"I am a scientist": How setting conditions that enhance focused concentration positively relate to student motivation and achievement outcomes in inquiry-based science

Robin B. Ellwood

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"I am a scientist": How setting conditions that enhance focused concentration positively relate to student motivation and achievement outcomes in inquiry-based science

Abstract
This research investigated how student social interactions within two approaches to an inquiry-based science curriculum could be related to student motivation and achievement outcomes. This qualitative case study consisted of two cases, Off-Campus and On-Campus, and used ethnographic techniques of participant observation. Research participants included eight eighth grade girls, aged thirteen to fourteen years old. Data sources included formal and informal participant interviews, participant journal reflections, curriculum artifacts including quizzes, worksheets, and student-generated research posters, digital video and audio recordings, photographs, and researcher field notes. Data were transcribed verbatim and coded, then collapsed into emergent themes using NVIVO 9. The results of this research illustrate how setting conditions that promote focused concentration and communicative interactions can be positively related to student motivation and achievement outcomes in inquiry-based science. Participants in the Off-Campus case experienced more frequent states of focused concentration and out performed their peers in the On-Campus case on forty-six percent of classroom assignments. Off-Campus participants also designed and implemented a more cognitively complex research project, provided more in-depth analyses of their research results, and expanded their perceptions of what it means to act like a scientist to a greater extent than participants in the On-Campus case. These results can be understood in relation to Flow Theory. Student interactions that promoted the criteria necessary for initiating flow, which included having clearly defined goals, receiving immediate feedback, and maintaining a balance between challenges and skills, fostered enhanced student motivation and achievement outcomes. This research also illustrates the positive gains in motivation and achievement outcomes that emerge from student experiences with extended time in isolated areas referred to as "hot spots." Implications for science teaching and future research include shifting the current focus in inquiry-based science from a continuum that progresses from teacher-directed to open inquiry experiences to a continuum that also deliberately includes and promotes the necessary criteria for establishing flow.

Keywords
Education, Sciences

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"I AM A SCIENTIST:"
HOW SETTING CONDITIONS THAT ENHANCE FOCUSED CONCENTRATION
POSITIVELY RELATE TO STUDENT MOTIVATION AND ACHIEVEMENT
OUTCOMES IN INQUIRY-BASED SCIENCE.

BY

ROBIN B. ELLWOOD
Baccalaureate Degree (BA), University of New Hampshire, 1985
Master's Degree (MEd), University of New Hampshire, 1993

DISSERTATION
Submitted to the University of New Hampshire
in Partial Fulfillment of
the Requirements for the Degree of

Doctor of Philosophy
in
Education

September, 2013
This dissertation has been examined and approved.

Eleanor Abrams, Dissertation Director
Professor of Education

Michael Middleton
Associate Professor of Education

Barbara Houston
Professor of Education

Thomas Lee
Professor of Natural Resources and the Environment

David Sobel
Core Faculty Department of Education
Antioch New England Institute
DEDICATION:

This dissertation is dedicated to my partner Anne. Thank you for your endless support, encouragement, and sacrifice throughout this entire process.
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I would like to acknowledge the many people, and organizations, that have provided support throughout my research efforts. First, I must thank my entire dissertation committee; I thank each of you for the patience, support, insights, and wisdoms that you have shared throughout this process. I am especially grateful to my committee chair, Dr. Eleanor Abrams. Eleanor has offered unwavering support and inspirational guidance. She has been a role model as an educator and a researcher. Our weekly meetings provided intellectual challenge and encouragement for me to grow as a researcher and educator. I will carry the lessons I have learned from Eleanor into my future research efforts.

