item	Pre-test values		Post-test values		<i>df</i>	<i>t</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
My parents encourage me to continue with science	4.60	0.821	4.75	0.550	19	-1.37
I plan to take science classes in high school	4.55	0.887	4.60	0.754	19	-0.567
Science helps me to work with others to find answers	3.75	0.967	4.35	0.813	19	-2.56*
Learning science helps me to evaluate my own work	3.65	0.988	4.20	0.834	19	-2.77*
Learning science helps me understand the environment	4.50	0.688	4.60	0.598	19	-0.698
Emotion has no place in science	2.65	1.23	2.40	1.31	19	-0.754
Learning science helps me to judge other's people's point of view	3.50	1.05	3.75	1.02	19	-1.00
Science will help me understand more about world-wide problems	4.15	0.813	4.50	0.761	19	-1.79
Science has nothing to do with my life out of school	1.35	0.671	1.30	0.801	19	0.370
Experiments in science help me to learn with a group	3.90	0.912	4.25	0.967	19	-1.38

\* =  $p < .05$ , \*\* =  $p < .01$

Table 6 (cont'd)

CARS item	Pre-test values		Post-test values		<i>df</i>	<i>t</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Science teaches me to help others make decisions	3.50	1.05	3.75	1.02	19	-0.865
Knowing science will not help me in sports	2.75	1.33	2.75	1.45	19	0.00
Science has nothing to do with buying things, such as food and cars	2.30	1.30	1.70	0.979	19	2.26*
Knowledge of science could make it easier to fix a bicycle	3.90	1.17	4.40	0.883	19	-1.60
Science teaches me to think less clearly than I already do	1.90	1.29	1.35	0.671	19	1.68
Making a good decision is a scientific process	3.65	1.14	3.80	1.24	19	-0.529
Learning science at school and other places will help prepare me for college or university	4.80	0.410	4.70	0.470	19	0.809
Much of what I learn in science classes is useful in my everyday life today	4.05	0.945	4.45	0.999	19	-2.18*
Learning science can help me when I pick food to buy	3.70	0.979	4.35	0.875	19	-3.58**
Caring about people is part of making scientific choice, such as whether to use pesticides on plants	3.70	0.865	4.05	1.19	19	-1.32
Science helps me to make sensible decisions	3.85	0.988	4.20	0.894	19	-1.93

\* =  $p < .05$ , \*\* =  $p < .01$

Table 6 (cont'd)

CARS item	Pre-test values		Post-test values		<i>df</i>	<i>t</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
The things I do in science have nothing to do with the real world	1.25	0.444	1.45	0.945	19	-1.29
Science helps me to make decisions that could affect my body	4.20	1.01	4.40	0.754	19	-0.748
Learning science will have an effect on the way I vote in elections	2.95	1.36	3.80	1.01	19	-2.33*
Making decisions can be difficult without the reliable evidence	4.55	0.686	4.60	0.821	19	-0.438

\* =  $p < .05$ , \*\* =  $p < .01$

Table 7

*Paired Sample T-tests of Pre- and Post-Test of CARS Instrument for Experienced*

*Participants (N=10)*

CARS item	Pre-test values		Post-test values		<i>df</i>	<i>t</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
My parents encourage me to continue with science	5.00	0.00	5.00	0.00	9	0.00
I plan to take science classes in high school	4.90	0.316	5.00	0.00	9	-1.00
Science helps me to work with others to find answers	4.40	0.699	4.90	0.316	9	-2.24
Learning science helps me to evaluate my own work	4.40	0.516	4.90	0.316	9	-3.00*
Learning science helps me understand the environment	4.50	0.707	4.90	0.316	9	-1.81
Emotion has no place in science	2.20	0.919	1.90	1.10	9	1.00
Learning science helps me to judge other's people's point of view	4.20	0.632	4.60	0.516	9	-1.81
Science will help me understand more about world-wide problems	4.50	0.707	4.80	0.421	9	-1.96
Science has nothing to do with my life out of school	1.30	0.675	1.40	1.26	9	-0.208
Experiments in science help me to learn with a group	4.10	0.738	4.60	0.516	9	-1.86
Science teaches me to help others make decisions	3.80	0.789	4.20	0.632	9	-2.45*

\* =  $p < .05$ , \*\* =  $p < .01$

Table 7 (cont'd)

CARS item	Pre-test values		Post-test values		<i>df</i>	<i>t</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Knowing science will not help me in sports	2.10	1.37	2.10	1.45	9	0.00
Science has nothing to do with buying things, such as food and cars	1.60	0.699	1.10	0.316	9	2.24
Knowledge of science could make it easier to fix a bicycle	4.50	0.527	4.40	1.26	9	0.287
Science teaches me to think less clearly than I already do	1.30	0.675	1.30	0.675	9	0.00
Making a good decision is a scientific process	4.20	0.919	4.30	0.675	9	-0.557
Learning science at school and other places will help prepare me for college or university	4.70	0.483	4.80	0.422	9	-1.00
Much of what I learn in science classes is useful in my everyday life today	4.10	0.738	4.30	0.823	9	-0.557
Learning science can help me when I pick food to buy	4.20	0.632	4.60	0.516	9	-1.81
Caring about people is part of making scientific choice, such as whether to use pesticides on plants	4.00	0.943	4.10	1.66	9	-0.198
Science helps me to make sensible decisions	4.40	0.517	4.70	0.675	9	-1.41

\* =  $p < .05$ , \*\* =  $p < .01$

Table 7 (cont'd)

CARS item	Pre-test values		Post-test values		<i>df</i>	<i>t</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
The things I do in science have nothing to do with the real world	1.00	0.00	1.40	1.26	9	-1.00
Science helps me to make decisions that could affect my body	4.20	1.03	4.70	0.483	9	-1.46
Learning science will have an effect on the way I vote in elections	3.60	0.843	3.50	0.972	9	0.231
Making decisions can be difficult without the reliable evidence	4.50	0.850	4.80	0.422	9	-1.15

\* =  $p < .05$ , \*\* =  $p < .01$

The science terms that the qualitative instruments could assess were specific to inquiry, not those connected to specific fields of science. Field notes and the program also confirmed that instructors focussed on using generic SI vocabulary. Participants also communicated with each other using these terms (e.g., variables, replications, quantitative, etc.).

### **Views Towards Science and SI—Findings From VOSI-E Instrument**

Views were previously defined as a combination of beliefs and knowledge. Since the camp was intended to develop the participants' knowledge about science and SI, the study addressed if there would be an impact on their views. To continue to explore the second research question, the VOSI-E instrument (see Appendix E) was used to collect data from the participants before and after the YSIDC about their views towards science and SI. The VOSI-E is a short response qualitative survey that has six questions, three of which had multiple parts to them. Participants' responses were transcribed, coded, and then inductively analyzed

This section will elaborate four themes that emerged from the data corpus. These themes are: (a) shift in a view of science as content to science as inquiry, (b) importance of questioning in SI, (c) role of data in SI, and (d) deeper understanding of SI. Each of these four themes will be used as a framework to present the findings from the survey.

#### **Shift From Science as Content to Science as Inquiry**

The first two questions probed the participants about their views of the work scientists do and how they do their work. Several participants articulated a shift from a view that scientists' work was content focused to one that was more inquiry-based. For example participant 16 originally stated, "Astronomers study the universe while

biologists study plants and life forms.” However, in the post-survey participant 16 stated, “Scientists do a lot of different kinds of work. Scientists think of a question and solve it.” In addition, another novice participant had a much more sophisticated impression of what scientists do after the camp; participant 7 originally wrote “They study plants.” In the post-survey, participant 7’s response changed to “They ask questions and answer them with data. And use the data and evidence to support their conclusions.” These participants reflected that some of the individuals began the camp with a view that science was about learning content and being experts in content and that scientists solved problems by being experts in certain fields. However, responses shifted in the post-surveys to reflect that scientists actively learn within their fields by engaging in inquiry and constructing new meaning through the work they do.

This model of more active engagement in knowledge construction is evident in participant 21’s responses to the question regarding whether or not the observational biological study in question 3a was scientific. Participant 21’s initial answer was, “Yes, because she did background research about birds and what they eat to form a conclusion,” but after the YSIDC this same participant wrote, “Yes because she studied the correlation between beaks and food.” There is a slight shift in the answer from one in which the scientist uses background research to make her conclusion to one in which the researcher uses her observations about beaks and food to make her conclusions.

The YSIDC specifically did not focus on presenting science topics; rather the vast majority of the time was spent on activities and challenges that had participants actively learning by solving problematic situations. This intentional decision was to demonstrate to the participants that scientists engage in knowledge construction by actively engaging

in their work and making meaning of it. One of the ways that scientists engage in their work is in being question generators, which is the second theme that emerged from this survey.

### **Importance of Questioning**

Another theme from the survey is that participants increasingly recognized the importance of questioning in the work that scientists do. Several participants mentioned questioning in reference to the items about how scientists do their work in their post-surveys, like participant 27 in response to question 1: “Scientists do their work by asking a question. Because they want to solve their question, they create an experiment or a new design.” Participant 28 also wrote about questions with the following post-survey response: “Scientists first come up with a question and try to answer it using research, study, observation, or an experiment. Then they analyze and communicate their findings.” These two participants clearly state that inquiries begin with a question. Both also communicate that there are many ways in which their questions can be answered.

Some participants significantly changed their responses after the intervention to emphasize the importance of questions in how scientists do their work. For example, participant 12 initially stated in question 1 that, “First they would probably analyze what they found and place it in a category based on what they do and then they study it to see what it is,” then responded in the post-survey with: “Well they first ask a question about something and then experiment to try to find the answer to it.” This participant also demonstrated a growth by better understanding how scientists initiate the work they engage in. This shift of the importance of questioning in the work scientists do is consistent with the findings of questioning in the SPSI instrument and an intended focus

of questioning in the YSIDC. The major focus on questioning at the camp might have limited the participants' appreciation of the complexity and diversity of how different scientists do their work.

The importance of questions also arose when participants answered the item of when scientists are creative. Some of the participants, all but one were in the experienced cohort, initially identified generating questions is when scientists are creative in an investigation. However, several more recognized questions in their post-survey as a creative part of SI. Participant 16 succinctly stated, "They are creative when making up the questions." This differed from the initial response that explained that scientists are creative when proving their results.

Others who did not mention questions in the pre-survey added them to the list of processes that scientists engage in creatively. For example, participant 27 includes questioning in her post-survey list with this response: "They're creative when doing an investigation when they come up with ideas on how to experiment their hypotheses, and also scientists are creative when they come up with questions because their minds are always running."

The YSIDC clearly had an impact on how participants situated questioning in the inquiry process. This was evident when over half of the individuals in the study commented on this skill throughout the VOSI-E survey. The other skill that was also mentioned on this survey was the importance of collecting data and evidence and using it to defend a conclusion, which is the next theme that will be explored.

### **Data in Scientific Inquiry**

Another area in which participants' responses were more sophisticated on the

post-surveys were their understandings of the importance of collecting and analyzing data and evidence to support the work that scientists do. Question 3 on the VOSI-E had three parts that dealt with the work of predicting weather. Although there was no evidence of participants improving their understanding of models in this context, some individuals realized the importance of data in making conclusions on the post-test. Specifically, participant 7 could not explain on the pre-test why some reporters disagree on the weather, but alluded to the importance of data in making a prediction with this statement on the post-survey: “Because sometimes they don’t get the amount of evidence that they need.”

The YSIDC had several activities and inquiries, including the main open inquiry where participants needed to defend their work with the data they collected. Instructors differentiated between qualitative and quantitative data and expected that participants record, analyze, and communicate their data to support their findings. Participant 25 discussed how scientists might even have access to the same data, but might interpret it differently with the following post-survey response: “They don't always agree because people interpret data differently.” A few other participants had similar answers too. During the YSIDC many groups were struggling with how to record and interpret their data that might have led them to realize that not every scientist will organize the data and communicate in the same way.

Several participants also mentioned data on the post-survey question about how scientists do their work. Participant 27 mentioned data in her pre-survey response, but articulated more clearly at the end of the camp with this answer: “They also analyse their data and defend their work with supportive evidence from their work.”

Despite some understanding of evidence and data in the pre-survey, there was a shift towards a more mature comprehension of the role data and evidence plays in SI in the qualitative answers to some questions on the VOSI-E. The growth in their questioning and use of data also seem to contribute to participants moving away from a basic understanding of inquiry as TSM to one that is a more complex model of inquiry.

### **From Scientific Method to a Broader Understanding of Inquiry**

The final theme that emerged out of the VOSI-E survey was perhaps the most compelling. Participants developed a broader understanding of SI, not limiting it to a scientific method. In fact, participants began to describe the different kinds of work scientists do and identify control experiments from other types of inquiry. Question 3 on the survey asked the participants if the observational study done on birds was scientific and then had them choose whether or not it was an experiment. In both the pre- and post-surveys the vast majority of respondents identified the work as scientific, and many even in the pre-survey correctly believed that the case was not an experiment. However, eight additional participants switched their responses from thinking it was an experiment to that it was not, like participant 24 who began with: “I think it is because she examined birds that eat the same thing have a similar beak. Which can be a question.” In the post-survey this participant believed the situation was not an experiment and supported this decision with: “No, because she did it like a research more than an experiment. For example, she didn't use the birds, she examined the birds.” Although this participant did not provide substantial evidence to support her new position, she began to articulate a difference between research and controlled experiments.

Participant 16 more clearly communicated why the situation was not an

experiment in the post-survey response. Originally participant 16 wrote, “No, the scientist did not experiment, she conducted a survey,” but after the YSIDC, the participant wrote for the same question, “No, the work is not an experiment, there are no variables you can change, it is an observation.”

Other students mention the lack of controlled variable testing in the post-responses to justify why the work was not an experiment. This is a major shift by identifying elements of different scientific work that was lacking in the pre-survey responses. Finally, participant 28 also changed his mind and concluded on the post-survey that, “No. I don’t think her work was an experiment, I think it was an observation/study because she studied the birds and noticed things and did not set up an experiment.” Although none of these responses perfectly articulate the difference with confidence, they are beginning to delineate different types of work that scientists do and have begun to use scientific terms like variables, field tests, observations, or studies. Virtually all of the participants left the YSIDC believing the observational study constituted scientific work, but was not necessarily considered an experiment.

This theme was even more pronounced in the responses to question 6 that directly asked students if scientists have to follow TSM. Table 8 summarizes the results from the first part of question 6. Nine more participants identified after the YSIDC that scientists do not need to follow TSM, including two experienced students. Both of these participants clearly expressed their developing understanding of the work scientists do. Participant 25 initially defended TSM by saying, “I think scientists must follow the method because it is like a guideline. They don't necessarily have to follow it exactly but the order is a way to efficiently collect and share data.”

Table 8

*Summary of Pre- and Post-Survey Responses for Question 6 Part 1 on VOSI-E*

VOSI-E item:	Pre-Test Values		Post-Test Values	
	# Participants	%	# Participants	%
Do you agree that to do good science, scientists must follow the scientific method?				
Yes	11	36.6	2	6.67
No	18	60.0	27	90.0
Not Sure	1	3.33	1	3.33

After the YSIDC, participant 25 changed the response and justified this change with, “Science doesn't always use the scientific method like the guy who discovered the certain type of leech. He made a scientific discovery not using the scientific method.” In this case, participant 25 actually referred to a video that was shown at the camp illustrating the work of a field biologist.

The YSIDC provided several examples of scientists who conduct inquiries that do not use a standard method. Participants also had opportunities to participate in a variety of scientific activities; some were controlled experiments while others were not. Participant 29 similarly began the YSIDC with the view that scientists must follow TSM. Participant 29 justified this position with, “Because otherwise without using scientific method the experiment can be compromised if they don't identify the variables or they don't accurately design the experiment.”

After the YSIDC, participant 25 changed her view and defended it with, “All scientists have different ways of conducting experiments, designing them and analysing data. I think what is important is not the method but the end results (whether or not it is accurate, etc.).” The response demonstrates a shift of thinking towards a much more flexible model of SI.

Other participants began believing that scientists did not need to follow the scientific method. However, many of their justifications improved after the camp. For example, participant 5 initially stated, “Research is still scientific yet it doesn't use the scientific method”; however, after the camp, the response changed to, “There is no scientific method. There are scientific methods.” In the first response, it is not clear what he means by research. Participant 5 might be referring to collected knowledge and not addressing how that knowledge is acquired. His post-survey result is still vaguely written,

but still gets to the sentiment that there are multiple ways of conducting inquiries that was missing from the first answer. Other participants also used clearer language about multiple right ways of conducting scientific work while others mentioned that the strict order of TSM is not always followed in a linear way. Although, there were three students who either still believed that all scientists used the scientific method or were not sure after the intervention the majority could adequately articulate why that statement is false. The majority of the responses significantly improved over their initial responses, but many still lacked a detailed argument to support their view that would indicate that their view could be still fragile.

### **Pre- and Post-Intervention Interviews**

Six participants were interviewed before and after the YSIDC. These individuals were specifically selected to represent the range of participants in the camp. There were three females and three males including four who were enrolled in the novice program and two in the experienced program. The purpose of the interviews was to provide context and triangulate the findings from the survey data. The interview protocol used can be found in Appendix F. Participants' responses were transcribed, coded, and then inductively analyzed. The third research question for this thesis was: How does the program of the camp facilitate student inquiry learning? The data from the interviews provided some insight into this question as well as supporting and elaborating on the previous findings in this chapter. It will be presented using two major themes that emerged from the data. Participants identified how the YSIDC positively impacted their knowledge about science and SI as well as the impact of the YSIDC on their inquiry process skills, and secondly, they contrasted their learning experiences in the YSIDC with how science is taught in schools.

### **Impact of YSIDC on Knowledge of Science and SI as well as on SI Skills**

One of the YSIDC objectives was to improve SI skills throughout the week by providing opportunities to participants to engage and be supported in inquiries. Skill development was previously reported in this chapter through the SPSI instrument. That instrument and the interviews indirectly assessed participants' self-efficacy by measuring the impact of YSIDC had on students' SI skills. Overall, the interview data supported the findings of the SPSI instrument. Knowledge acquisition and skill development were intractably interwoven in the participants' responses from the interviews and therefore, will be presented together.