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TABLE OF CONTENTS

DEDICATION............................................................................................................iv
ACKNOWLEDGEMENTS..........................................................................................v
LIST OF TABLES.....................................................................................................xiii
LIST OF FIGURES..................................................................................................xiv
ABSTRACT...............................................................................................................xv
CHAPTER ONE: INTRODUCTION.............................................................................1
  The meaning of Inquiry-based Science...............................................................6
  A Brief History of Inquiry-based Science...........................................................8
  An Introduction to the Benefits of Inquiry-based Science..............................10
  An Introduction to the Barriers of Inquiry-based Science..............................11
  My Research Question.......................................................................................13
  Statement of Research Significance..................................................................16
CHAPTER TWO: LITERATURE REVIEW.................................................................17
  Inquiry-based Science: A Historical Perspective............................................18
  Inquiry-based Science: Definition and Goals..................................................25
  Inquiry-based Science: Characteristics of Three Levels..............................30
    Teacher-Directed Inquiry.................................................................................30
    Teacher-Guided Inquiry.................................................................................36
    Open Inquiry..................................................................................................43
Ultimate Outcomes: Time Span Summary..................................................311
Case Comparison of Ultimate Achievement Outcomes..........................312
Pre and Post Student Perceptions of the Term:
  Acting Like a Scientist........................................................................314
Overall Project Summary.........................................................................317
Synthesis of Research Results.................................................................320
The Influence of Student Social Interactions on Dimensions
  of Flow.....................................................................................................328
Research Conclusions..............................................................................333
CHAPTER SIX: Future Implications..........................................................342
  Implications for Educators.......................................................................343
  Clear Goals............................................................................................344
  Immediate Feedback................................................................................347
  Maintain a Balance Between Skill and Challenge Level.........................349
Flow Theory and IBS................................................................................352
Time..........................................................................................................355
Location....................................................................................................359
Teaching Teachers of Science.................................................................361
Implications for IBS Research.................................................................364
Concluding Statements............................................................................369
APPENDIX A1: Pre-Project Formal Interview Guide.................................373
APPENDIX A2: Post-Project Formal Interview Guide.................................377
APPENDIX A3: Informal Interview Question Guide....................................381
LIST OF TABLES:

Table 1: Demographic summary and comparison to state.......................... 120
Table 2: Comparison of CMS and state NECAP scores.............................. 121
Table 3: Characterization alignment with ISTREAM and research questions .................................................. 185
Table 4: Representative lessons and criterion for flow............................ 224
Table 5: Category frequency and occurrence across cases....................... 225
Table 6: Summary of research site explorations...................................... 240
Table 7: Summary of student research questions from the On-Campus case ................................................................. 251
Table 8: Summary of student research questions from the Off-Campus case ................................................................. 252
Table 9: Comparisons between the On-Campus case and Off-Campus case ................................................................. 265
Table 10: Summary and comparison of frequency and occurrence.............. 293
Table 11: Comparison of achievement scores across cases........................ 313
Table 12: Summary of comparisons between the On-Campus and Off-Campus cases ................................................................. 318
Table 13: Summary comparison between the On-Campus and Off-Campus cases ................................................................. 319
Table 14: Analysis pathway leading to Flow Theory............................... 332
LIST OF FIGURES

Figure 1: The number of published journal articles with multiple authors ................................................................. 65
Figure 2: Bandura's Model of Reciprocal Determinism ....................................................................................... 88
Figure 3: Sample equipment that was available to all students ........................................................................ 118
Figure 4: Case study comparison ....................................................................................................................... 119
Figure 5: Video camera and microphone positioning .......................................................................................... 140
Figure 6: Optimal Conditions for Flow as depicted by Csikszentmihalyi ................................................................. 194
Figure 7: Pathway of common outcomes from the Concurrent Path time span .............................................................. 227
Figure 8: Social interaction patterns leading to flow and enhanced outcomes .......................................................... 267
Figure 9: Social interaction patterns leading to enhanced flow and outcomes ......................................................... 295
Figure 10: Model showing the influence of flow on IBS outcomes ................................................................. 330
ABSTRACT

"I AM A SCIENTIST:"
HOW SETTING CONDITIONS THAT ENHANCE FOCUSED CONCENTRATION
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OUTCOMES IN INQUIRY-BASED SCIENCE.

by
Robin Ellwood
University of New Hampshire, September, 2013

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CHAPTER 1

INTRODUCTION

I have been an 8th grade science teacher for twenty years. In that time, I have implemented lessons that I have thought went extremely well, based on student achievement outcomes and student's attitudes towards science. I have implemented original lessons, pre-packaged lessons, and those that were pre-designed but which I modified in order to more appropriately suit my students needs, my style of instruction, as well as grade level curriculum goals and standards. Many of the lessons that I have considered to be the most successful have included those that were inquiry-based. Having witnessed elevated student success from inquiry-based science lessons and units, I have striven to make such lessons an integral part of my science curriculum. Although I have had tremendous success with inquiry-based science lessons, the success has been inconsistent and variable. I aimed to secure an elusive consistency for inquiry-based science (IBS) instruction.

Over the years, in efforts to develop and implement lessons that achieved increasingly successful, and consistent, results from IBS lessons, I began searching for explanations as to why IBS lessons were successful and for ways in which to improve instructional practices within IBS. What I discovered was a
literature replete with explanations, and instructional suggestions for successful inquiry-based science lessons, that did not entirely fit my lived experience. According to the literature, IBS lessons that are properly scaffolded along an inquiry continuum, implemented by skilled teachers that understand the inquiry process, and that provide students with hands-on experiences and opportunities to act like scientists, can expect successful results (Chang & Song-Ling, 1999; NRC, 2000; Marx, Blumenfeld, Krajcik, Fishman, Soloway, Geir, and Tal, 2004; Cuevas, Lee, Hart, and Deaktor, 2005; Wolf & Fraser, 2007; and Wilson, Taylor, Kowalski, and Carlson, 2009). My experiences, however, indicated that such explanations and instructional suggestions were inadequate to comprehensively explain why IBS lessons were successful. My experiences suggested there were other influences besides the proper scaffolding of IBS lessons and the provision of hands-on experiences for students that fostered success. I have diligently attended to the proper scaffolding of IBS lessons as described, and recommended, within the literature. Within these lessons, I have provided hands-on experiences for students and I believed students were acting like scientists. I continued, however, to struggle with achieving predictable, and consistent, results from inquiry-based lessons. I was not alone in this frustration. According to the literature, and my own discussions with other science teachers, many teachers claim the unpredictable results from IBS to be a frustration and a major reason for ceasing efforts to implement IBS within science classes (Flick, 2006).

The IBS lessons that I have found to be the most successful, as measured by their positive influence on student achievement and motivation outcomes,
have included lessons in which student interest was high, and social interactions which focused on content material, were abundant. I interpret student achievement to include high scores on classroom and standardized assessments, an ability to demonstrate conceptual understanding of content material and reasoning skills, an ability to engage in authentic scientific investigation, as well as to collaborate with others. I interpret motivation to include processes “whereby goal-directed activity is instigated and sustained” (Schunk, Pintrich, and Meece, 2008, p. 378). During successful IBS lessons that I have implemented, students tended to view me as a facilitator of the task, a resource for assistance, or someone with whom to share their excitement and discoveries. I felt that I could have left the room and the students would have continued working without ever noticing that I had left. I do not mean that students would have simply continued to behave and complete the assigned work. I mean I could have left the room and I believe students would have remained completely focused and engaged in the task at hand, would have collaboratively and enthusiastically continued working on the task, and would ultimately understand and be able to transfer the application of the content material that had been learned through their participation in the lesson. During such lessons, students were entranced with the activity; they were interested and invested in learning.

Such experiences with IBS lessons in my classes led me to believe that there were currently unaccounted influences on IBS lessons that impacted the ultimate success of these lessons and that without attending to these
unaccounted influences, IBS may be unable to reach consistent results and it's higher potential. A noticeable difference between what the literature claimed to be the reasons for IBS success and what I witnessed within my science classes was an awareness of the potential importance of the student social interactions that unfolded within such lessons.