All participants within the interviews identified development in their understanding of SI. Participant 2 initially did not provide an answer to "what is science" during the pre-survey, but on his post-interview described science as: "Asking a lot of different questions and then finding the answer to something." Although his response was not specific, it demonstrates a basic understanding of inquiry. Even though some experienced participants seemed to have some understanding of the importance of questions in inquiry, participant 6, one of the oldest individuals in the study and who was attending a third camp, stated that, "O.K., so last week I learned a lot about how to form questions and about the importance of that in science." Despite the fact he identified in the pre-interview that questions are an important part of science, he believed that he built upon this knowledge in this YSIDC.

Participant 1 was more detailed about knowledge he gained from the YSIDC; he reported that he learned, "The three variables...the independent variable, the dependent variable and the controlled variable." Participant 4 also communicated her increase in

knowledge about SI when she was explaining that she would be more comfortable conducting an independent SI with the following response: “I feel a little bit more confident now because I have a better understanding of science and scientific methods and different ways to do things.” Participant 4 only described that scientists have to include details when reporting their conclusions before the YSIDC; however, after the intervention, this participant responded with:

Well they have to give evidence to their conclusion like even with their hypothesis they have to state why they think that and why they think their conclusion is what happened or their results...scientists would have to just back up what they said and that's what I think is important.

Once again, this is not an eloquent response, but it does include the importance of evidence and scientists defending their work. Participant 6 was also more specific about the use of data in his post-interview with this comment: “But I think data is the main part that they need to present. ...They have to have proof that it is true.”

Participant 4 really summed up what many participants might have learned from the camp with this response:

Well I learned a lot from the camp. Some of the things that I learned I knew from the previous year I went to the camp which would be that there's nothing wrong with failing and it might take more than one try to succeed and you really have to do trial and error. And then some of the best ideas come from collaborations and working as a group and getting help from experts. You really have to record your data accurately, I learned from experience from that and other things—there is no really scientific method. You can do things in any order and that you should have

time to muck around or to experiment before you actually get on with what you are working on. And that there is no one right way to do science.

The most consistent and significant knowledge that participants obtained from the camp were views about SI. This response also commented on knowledge building from last year's camp. Other participants made mention of this as well and demonstrates the importance of a consistent focus running through the programs from year to year. Similarly, participant 6 in the interview claimed that more was learned about the importance of being curious and having the patience of "playing" in the experimental domain before designing experiments. Those interviewed regularly discussed habits of mind, not necessarily content that they learned. Participant 5 really summed up this sentiment with the following answer to the question of what she learned at the YSIDC:

I learned that it's okay to fail and if you're trying to do something and you don't do it the first time, it's okay to fail and you don't have to feel bad. Don't have to give up just try again and use what you learned and just make it better. And also to just trust your instincts too and always ask questions. It's always okay to ask and to not know some things because by asking them you will learn more...just experiment a lot. If you're curious just go for it.

There was a common thread of feeling better about taking risks and learning from mistakes. This view is a very important goal of the YSIDC and helps to inform what is SI.

Regardless of the evidence of growth in knowledge about science and SI, some of the responses during the interviews suggested that there are still areas of knowledge deficits even after the completion of the YSIDC. Specifically, it seems that some participants continue to have a misconception of what a scientific model is. Participant 1

alluded to this with the following response: “Yeah the models, I’m not good at it. Like I am not the builder. I am more the research person.” This participant is describing a model as only a physical model to be built, much like a prototype. The YSIDC did not explicitly address the use of models in the activities, inquiries, or brief instructor-led discussions. Perhaps the lack of attention to scientific models did not help with participants gaining insight into them and can explain why their self-efficacy still remained low after the camp.

Additionally, all of the interviewed participants demonstrated more sophisticated explanations of science and SI in their post-interviews, there is still quite a range of understanding these constructs between the older more experienced participants and the younger novice individuals. However, the YSIDC was able to support the knowledge and skill development across the age and experience range of participants in the camp.

### **Contrasting the YSIDC and Science Education in Public Schools**

To explore the third research question—How does the program of the camp facilitate student inquiry learning?—the experiences of the YSIDC will be contrasted by those interviewed on their experiences at the camp with those in science classes at school. All six interviewees clearly articulated a preference of learning science at the YSIDC than at school. Their views on the differences between the two will be presented here.

In the pre-interview, individuals were asked about their previous experiences with science. Four of the six participants communicated negative views towards science learning at school in this question even though the question was not framed to obtain qualitative assessment of previous science experiences in school. Participant 3

demonstrated a strong position about science teaching in school with the following response:

Oh dear, well, I guess last year at the camp, but in school no one really likes science, like we don't really do anything that is actually science. Real science that is actually fun. So, yeah, I guess really only the camp last year.

Even before the week got started, this participant shares her frustration with the lack of what she perceives as science in school. The view that science occurs infrequently in school was also supported by participant 6 who answered the same question this way:

Well, the science projects. I have done three. I'm going to do my fourth this year. And umm you know school science, but at my school they didn't do a lot of science and I don't know the reason was, but my gym teacher actually taught me science for a long time, so it wasn't very good.

This participant also identified not doing a lot of science in school and made a qualitative assessment that it was not done well due to the quality of teaching. Participant 6 alluded to the fact that the teacher was potentially not qualified to deliver a strong program.

All participants were directly asked about what they thought about how science is being taught in schools right now both before and after the YSIDC intervention. The first difference between how the participants felt about the YSIDC and science in school is that the camp was more about doing science, rather than just reading about it. Participant 1 responded in his post-interview about this difference:

The stuff that you did in the camp was like a lot harder and it taught me a lot more. Because what I did at school was like copying stuff off of the Internet and we did it all the time.

The response before the intervention was similar about what they did, but the participant was more positive about it and even reported enjoying completing projects. However, it was shared that the participant did not see the connection between the content being taught. It is interesting that participant 1 felt the camp was both more challenging and rewarding in terms of what he learned. This view of receiving a content-based curriculum at school was a recurring theme in their answers. Participant 2 supported this stance with his response in the post-interview: “We read by a textbook and then do our questions. ... Pretty much what the textbook says.” Other participants also shared experiences about primarily learning from textbooks and disliked the passive nature of this pedagogical approach. Rather, they seemed to universally desire more chances to engage in inquiry during science at school. This sentiment was articulated by participant 3 who shared:

I think [science teachers in school] should do more hands on things in school than worksheets. Because I get more out of doing things with my hands and actually doing it than like maybe watching people do it or like reading how to do it.

The majority of the time participants did not directly distinguish between hands-on activities that might be more inquiry-based compared to those that are still directed by the teacher. Even the more experienced participant 5 complained of a lack of doing science with this response in the post-interview:

I like school, but it's all of just saying that there is the one way how to do this and don't do it, it's wrong. You have to memorize a lot of things that it's this way or you're not doing it right with experiments that we do. I also think that there should be more hands on activities because there a lot more learning experiences for kids.

Participant 5 brings up an interesting point about not having the pressure of being right on worksheets or in experiments. This would suggest why students' self-efficacy in science may have improved because taking risks and learning from their mistakes were encouraged at the YSIDC. This notion of possibly having several correct models or explanations was elaborated upon by participant 6:

I think the camp was a lot more hands-on than school and I think that there were different ways I saw that you can build things like the towers like, when we build the floating towers, mine was kind of like leaning and it was like almost kind of a three straw thing that kept on going up, but my brother's was just like a square base and it only had 10 straws or something and it was just as high, well a little lower than mine ... so, like there is not a right way, there is just different ways to doing it. And in school they don't really teach you that way, like there are different ways.

Participant 6 identified a potential significant impact of the lived experience of students taking science in school. Requiring students to complete closed inquiries and implying there are right answers will result in students taking less risks and having few opportunities to problem solve and learn from their mistakes.

The participants not only found the camp more open-ended, challenging, and inquiry-based but also found their experiences at the YSIDC more enjoyable. Participant 2 was quite direct in his post-interview and stated that, "It's obviously more fun at the camp." His sentiment was echoed by participant 6 who commented in the post-interview, "but I think it (YSIDC) was a funner way and a way to learn." The YSIDC was therefore enjoyable to the participants because they valued the challenging open inquiry activities

and found they had a chance to take risks, be wrong, and reflect on their learning. The last element that clearly came out of the interview data is that the participants felt positively about the co-operative learning at the YSIDC. Participant 5 provided some great insight into this and linked the cooperative work with deepening her own learning with her following response:

And also there are more instructors which means that you are able to ask more questions and have more time to work on things and also you get to work with people which doesn't happen a lot in school. You either just get picked to be put with someone or you mostly just pick the same person a lot. But you don't really get to learn what everyone else's view on science is if you are with the same person each time. So that is why I like to go to this camp. ... We don't ask questions in science in school. It's just a lot of trying to find the definitions and worksheets.

Finally, participant 6 added the importance of students being given the chance to ask their own questions and learn from others in a community. How can students improve their ability to frame great questions and then seek the answers to their questions without being given the opportunity to do so?

The interview data provided insight into how students felt about their self-efficacy with inquiry skills, what kind of knowledge they felt that they learned at the YSIDC, and how the camp's experience differed from science classes in school. The benefits of the camp over science instruction in schools will be furthered explored in chapter 5. Many of the findings from the four data sources can be connected and provided a richer context of the impact of the YSIDC; these areas will also be explored in the next chapter.