A salient feature of successful IBS lessons in my classroom has been abundant social interactions and content related discourse among the students. The student social interactions I witnessed during these lessons reflected interactions and discourse consistent with acting like a scientist. I began to suspect, however, that the currently accepted notion of what it means to act like a scientist that is presented within the literature, the one that is used by educational practitioners to explain why IBS lessons can be successful, was inadequate. The accepted meaning of the term within the literature equates acting like a scientist with going through the procedural steps of "the scientific method" (Wong & Hodson, 2008). With this interpretation, scientists, and students, would develop research questions, hypotheses, develop and implement experiments, collect and analyze data, and report their findings to others. Certainly this is, at least partially, reflective of acting like a scientist. However, when we habitually reduce the notion of acting like a scientist to following prescribed procedural steps, we eclipse other aspects, such as social interactions, that are also an integral part of what it means to act like a scientist. The currently unaccounted influences of student social interactions are what I sought to expose and explain in my research.
Throughout this dissertation, I present my contention that our current interpretation of what it means to "act like a scientist" is deficient. Acting like a scientist is far more complex than simply following experimental procedures. As described in a study by Wong and Hodson (2008), in which the researchers asked scientists to explain what it means to act like a scientist, scientists identified interacting with other scientists, facing political pressures, solving problems, and challenging each other's research as integral to the meaning of the term; acting like a scientist involves a myriad of social interactions (Wong and Hodson, 2008). Our willingness to readily accept the current "hands-on/acting like a scientist" explanation for the measured increases in student achievement and motivation through IBS experiences masks other potentially important influences, such as student social interactions, that impact the outcomes of IBS. By neglecting other possible influences, we leave our current understanding of inquiry-based science incomplete; the full educational potential of these experiences may, therefore, not yet be realized. Shifting our attention to include other influences, such as student social interactions, will advance our understanding of IBS and our ability to develop more effective IBS lessons and opportunities for students. My research, therefore, directly investigates the relation between student social interactions during IBS experiences and student achievement and motivation outcomes in science.

Two key terms associated with my research, "social interactions" and "inquiry-based science," are interestingly complex; both are broad in scope and require clarification of meaning. Social interactions are ubiquitous in everyday
life; it is difficult to definitively identify which are consistent with acting like a scientist and which are not. In my research, I focused upon social interactions, including those that were both verbal and physical in nature, which either facilitated or hindered participant progress within student investigations as they navigated through the curriculum. Although the term is explained in further detail later in the dissertation, I mention it here to alert readers to my acknowledgement of its complexity.

The term "inquiry-based science" is equally complex. Having a general understanding of the meaning, history, benefits, and the inherent obstacles of IBS will not only assist readers in understanding the potential influences of my research, but also assert my awareness of its complexity. I therefore turn now to a brief discussion of these factors, each of which is discussed in greater detail later in the dissertation. I begin with an introduction to the meaning of inquiry-based science.

The Meaning of Inquiry-based Science:

The meaning of IBS has been a source of confusion and uncertainty throughout its long history. The definition of IBS that I assume throughout this dissertation is one that has been stipulated by the National Resource Council (NRC). The NRC states that IBS is an educational strategy that fosters a student's ability to "learn the principles and concepts of science, acquire the reasoning and procedural skills of scientists, and understand the nature of science as a particular form of human endeavor" (NRC, 2000, p. xiii). Assuming
this definition of IBS, students will develop an understanding of how to inquire; they will learn various methods and strategies for conducting scientific investigations that involve the reasoning and procedural skills of scientists. Students will also develop an understanding about the process of inquiry; they will understand that as a human endeavor, inquiry can be biased or subjective and so will learn how to evaluate and assess inquiry-based efforts for bias and unwarranted subjectivity. Students will also develop an understanding of scientific principles and concepts through the process of doing inquiry; students will conduct inquiry-based investigations.