### **Summary of the Chapter**

Chapter 4 summarizes the results and findings of the instruments and methods used to answer the research questions for this thesis: descriptive field notes, SPSI, CARS, VOSI-E surveys, and interview data. Qualitative and quantitative findings for each survey and interview data were presented separately followed by a brief synthesis of the major overlapping themes from those data sources.

The conditions that made the YSIDC a success will further be explored as well as recommendations for public school science education policy makers. An overview of future directions is provided that may be explored for the impacts of informal science education experiences on participants.

## **CHAPTER FIVE: DISCUSSION AND IMPLICATIONS**

This study set out to examine the impacts of an informal science program, the YSIDC. Three research questions guided the study: (a) What is the impact of the YSIDC on participants' self-efficacy and knowledge of SI skills? (b) What is the impact of the YSIDC on participants' attitudes, and views towards science and SI? (c) How does the program of the camp facilitate student inquiry learning? This chapter provides a brief summary of the study, a discussion of the major contributions of the study in relation to the literature, the theoretical and practical implications of the study, as well as suggestions for further research.

### **Summary of the Study**

In this study the impacts of the YSIDC were assessed using a mixed-methods research design. The YSIDC is a week-long camp for participants ages 9 to 14 that encourages and supports independent inquiry through technological design challenges, mini-guided inquiry activities, and a culminating open inquiry in which participants select their topic, questions of inquiry, experimental design, methods for collecting and organizing data, and strategies for sharing their findings with the community (see Appendices A and B for the two schedules). Throughout the camp, participants worked collaboratively with their peers while engaged in inquiry-based learning. The instructors acted as mentors who supported learning through the use of effective questioning, but did not solve most of the challenges the participants faced.

At the onset of the study, demographic and baseline data were collected through surveys and interviews before the start of the YSIDC. Surveys were specifically used to collect information about participants' self-assessment of SI skills (SPSI; Bourdeau &

Arnold, 2009), attitudes towards science (CARS; Siegel & Ranney, 2003), and views about science (VOSI-E; Ko & Lederman, 2005; Schwartz et al., 2008). These instruments are found in Appendices C, D, and E, respectively. The SPSI and CARS are quantitative instruments with 5-point Likert scales. The VOSI-E is a short-answer qualitative instrument. Interviews were also conducted with six participants immediately after the initial surveys were completed. All surveys, except for demographic data, were also completed on the final day of the camp. Pre- and post-test means for the SPSI and CARS surveys were compared using a two-tailed paired sample t-test. Pre- and post-responses for the VOSI-E were inductively coded and analyzed for common themes to triangulate, clarify, and provide context for the survey data. Finally, interviews with the same six participants were conducted between 5 to 13 days after the last day of the YSIDC. Participants' responses from these interviews were triangulated with the other data sources and helped to provide context for some of the patterns found in the survey data.

From these data collection instruments, four themes were identified and provide an organizational framework for this chapter. The four emergent themes are: (a) increased understanding of SI, (b) self-assessment of SI process skills, (c) positive impacts on attitudes towards science and SI, and (d) comparing YSIDC to science education in schools. These themes helped to address the study's three research questions and will be explored in the discussion section.

### **Discussion**

This section of the study will discuss the findings, to gain an understanding of the impact of the YSIDC. The four emergent themes identified above will be explored as well as a brief explanation of the context of the results.

### **Increased Understanding of Scientific Inquiry**

The first research question sought to determine the impact of YSIDC on participants' knowledge of SI. Four subthemes emerged that indicated that participants' knowledge about SI changed: (a) shifting perceptions of how scientists work, (b) increase role of questioning in SI, (c) better understanding of data in SI, (d) deeper understanding of SI.

**Shifting perceptions of how scientists work.** The impacts of the YSIDC are consistent with the current literature concerning constructionist inquiry-based camps. Fields (2009) described two groups of informal science camps for students. The first group focuses on student-led inquiry using laboratory tools and technologies (Gibson & Chase, 2002; Hay & Barab, 2001). These camps are constructivist and emphasize a full cycle of research including defending their work. The second group connects individuals or small groups to scientific mentors. The goal of this second type of camp is to learn about the practices of scientists by learning about their work and connecting with them on a personal level (Bell et al., 2003; Hay & Barab, 2001). The YSIDC would be considered in the first group which research has demonstrated is effective at promoting ownership of work and creativity while developing inquiry skills. These camps effectively have participants learn what kind of tasks scientists engage in. However, Fields reported that mentor camps do a better job at digging deeper into the work of individual scientists and connecting research to larger community of practice of scientists. Findings from this research study have demonstrated that the YSIDC impacted the participants' scope and depth of their understanding of what scientists actually do, especially concerning the

scientific process skills. This finding is consistent with the impacts of other constructionist inquiry-based camps.

The qualitative analysis of the VOSI-E pre- and post-surveys and student interviews revealed that participants increased the knowledge of how scientists do their work. More specifically participants developed a more sophisticated understanding of the different types of ways scientists do their work and the different types of skills they use when researching. Many participants shifted their understanding of scientists as primarily content experts to one which includes the scientist as an active knowledge creator. This included being able to distinguish between controlled experiments from other types of scientific work and designs. This research aligns with the findings of other constructivist science camps (Hay & Barab, 2001). I believe that many participants improved their understanding of how scientists engage in inquiry because they had a chance to see various models of inquiry and struggled through making meaning of their own guided and open inquiries throughout the week. However, data from this study did not suggest that students improved their understanding about situating their work within the larger community of practice of scientists which is more consistent with camps that are mentored focussed (Hay & Barab, 2001). Nor did the VOSI-E or the interviews demonstrate that participants learned any significant content knowledge from a specific field in science. This finding is reasonable as students were not mentored by an expert scientist. Expert scientists often will emphasise content knowledge in their field of work while mentoring others.

**Increase role of questioning in scientific inquiry.** Teaching questioning skills is vitally important for children to reason effectively, especially if they are engaging in

inquiry-based science (Gillies, 2011; Gillies, Nichols, Burgh, & Haynes, 2012).

Literature also suggests that children do not spontaneously ask thought-provoking questions about their own learning (Meloth & Deering, 1999; Zuckerman et al., 1998). Questioning was the domain within SI that was most identified in post-surveys and interviews by the participants that felt they most improved. Participants consistently mentioned the fact that they and scientists alike begin inquiries with questions. Many also mentioned that it was through questions that scientists are creative.

When teachers regularly ask higher-order questions, students' responses improve and it has a positive impact on their learning. Erdogan and Campbell (2008) determined that teachers that employed a high degree of constructivist teaching practices where students were engaged in open-ended inquiry, asked significantly more questions, and posed higher-ordered questions than students from classrooms taught with teacher-directed practices. This finding was consistent with the YSIDC as instructors posed higher-ordered questions throughout the camp.

Participants also had multiple opportunities to ask questions throughout the YSIDC. Specific programming pertaining to question generation was emphasized in many components of the program. Participants also received regular feedback from peers and instructors about the quality of their questions. Effective instructor modelling and participant practice were probably responsible for the gains participants felt in the questioning skills.

**Better understanding of data in scientific inquiry.** Although there is a common belief that inquiry-based approaches to learning science are engaging for students, there is conflicting results about the learning outcomes of the inquiry approach

without mindful guidance from well-trained instructors (Hofstein & Lunetta, 2004). Anderson (2007) described challenges for teachers to implement inquiry-based instruction which included the need to learn new instructional practices and barriers that prevent teachers from even wanting to learn these new approaches. With teachers who either lack skill, will, or both it is challenging for teachers to adequately support the role of process skills in science, including data analysis. After the YSIDC many participants distinguished between qualitative and quantitative observations and some participants even articulated in the post-surveys and interviews about the subjectivity of data analysis. The YSIDC included activities about collecting, organizing, and analyzing data. They also relied on their data to develop conclusions for the major open inquiries. A useful experience was providing participants the opportunity to analyze data and encourage them to take time to look for potential patterns. Next, participants had a chance to share their conclusions looking at the same data and hearing different interpretations of identical data sets.

**Deeper understanding of scientific inquiry.** Windschitl et al. (2008) assert that TSM is not scientific at all and subverts students' understanding of inquiry and the nature of science. They believe that linear model of TSM is far too simple and does not adequately describe the complex nature of SI. Furthermore, Bauer (1992) argued against a universal method, describing a variety of ways in which distinctive disciplines in science pose questions, acquire data, deal with theory, and argue evidence. After the YSIDC, participants were not confined to describing SI as a simple linear series of steps on post-surveys and interviews. Many shifted from describing inquiry as a controlled orderly experimental design to inquiry that is a complex and specific to each case. There

was also an increase in awareness of descriptive and correlation studies. The YSIDC provided both learning experiences and examples of several inquiry approaches. For example, participants saw videos of scientists conducting science in a variety of fields of study. Even though most of their inquiries were controlled experiments, the majority of groups struggled at points in their investigations and needed to revise their plans; some even slightly changed their questions and designs. I believe that having the opportunity to solve authentic challenging problems in their inquiries, which is largely absent in science at school, helped them to better understand the complex nature of SI.

### **Self-Assessment of Scientific Inquiry Process Skills**

The development of scientific process skills allows students to better model and utilize authentic scientific practices (Duschl et al., 2007). Studies like Keselman's (2003) concluded that students find it difficult to apply the appropriate inquiry skills at every stage of the inquiry process, including setting the problem, devising and executing a plan, as well as drawing conclusions from the data. However, data collected from both the SPSI instrument and the interviews revealed that participants' self-efficacy of SI process skills improved by the end of the YSIDC. Eight out of 11 items of the SPSI instrument significantly improved after the camp. The highest t-scores were associated with items about questioning. This was confirmed with the post-interview data. Participants saw that asking questions was paramount to SI. The researcher's field notes also noted that the camp provided multiple opportunities for individuals to ask questions and sort them into categories, including those that were best to be answered through inquiry.

Unfortunately, teachers often model using low-level questions in the classroom rather than requiring thought-provoking responses to critical questions (Herbal-Eisenmann

& Breyfogle, 2005). If students lack good modeling of inquiry questions by their teachers and are not provided opportunities to generate and investigate their own inquiry questions, it is not surprising that they responded positively to the experiences that encouraged and supported questioning at the YSIDC.

Participants' self-assessment also improved in the domain of collecting, analyzing, and using data to support conclusions. Babai and Levit-Dori (2009) argued that the ability to identify the relevant variables to an inquiry and disregard irrelevant ones had a significant impact on their ability to develop procedures and interpret their results. Participants of the YSIDC participated in activities about variable testing before they created their inquiry plans. Perhaps this was important to support the analysis of their results as variables provided a framework to interpret their findings. In addition, during the YSIDC, participants often were asked to collect, record, and make sense of their data without specific instructions on how to do so. They had to struggle through how best to handle data and often reflected and made changes to their approaches, sometimes even asking specific targeted questions to the instructors when really stuck. Even though self-assessment in this domain significantly improved, some participants mentioned in their post-interviews that data collection is still an area that they felt they could improve despite the amount of time doing it at the YSIDC. I believe that the data from the SPSI and interviews suggest that significant gains were made from the intervention, but the gains may be short-lived and that more evidence would be required to suggest that impacts are long lasting.

Participants' SI process skills were assessed indirectly by having them complete the SPSI instrument before and after the intervention. Higher scores could indicate that

students felt more confident or have higher self-efficacy performing these skills. Self-efficacy beliefs can affect academic performance by influencing a number of behaviour and psychological processes (Bandura, 1997) and is a useful framework to predict the future academic achievement of students. Self-efficacy cannot only be a useful predictor of future student academic performance, but also can impact choices of science-related activities, the effort they expend on those activities, the perseverance they demonstrated when they encounter challenges, and the ultimate success they have in science (Bandura, 1997; Britner & Pajares, 2001). Although the SPSI instrument was not designed to specifically measure self-efficacy, student self-assessment of their SI skills can provide an indirect insight into student self-efficacy in SI. It is interesting to note that participants' self-assessment on the SPSI was relatively high before the YSIDC. This might be explained by the fact that these individuals selected to attend the camp and were motivated to learn even more about SI. Nonetheless, based on the SPSI data, all of the participants ranging from novice to experienced seemed to at least maintain or more likely improve their self-assessment of SI skills and thus may also be increasing their self-efficacy towards SI skills.

The most influential source of increased self-efficacy beliefs in science is the interpretation of previous performance or mastery experience (Britner & Pajares, 2006). Experiences in which individuals overcome challenges promote a stronger sense of self-efficacy than those that are more easily won. The other sources of self-efficacy are: vicarious experiences or observing others perform similar tasks; social persuasion, which includes judgements of others (verbally or nonverbally); and finally physiological states such as anxiety and mood states (Britner & Pajares, 2006). The YSIDC program

provided challenging experiences throughout the week in which answers were not easily obtained. Strengths of the YSIDC were the design challenges, mini-activities, and an open inquiry activity that were perceived by participants as challenging and authentic. To accomplish these activities, they collaborated with each other and persevered during their inquiries. Instructors and peers both encouraged and modeled success in activities and participants' moods seemed positive and less stressed than students at school. Perhaps all of these factors combined help to contribute to having students feel an improved self-efficacy of SI skills.

### **Positive Impacts on Attitudes Towards Science and SI**

Research has demonstrated a link between student motivation in science and their achievement (Bathgate, Schunn, & Correnti, 2014). However they also reported that less is known about how concrete science experiences (e.g., science camps or science in school, etc.) relate to motivation towards science. Early middle school children, same as those in this study, demonstrate a gradual decline in science motivation as they approach adolescence (Osborne et al., 2003; Zimmerman, 2012). They argue that any gains in developing participants' positive attitudes towards science and SI would address a significant concern in the literature. Several studies (Gibson & Chase, 2002; Haussler & Hoffman, 2002; Perrier & Nsengiyumva, 2003; Siegel & Ranney, 2003) have already determined that summer science camps or informal after-school programs that promote active inquiry learning can improve attitudes.

The participants' views and attitudes of science and SI were assessed using the CARS instrument and triangulated with the interview data. Although the impact on attitudes of the participants was not as statistically significant when compared to the

changes in scientific process skills, there were some significant results. Overall, there was an overall improvement in attitude scores on the CARS instrument. Twenty-one of the 25 items had higher means on the post-test with seven of them being significant. Even this modest impact on attitudes is an important finding that indicates that the YSIDC went beyond supporting the development of skills and knowledge.

Specifically, a few items on the CARS instrument that significantly increased were those that addressed scientific collaboration. This was corroborated with interview data that suggested participants learned from each other and enjoyed working with different peers. Observations from the YSIDC supported participants working well with both homogenous and heterogeneous partners. This is consistent with other research that concluded that developing and celebrating peer relationships are important factors in successful informal science experiences (Fields, 2009; Mohr-Schroeder et al., 2014). At the onset of the study, the YSIDC was developed in alignment with social development theory in mind (Vygotsky, 1978). Activities in the camp were created to be completed in groups and learning was to be in a safe yet social context. It is interesting that the intended structure of the YSIDC had a significant positive impact on participants' attitudes towards co-operative learning

Comparisons were made between the CARS data for both the novice and experienced cohorts. However, no significant statistical findings were found. Nonetheless, it was noteworthy that participants' attitudes towards science were not as significantly impacted as their SI skills assessed by the SPSI instrument. The broader nature of the attitudes assessed was probably responsible for the smaller impact. Longer interventions are probably required to have more substantial effects on attitudes in science.

### **Comparing YSIDC to Science Education in Schools**

Although there are examples of exemplary SI teaching and learning in Ontario schools, often the focus in elementary classrooms is on teaching and learning disciplinary content. Typically students are engaged in closed-ended inquiry that is teacher-directed. These experiences do not let students demonstrate their creativity, imagination, or problem-solving skills (Pedretti & Bellomo, 2013). Moreover, teachers who have a vague understanding of inquiry through the classical scientific method have difficulty posing thought-provoking questions and struggle to understand the various methods of science (Melville, Bartley, & Fazio, 2012). Therefore, Ontario schools have the challenge of providing experiences that promote the development of SI skills in their students.

Ontario students' scores have been on the decline in the Trends in International Mathematics and Science Study (TIMSS) and in science (Education Quality and Accountability Office, 2012). In fact, both the Canadian grade 4 and grade 8 mean score results have been declining since 2003. Fazio and Karrow (2013) argue that the decline of student achievement in science in Ontario can be attributed to the unintended consequence of focusing too much on literacy and numeracy. There is a need to investigate strategies to improve achievement in science education in Ontario. Among the recommendations that Fazio and Karrow suggest is providing school districts with the autonomy to innovate at the local level and invest in their teachers. The YSIDC is a structure that can be used to satisfy both of these recommendations.

The OME (2007) states that “An important part of scientific and technological literacy is an understanding of the nature of science, which includes an understanding of

... how scientific knowledge is generated and validated” (p. 4). One of the goals of the YSIDC was to expand each participant’s understanding of how scientists do their work and increase their knowledge about SI. The OME (2007) also values the development of students’ scientific SI skills, “Along with knowledge foundation, the study of science and technology offers students varied opportunities to learn and master skills that are relevant to their everyday world” (p. 12). Despite the intentions of the curriculum developers, research includes several examples of failed educational innovations (Guskey, 2002; van Driel, Beijaard, & Verloop, 2001). Some authors report the failings of top-down implementation approaches that lead to “the failure of teachers to implement the innovation in a way corresponding to the intention of the developers” (van Driel et al., 2001, p. 137). Falloon and Trewern (2013) suggest that the incorrect premise is that curriculum developers understand how the curriculum needs to be changed and that teachers can change their practice with traditional professional development. Top-down approaches to changing instructional practices fail on two accounts. First the approach ignores what motivates teachers to engage in professional development. Second, it does not take into account the processes in which teachers actually change their teaching methods (Guskey, 2002). Rennie (2007) identified informal out-of-school programs as viable options to address the stale curriculum taught in most schools and suggested that these programs are under-researched and undervalued.

Osborne et al. (2003) reviewed the literature of attitudes towards science and found that there has been general decline in a student’s life. One of the cited factors was that science in school was having a cumulative negative impact on students’ attitudes towards science. Ebenezer and Zoller (2003) and Sundberg, Dini, and Li (1994) suggest

that the root cause of students being turned off of science is the message presented in school science—that science is disconnected from their lives and that they should study it for its own sake. Ultimately, schools should make their programs inquiry-based.

The data that contrasted the YSIDC with students' experiences in learning science at school came primarily from the interview data. Participants brought up some powerful and consistent points about differences between the two contexts. Science in school usually has a traditional pedagogical approach where students are expected to learn content through reading textbooks and completing worksheets. Participants also specifically noted the lack of “hands-on” activities in school, whereas they enjoyed the inquiry approach to the YSIDC, especially using scientific equipment. Finally the participants clearly communicated their preference for the YSIDC to learn science and even enjoyed the higher more open-ended expectations of the camp.

The YSIDC had some unique conditions that set it apart from science education in schools. First, the participants were immersed in science for 5 uninterrupted days which really contrasts the 250 to 300 minutes students receive in Ontario schools in a 2-week period. Focussing on science with a large block of time allowed participants to conduct longer investigations and connect experiences between activities because the time in between was so short. Secondly, the participants had access to several pieces of equipment and instruments that are not commonly found in elementary science classrooms in Ontario. Additional resources were necessary for some of the more technical investigations (e.g., all novice students conducted water testing using a battery of tests). In addition, the wide variety of digital probes made it easy for students to measure a host of variables accurately and give them a chance to use similar basic

equipment found in research science laboratories. Third, instructors were not bound to provide evaluation of participants' progress although they provided regular formative feedback that was often qualitative and informal (e.g., conferences). Fourth, the ratio of instructors to participants was 1 to 10, and there were two secondary school students at the YSIDC that supported the instructors. This increased the level of possible feedback and permitted much more sophisticated mini-activities as the prep time required to setup valuable learning experiences could be split among instructors and secondary school students. The fifth difference was that the instructors all had science backgrounds. They all took science courses in their undergraduate degrees and recently participated in science professional development. Although not assessed, it is possible that their level of self-efficacy in supporting learning science was significantly higher than the average science teacher in elementary schools. The sixth point is that the participants at the YSIDC were probably not reflective of the greater student population in the area and were highly motivated to learn science and wanted to attend the camp. Student behaviour was exceptional and all participants were willing to collaborate with each other. Finally, one of the most significant differences was that the program was designed to promote SI skills through a gradual release model, loosely based on the Youth Science Canada (2011) Smarter Science framework. This narrow instructional focus compared to the Ontario Science Curriculum provided a context for greater gains in knowledge and skills of SI. Many of these differences align with Osborne et al.'s (2003) findings that suggest the type of value of task and competency of the teacher are major factors in providing an engaging science program that will benefit students' attitudes towards science.

Based on the interview data, participants strongly felt that the YSIDC was much

more beneficial to their own learning than the time they spend in science classes in school. How the findings of this study can help to inform the practice of science education in schools will be further explored later in this chapter.

### **Impacts of Long-Term Relationships in the YSIDC**

Some of the participants of this study have participated in previous YSIDCs as well as small group science fair coaching sessions. Their scores and attitudes were generally higher than participants who came to the YSIDC for the first time. I believe that to effectively develop skills in SI and significantly impact students' attitudes and views of science, a long-term intervention is required. With strategic differentiated programming, participants can successfully build upon their knowledge and skills from one session to another. This model aligns with how athletes are developed in non-competitive and competitive sports organizations. Additionally, the YSIDC has a small group of instructors who make themselves available to families of the participants. Building strong relationships between instructors and participants will be an important factor to consider when developing informal science educational programs.

### **Summary of Discussion**

Findings in this study confirm Rennie's (2007) belief that informal science educational experiences can have profound effects on its users. The YSIDC positively impacted the participants' understanding of SI as well as their perceptions of inquiry process skills. In addition, the results suggest that attitudes towards science can also be positively affected by informal science experiences. Finally, participants articulated conditions in the YSIDC that they found favourable compared to science educational

experiences in school. These major findings will inform the implications of this research in the following sections.

### **Limitations of the Study**

The findings of this thesis are significant and profound; however, there were some limitations to the study. Despite the fact that every effort was made to collect and analyze the data objectively, my previous position in developing the YSIDC and being a previous instructor made it difficult to be completely unbiased in terms of the positive impacts of the results. However, many of the data collection instruments were reliable and valid (from previous research), and the results found in this study were valid and verifiable.

Another limitation is that the findings cannot be generalized to other informal science education experiences. The impacts found within this study may be unique to the specific program and conditions that the participants experienced, including the knowledge and skills of the instructors. Moreover, the cohort of student participants was most likely not representative of the broader student population in Ontario.

One final limitation was that the impacts of the YSIDC were only assessed immediately after the camp except for the post-surveys which were conducted within the subsequent 2 weeks. Therefore, it is difficult to predict the long-term impacts of attending the YSIDC.

### **Implications for Practice**

One of the goals of science education is to improve the SI skills of the learner as well as positively impact learners' attitudes and views of science (Hodson, 2014). This study has confirmed that it is possible that an informal science experience can

significantly impact participants' SI skills and begin to influence their attitudes and views of science and SI inquiry in a very short time frame. Educational policy makers should consider which tenets of informal science learning experiences are essential for effective programming and reflect conditions that may be better integrated into science classrooms in publicly funded schools. Suggestions for policy will be made in this section.

An overemphasis on literacy and numeracy in Ontario through standardized testing and Ministry of Education support has had a negative impact on other subjects including science (Fazio & Karrow, 2013). Perhaps a consequence of focusing on literacy and numeracy in Ontario is a lack of professional development in science and fewer resources being committed to science programming. Evidence of poorer student performance is demonstrated in the latest TIMSS results where Ontario students have trended downward in both the grade 4 and 8 tests since 2003 on the 2007 and 2011 assessments (EQAO, 2012). The percentage of both grade 4 and 8 teachers from Ontario surveyed on the TIMSS assessment who had science as a major study in university (38%) was considerably smaller than those from Alberta (56%) and Quebec (69%), the other two provinces whose students were tested, as well as the international average (79%). Additionally, only 32% of grade 4 students and 22% grade 8 students felt they were taught by teachers who emphasized science inquiry in at least half of their lessons (EQAO, 2012). These data suggest that there is a need to significantly support the teaching of inquiry science in Ontario's elementary schools. However, with a continued focus in Ontario on literacy and numeracy (Fazio & Karrow, 2013), it is going to be challenging for proponents of SI to create effective structures to help support the development of teachers' skills in this area. One potential strategy to build capacity is to

use informal out-of-school programs to support students directly, but also use these sites as places for teacher development.

This study has demonstrated that one way to effectively support SI skill growth in students is to provide a week-long focus time in inquiry science in an informal setting.

Some of the core elements of the YSIDC are:

1. Participants learn in flexible collaborative groupings throughout the camp. There is an emphasis of a community of learners that supports each other's development and knowledge acquisition.
2. YSIDC includes several technological design challenges in which participants get a chance to perform a problem-solving task twice. The second time completing the task provides an opportunity to implement learning from their peers and value the importance of community in knowledge generation.
3. Mini-inquiries that are semi-guided and scaffold SI skill development including its language.
4. Exposure to a diversity of scientific work through the use of multimedia.
5. Culmination of YSIDC is an open inquiry in which participants conduct an inquiry from a question to presenting their results to their peers. Participants are supported by the mini-inquiries and instructor support.
6. During the YSIDC, core views about SI (e.g., SI is complex, there are multiple models of SI, and participants are active capable problem solvers) and objectives (e.g., to improve SI process skills) are clearly stated.

This study can also help to more directly inform practice in elementary science classes. Professional development for teachers should focus on increasing both their

knowledge of science and SI as well as their teaching knowledge of science and scientific inquiry (Chiappetta & Adams, 2004; Gyllenpalm, Wickman, & Holmgren, 2010). The latter refers to teachers being able to accurately assess their students SI skills and be able to know the next best move to support their development. It is not enough to know what effective SI looks like; a teacher needs to know the stages of development and feel comfortable supporting a diverse class of learners.

This study suggests that students be given more time to generate and test their own questions and to develop their experimental designs and time to revise them if necessary. Although this takes more time, students will be collaborating on problem solving and see themselves as active learners in contrast to the passive learners they may feel in a didactic approach. Classrooms can also emphasize the collaborative nature of inquiry and celebrate when the community supports each other in skill and knowledge acquisition. Teachers should thus position themselves as learners and encourage their students to learn from one another.

Hodson (2014) concluded that teachers need to align their lessons to the intended learning outcome which requires a variety of teaching and learning approaches. The findings in this study revealed a gap in the instruction of SI in schools that needs to be addressed. Hodson would argue that deficiencies in instruction are often the result of a limited range of learning activities. In school, teachers should expose their students to a variety of scientists' research to help provide a broader definition of SI. Students should learn about a variety of inquiry models and wrestle with what actually constitutes SI informed from the perspectives of several scientists' voices. Communities within or close to universities, colleges, as well as other organizations and corporations that

conduct scientific work should invite scientists from those institutions in to share the type of work they do. For example, the local university has a mentorship program for senior secondary students who receive credit for the research work they do with their professors. These strategies can be used to increase the social interactions of science and scientists with situating student learning in a community of scientists (Hodson, 2014).

### **Implications for Theory**

This study did not try to directly assess the impact of constructivist approaches to learning scientific concepts and models; however, it was supported by Vygotsky's (1978) social development theory. The YSIDC was built on the premise that participants will learn in a social context and be caught up in their learning with each other. The favourable participant to instructor ratio was a condition that effectively supported small group and individual feedback from knowledgeable others. Participants continually worked and learned together to solve problems. Even though there was support from others, the YSIDC promoted experiential learning through inquiry.

The YSIDC also prescribed using inquiry teaching to promote inquiry learning. This framework contrasts the rigid construct TSM. TSM is often the model of inquiry used in elementary schools; however it does not adequately represent the complex nature of how many scientists do their work. In both the YSIDC and this study, SI is defined as a process in which students answer their own questions, like scientists using the activity model described by Harwood (2004).

Therefore the YSIDC sought to use inquiry as a guiding force to learning, especially with the goal of learning about and developing SI skills. This constructivist approach to learning science is supported by research (Dewey, 1902; Lederman, Antink,

& Bartos, 2014); however, inquiry is not common in schools (Melville & Bartley, 2010). Anderson (2002) suggests dilemmas that teachers face implementing inquiry into their programs. These include limited conceptions of the nature of science and a lack of content knowledge as an understanding of inquiry and inquiry-based approaches. The success of the YSIDC might be explained because the instructors had been trained and had a better understanding of Anderson's dilemmas.

Despite the support of a constructivist approach to learning inquiry, there are researchers who question its merits and favour direct instructional guidance (Kirschner, Sweller, & Clark, 2006; Mayer, 2004). They worry about the cognitive load and issues of working memory to consolidate learning in these unstructured environments. Their greatest concern is about using SI to learn complex scientific concepts. Using guided SI might be inefficient at learning concepts; however, it still remains effective at developing SI skills and improving attitudes in science.

This study supports a constructivist approach for developing SI skills. Nonetheless, instructors were available for guidance and supported inquiries when groups were unable to proceed. Support was rarely given by simply providing solutions; rather, instructors questioned students and made a menu of potential suggestions that participants selected. Perhaps theorists need to investigate when open-inquiries are most effective and explore the impact on a variety of learners (e.g., different learning preferences, differences in attitudes towards science, cognitive ability, etc.).

### **Implications for Further Research**

This mixed-methods study was designed to gain a deeper understanding of an informal science educational program and its impact on participants' knowledge of

science and SI as well as how the program impacted SI skills, attitudes, and views of science. Although, the findings of this study are encouraging about the use of informal science educational programs, several implications for further research in the areas of informal educational science programs and science education in publicly funded schools are recommended.

Rennie (2007) suggested that informal education out-of-school programs are under-researched and undervalued. Many studies have demonstrated that participants benefit from attending informal science experiences (Bhattacharyya et al., 2011; Fields, 2008; Gibson & Chase, 2002; Jarvis & Pell, 2004; Jenzen, 2013; Mohr-Schroeder et al., 2014). However, the issue with researching informal science programs is that they are often unique in their nature and context, so generalizing from them is difficult. For that reason, a body of knowledge researching a variety of these programs is necessary to see whether there are patterns of findings and benefits. Eventually a meta-analysis of different programs needs to be conducted to determine best practices.

Alternative instruments might be useful for other educational practitioners or researchers who wish to replicate this study. Since self-efficacy in SI skills was not directly assessed, but findings indicate that there might be an impact, it is recommended to assess this construct directly in future studies. This is consistent with the literature that students with higher self-efficacy are more likely to expend additional effort, welcome challenges and complexity, and diversify their learning choices that students with lower self-efficacy (Pajares, 2000). There is limited research conducted on students' self-efficacy in regards to SI, but Ketelhut (2007) did conclude that self-efficacy had an initial effect on positive behaviours in an informal science experience; however, the initial

effect reduced as the learning experienced continued. Ketelhut theorized that the context of SI in the informal setting was contextually different from the classroom setting and might have contributed to the surprising finding. Regardless, this is an area that is under-researched and understood.

One limitation is that the design used did not incorporate a control group. In the future it would be beneficial to contrast the participants in the intervention with those who do not participate to better compare changes and understand the characteristics of those that attend informal science programs. Researchers could also investigate the conditions that led participants to join these types of optional science educational programs to learn how to better encourage others to get involved.

Another limitation to this study was to determine the long-term impacts of the YSIDC on its participants. Further research might also be conducted to follow students after attending informal science educational programs to see if the impacts found here are resilient or only short lived. One possibility is to track the impacts investigated in this study over the course of 2 or 3 years. Not only would this longitudinal design be able to assess long-term impacts, but it also might begin to provide insight into retention rates and the conditions that might affect participants returning to these types of programs.

The success of the YSIDC might have been partly because of the particular cohort of students who participated. One research direction would be to contrast the impacts of informal science educational programs with different students from various social-economical and educational backgrounds to see if these programs could be used to support at-risk students. Lauer et al.'s (2006) meta-analysis determined that informal science programs have positive effects on student achievement in science. It would be

worthwhile to contribute to the literature if the impacts of the YSIDC can be replicated with at-risk students.

### **Conclusion**

The YSIDC was the product of a need to address a deficit in SI instruction in elementary schools and my own personal journey in science as a student, researcher, and educator. This study provided me the opportunity to investigate the impact of the program on participants' knowledge and skill development in science and SI as well as the impacts the camp had on scientific views and attitudes of the attendees.

A significant number of Ontario students are currently achieving below the international standard in the area of science. Unfortunately, this trend in science on the TIMSS assessment is moving in the wrong direction. Educational researchers and policy makers need make learning science a priority. Teaching science through inquiry is well researched and promoted in the literature (Anders et al., 2003; Anderson, 2007; Minner et al., 2009). However, the capacity in teachers to deliver effective inquiry programs is still lacking. Therefore, there is a need to address the problem in alternative informal settings and create exemplary learning models that can help inform instructional practice in classrooms.

This study has demonstrated that an informal science educational program (YSIDC) can impact participants' SI skills and improve their knowledge in science and SI as well as have some effects on their attitudes and views of science. Participants were positive about their involvement in the YSIDC and found it to be superior to learning science at school. The key components of cooperative learning using guided and open

inquiry should contribute to the body of work supporting these instructional strategies in both informal and formal educational institutions.

In conclusion, the need to put more emphasis on science education in our schools and communities is evident. It is hoped that this research helps to highlight the importance of informal science educational programs in the landscape of students learning science in Ontario and the continued need for further research in this area.

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## Appendix A

### YSIDC Schedule—Novice Students

Time	Monday	Tuesday	Wednesday	Thursday	Friday
8:00 – 8:30	Early Arrival – Sign in and Complete Initial Data Collection (Masters Study)	Early Arrival – Read Magazines or on-line science sites	Early Arrival – Read Magazines or on-line science sites	Early Arrival – Read Magazines or on-line science sites	Early Arrival – Read Magazines or on-line science sites
8:30 – 9:00		Ask and Answer Questions (On-Line)	Ask and Answer Questions (On-Line)	Ask and Answer Questions (On-Line)	Ask and Answer Questions (On-Line)
9:00 – 9:30	Introductions & Norms/Routines with Ice Breaker (blind instructions)	Design/Inquiry Challenge #3 Floating Towers	Design/Inquiry Challenge #4 Duct Tape	Design/Inquiry Challenge #5 Barbee Bungee Jump	Design Challenge/Inquiry #6 Grape Crusher
9:30 – 10:00	Design/Inquiry Challenge #1 Bubbles				
10:00 – 10:30	Break	Break	Break	Break	Key to a Great Presentation
10:30 – 11:00	The Importance of Questions in Science and Engineering	Intro to Sparks & Water Inquiry	Short Guided Hike with Cooperative Games (Science Twist)	Testing Barbee Bungee Jump	Work on Presentations Take a break when needed
11:00 – 11:30		Water Inquiry (3 Stations)		Introduction to Data Collecting and Excel	
11:30 – 12:00				Student led Probe Inquiry (How are you going to collect data?)	
12:00 – 12:30	Lunch	Lunch	Lunch	Lunch	Lunch
12:30 – 1:00	Intro to Smarter Science (Variables – Using Questions to Construct Inquiries)	Water Inquiry (7 Stations)	Student led Probe Inquiry (Focus will be Literature Review and Experimental Design with Trial Runs) Take a break when needed	Student led Probe Inquiry (Focus will be conducting Inquiry and Collecting Data) Take a break when needed	Work on Presentations
1:00 – 1:30					Break as Needed
1:30 – 2:00	Break	Water Inquiry Wrap Up	Outline Student Independent Inquiry and Time to Look at Probes	Final Wrap-Up and Surveys	Final Wrap-Up and Surveys
2:00 – 2:30	Design/Inquiry Challenge #2 Stacking Cups				
2:30 – 3:00					
3:00 – 3:30	Clean-Up	Clean-Up	Clean-Up	Clean-Up	Clean-Up
3:30 – 4:00	Journal Reflection	Journal Reflection	Journal Reflection	Journal Reflection	Journal Reflection

## Appendix B

### YSIDC Schedule—Experienced Students

Time	Monday	Tuesday	Wednesday	Thursday	Friday
8:00 – 8:30	Early Arrival – Sign in and Complete Initial Data Collection (Masters Study)	Early Arrival – Read Magazines or on-line science sites	Early Arrival – Read Magazines or on-line science sites	Early Arrival – Read Magazines or on-line science sites	Early Arrival – Read Magazines or on-line science sites
8:30 – 9:00		Ask and Answer Questions (On-Line)	Ask and Answer Questions (On-Line)	Ask and Answer Questions (On-Line)	Ask and Answer Questions (On-Line)
9:00 – 9:30	Introductions & Norms/Routines with Ice Breaker (blind instructions)	Design/Inquiry Challenge #3 Floating Towers	Design/Inquiry Challenge #4 Duct Tape	Design/Inquiry Challenge #5 Barbee Bungee Jump	Design Challenge/Inquiry #6 Grape Crusher
9:30 – 10:00	Design/Inquiry Challenge #1 Bubbles				
10:00 – 10:30	Break	Break	Break	Break	Key to a Great Presentation
10:30 – 11:00	The Importance of Questions in Science and Engineering	Independently Working on Arduino Circuit Challenges	Short Guided Hike with Cooperative Games (Science Twist)	Testing Barbee Bungee Jump	Work on Presentations Take a break when needed
11:00 – 11:30				Advanced Level Excel	
11:30 – 12:00				Student led Probe Inquiry (How are you going to collect data?)	
12:00 – 12:30	Lunch	Lunch	Lunch	Lunch	Lunch
12:30 – 1:00	Intro to Circuits and Arduino Chips	Independently Working on Arduino Circuit Challenges	Student led Probe Inquiry (Focus will be Literature Review and Experimental Design with Trial Runs) Take a break when needed	Student led Probe Inquiry (Focus will be conducting Inquiry and Collecting Data) Take a break when needed	Work on Presentations
1:00 – 1:30					Share Results and Celebrate Each Other's Work (Break will be provided)
1:30 – 2:00	Break				
2:00 – 2:30	Design/Inquiry Challenge #2 Stacking Cups	Outline Student Independent Design or Inquiry			Final Wrap-Up and Surveys
2:30: 3:00					
3:00 – 3:30					
3:30 – 4:00	Clean-Up	Clean-Up	Clean-Up	Clean-Up	Clean-Up
	Journal Reflection	Journal Reflection	Journal Reflection	Journal Reflection	Journal Reflection

**Appendix C**  
**Modified SPSI Instrument**  
**My Science Skills**

Name: \_\_\_\_\_

Age: \_\_\_\_\_

Date: \_\_\_\_\_

We would like to know how good of a scientist you are! Please fill in the circle that tells how much you currently can use each of the following skills when you work on a science investigation. Please check

#	Questions	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1.	I can use scientific knowledge to form a question					
2.	I can ask a question that can be answered by collecting data					
3.	I can design a scientific procedure to answer a question					
4.	I can communicate a scientific procedure to others					
5.	I can record data accurately					
6.	I can use data to create a graph for presentations					
7.	I can create a display to communicate my data and observations					
8.	I can analyze the results of a scientific investigation					
9.	I can use science terms to share my results					
10.	I can use models to explain my results					
11.	I can use the results of my investigation to answer question that I asked					

## Appendix D

### Modified Changes in Attitudes About the Relevance of Science (CARS) Instrument

#### My Science Attitudes

Name: \_\_\_\_\_

Age: \_\_\_\_\_

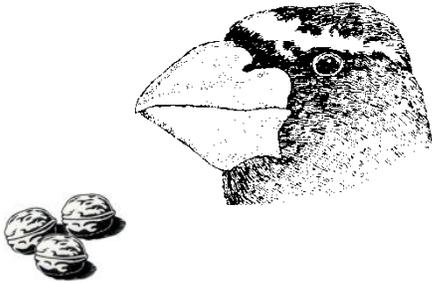
Date: \_\_\_\_\_

#	Questions	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1.	My parents encourage me to continue with science					
2.	I plan to take science classes in high school					
3.	Science helps me to work with other to find answers					
4.	Learning science helps me to evaluate my own work					
5.	Learning science helps me understand the environment					
6.	Emotion has no place in science					
7.	Learning science helps me to judge other's people's point of view					
8.	Science will help me understand more about world-wide problems					
9.	Science has nothing to do with my life out of school					
10.	Experiments in science help me to learn with a group					
11.	Science teaches me to help others make decisions					
12.	Knowing science will not help me in sports					
13.	Science has nothing to do with buying things, such as food and cars					
14.	Knowledge of science could make it easier to fix a bicycle					

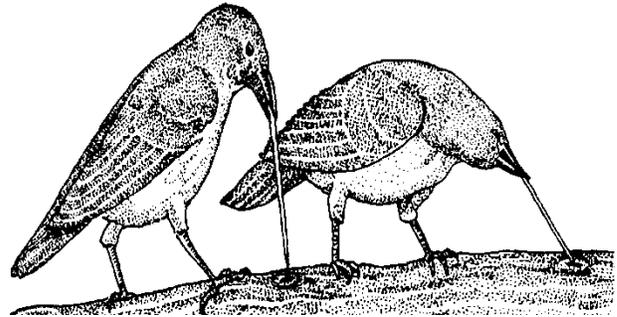
#	Questions	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
15.	Science teaches me to think less clearly than I already do					
16.	Making a good decision is a scientific process					
17.	Learning science at school and other places will help prepare me for college or university					
18.	Much of what I learn in science classes is useful in my everyday life today					
19.	Learning science can help me when I pick food to buy					
20.	Caring about people is part of making scientific choice, such as whether to use pesticides on plants					
21.	Science helps me to make sensible decisions					
22.	The things I do in science have nothing to do with the real world					
23.	Science helps me to make decisions that could affect my body					
24.	Learning science will have an effect on the way I vote in elections					
25.	Making decisions can be difficult without the reliable evidence					



3. A scientist studied many different kinds of birds. She noticed that birds who eat the same types of foods usually have the same shaped beaks. For example, many birds that eat hard nuts have short, strong beaks, and many birds that pick worms out of the ground have long, thin beaks. So, the scientist decided that there is a connection between beak shape and the type of food birds eat.



A bird who eats nuts



Birds who eat worms

(a) Do you think her work was scientific? Why or why not?

(b) Do you think her work was an experiment? Please explain why or why not.

4.
  - (a) How do the people who predict the weather on TV use science?
  
  
  
  
  
  
  
  
  
  
  - (b) How do they decide what the weather will be today?
  
  
  
  
  
  
  
  
  
  
  - (c) Weather reporters don't always agree with each other about the weather. Why do you think they disagree?
  
  
  
  
  
  
  
  
  
  
5.
  - (a) Do you think that scientists are creative when they do their work?
  
  
  
  
  
  
  
  
  
  
  - (b) Can you give me an example?
  
  
  
  
  
  
  
  
  
  
  - (c) When do you think they are creative when they are doing an investigation?

6. The scientific method is often described as involving the steps of making a hypothesis, identifying variables (dependent/independent), designing an experiment, collecting data, reporting results. Do you agree that to do good science, scientists must follow the scientific method?

\_\_\_ Yes, scientists must follow the scientific method

\_\_\_ No, there are many scientific methods

- If Yes, describe why scientists must follow this method
- If No, explain how the methods differ and how they can still be considered scientific

## Appendix F

### Interview Protocol

The semi-structured interviews that will take place before and after the intervention, but after the other instruments are administered will last about 30 minutes. Only six random students will be selected for this part. Interviews will be held at Brock University and will be audio-recorded. The questions for each interview are found below.

#### *Interview #1*

The objective of obtaining the qualitative data in this interview is to elaborate on the other instruments and get a richer sense of each of these participants' background as well as their attitudes and views towards science and science inquiry. Finally, some questions will probe their understanding of science inquiry.

Questions:

- (1) What is science?
- (2) What experiences have you had doing science?
- (3) Describe how comfortable you would be in conducting scientific inquiries all by yourself right now?
- (4) Which skills of scientific inquiry do you feel you still need to develop in?
- (5) What do you think about how science is being taught in schools right now?
- (6) Do you think science can help you help you in any way outside of getting good marks in school and finding a job when you have completed school? Explain your answer.
- (7) When scientists are ready to report their results to other scientists, what kind of information do you think they need to include in their report in order to convince others that they have a good conclusion? Be as specific as possible. Try to give an example.

#### *Interview #2*

The objective of this interview is to see any potential changes because of the YSIDC as well as determining what might have been learned or if attitudes or views were affected by the intervention.

## Questions:

- (1) What is science?
- (2) What did you learn at the YSIDC?
- (3) Describe how comfortable you would be in conducting scientific inquiries all by yourself right now?
- (4) Which skills of scientific inquiry do you feel you still need to develop in?
- (5) What do you think about how science is being taught in schools right now?
- (6) Do you think science can help you help you in any way outside of getting good marks in school and finding a job when you have completed school? Explain your answer.
- (7) When scientists are ready to report their results to other scientists, what kind of information do you think they need to include in their report in order to convince others that they have a good conclusion? Be as specific as possible. Try to give an example.

## Appendix G

### Observation Tracking Sheets (Field Notes Protocol)

During the YSIDC, the researcher will document what happens at the camp by recording descriptive fieldnotes about the participants' behaviour, especially the six randomly chosen participants that are part of the interview protocol. The researcher will also record reflective fieldnotes throughout the process.

The researcher will describe any potential behaviour that could indicate that a participant has learned something, been frustrated or off task, or had an experience that might have impacted their attitudes or knowledge about science or science inquiry. A sample tracking sheet is provided below.

#### Observational Fieldnotes – YSIDC

Setting:

Observer:

Role of Observer:

Name of Student Observed:

Date:

Time:

Length of Observation:

Time	Descriptive Notes	Reflective Notes