We currently place instructional efforts in IBS along a continuum that has three basic levels: teacher-directed inquiry, teacher-guided inquiry, and open inquiry. The placement of a lesson along the continuum depends upon the amount of control and responsibility that is given to the student. In teacher-directed inquiry-based lessons, the teacher determines what will be done by students and when. Within the continuum of teacher-guided inquiry lessons, teachers give increasing control of the procedures and decisions to be made within the lessons to the students. In open inquiry, the students take full responsibility for the procedures to be followed and make all decisions throughout the lesson; the student is in full control. It is the properly scaffolded progression along this continuum that is currently claimed to lead to effective IBS lessons and the positive outcomes of increased student achievement and motivation in science. The current continuum, and meaning of IBS, has resulted from historical oscillations in the reasons for using IBS as an instructional
strategy. A glance into the history of IBS illustrates how the current continuum and interpretation of the term arose.

A Brief History of Inquiry-based Science:

The literature reveals that the teaching of science through inquiry-based methods has an extensive history. The origins of this instructional strategy can be traced back to the mid 1800's when the work of British biologist Thomas Huxley advocated for including hands-on experiences for students in science in order to foster critical thinking skills (Lyons, 2010). By the late 1800's, the social scientist and philosopher Herbert Spencer pushed the educational community to provide opportunities for independent student learning rather than verification-style lessons in which students conducted experiments to prove already known scientific facts (Holmes, 1994). The early 1900's brought an emphasis on investigations that were increasingly of societal significance and social relevance in order to make connections with, and scientifically educate, an increasingly democratic society (DeBoer, 2006). In order to promote student interest in science, John Dewey, in the mid 1900's, advocated the learning of scientific principles through topics and experiences that were of direct interest, and relevance, to students' lives (Dewey, 1938). The launch of the Russian Sputnik satellite, in the 1950's, triggered a recognition of the importance of an emphasis on science to the security of the nation (Barrow, 2006). The goal of science education became to foster scientists and citizens that were scientifically literate; it was believed that the best way to accomplish this was through providing IBS
experiences that authentically reflected those of scientists (Mathews, 1994). Science education during this time became extensively content driven, comprehensive, and specific; instructional practices were largely teacher directed (Barrow, 2006). The intense focus on detailed and specific science content, however, resulted in a reduction of student interest in science and lower pursuits of science related careers (DeBoer, 2006). Throughout the 1970's, the National Science Teachers Association (NSTA) claimed that the goal of science education should be to develop individuals who were scientifically literate who possessed critical thinking skills (DeBoer, 2006). The goal set forth in the late 1990's by the National Resource Council, that of establishing scientific literacy within a global community, echoed the NSTA goals and persists today (NRC, 1996). IBS methods can provide an effective means of reaching these goals (NRC, 2000).

Throughout history, inquiry-based science has vacillated between a method used to teach specific scientific content and one that has aimed to foster student investigations into topics of personal interest and societal relevance. Both these desired goals of increased specific scientific knowledge and skillful scientific ability to investigate problems of interest have been combined into our current goals of science education; those stipulated by the NRC and the IBS continuum in which students take on increasing responsibility and control for their learning. IBS has been recognized throughout recent educational history as an effective means for reaching these stated goals. I therefore turn to a brief introduction to the stipulated benefits of implementing IBS lessons.
An Introduction to the Benefits of Inquiry-based Science:

There has been extensive research conducted, such as that of Basaga, Geban, and Tekkaya, (1994), Berg, Bergendahl, and Lundberg, (2003), and Taraban, Box, Myers, Pollard, and Bowen, (2007), that has demonstrated that student experiences with IBS opportunities can lead to tremendous academic success as measured by student achievements in, and motivation towards doing, science. IBS has been shown to be successful at all levels of education from elementary school through college (Cuevas et al., 2005; Marx et al., 2004; and Berg et al., 2003). Research conducted by Flick (1998), showed that success levels increased when students had sufficient exposure to IBS experiences at each level along the IBS continuum to accommodate an adequate development of skills necessary for success at subsequent levels. Additionally, studies, such as the LeTUS (Learning Technologies in Urban Schools) project, have also shown that the more exposure students have to IBS opportunities, the greater the positive outcomes of achievement and motivation become (Marx et al., 2004). Researchers, such as Gibson and Chase, have also shown that students that have successful experiences with IBS are more likely to enroll in continued science courses in high school and college and are more likely to pursue science related careers (Gibson & Chase, 2002). IBS has been shown to promote academic gains across all spectrums of race, socioeconomic status, ethnicity, ability level, and gender (Cuevas et al., 2005). IBS has been shown to be a potentially powerful instructional tool.
There is researched and documented support for the claim that IBS can be an effective instructional strategy that meets the stipulated goals of science education set forth by the NRC. The success of IBS has been published in educational research and science teaching journals and has been promoted at local, regional, and national science research and teacher conferences. Due to its purported success, many teachers strive to promote IBS experiences for their students within their classrooms, many administrators pressure teachers to include IBS opportunities for students within their curriculum, and there are increasing pressures from national science education standards to include inquiry-based lessons within science curriculums. Although there is often a desire among teachers, and administrators, to promote IBS lessons and units, as well as earnest attempts to implement IBS lessons, there are currently several barriers to the successful inclusion of IBS lessons. A mention of these barriers is warranted in order to more comprehensively understand IBS. I briefly present several of these barriers below.

An Introduction to the Barriers of Inquiry-based Science:

Although there is documented evidence to show that IBS can be an effective means of promoting student achievement and motivation in science, numerous barriers exist that interfere with any widespread success of IBS. I point here to four noted barriers. Perhaps the most notorious barrier to IBS is the element of time. Inquiry-based science lessons often take more time to implement than more traditional, lecture-based, lessons. Taking a longer amount
of time to teach required content material places pressures on teachers to rush through inquiry-based experiences and/or to rush through other lessons in order to create the necessary time for inquiry-based lessons (Holliday, 2006). The additional time required, or at least perceived, to implement inquiry-based science lessons is of ever-increasing concern during the current high stakes testing and accountability climate of education.

A second barrier to IBS is the lack of teacher training in, and understanding of, successful IBS implementation strategies. Teachers typically receive little, if any, training in IBS during teacher certification programs (Holliday, 2006). As a result, teachers enter the field with no, or minimal, training in IBS; its implementation in educational settings is thus limited (Wilson et al., 2009). Teacher training does not typically provide opportunities for teachers to practice skills necessary to facilitate student-generated inquiry-based experiences, particularly within a timely manner. The lack of teacher training leads to a third barrier to IBS. Many teachers are uncomfortable relinquishing control of their lessons to the students; such teachers also are uncomfortable allowing students to pursue avenues of student interest with which the teachers themselves may be unfamiliar (Holliday, 2006).

A fourth barrier to IBS arises from, and connects us back to, the narrow interpretation of why IBS is successful in the first place. Our current acceptance of the claim that IBS lessons are successful because they offer students hands-on experiences and opportunities to act like scientists precludes us from seeking more detailed and specific information about what precisely is most helpful and
what hindrances there are embedded in current IBS teaching practices. Without the investigation of more detailed explanations, we cannot confidently claim to adequately understand the reasons for IBS success, or sometimes failure, when they appear to occur. It is possible that gaps in our current understanding are preventing us from not only reaching an ability to consistently achieve positive outcomes from IBS lessons, but also from IBS reaching a higher potential. Understanding more holistically how students act like scientists within a classroom setting can begin to advance our understanding of IBS. By investigating the potential influences of student social interactions on the outcomes of inquiry-based science experiences, I sought to expose and address potential gaps in our understanding of IBS. I turn now to a discussion of my specific research question.

My Research Question:

In order to investigate the relation between student social interactions and student achievement and motivation outcomes in IBS, I designed and implemented a qualitative case study, comprised of two cases, in which I used an ethnographic approach. The specific research question I investigated was:

“**Within two approaches to inquiry-based science, how do student social interactions relate to student motivation and achievement?**”

Throughout my research, I focused on student social interactions that may have specific influence on student achievements and motivation. I was particularly attentive to verbal and physical interactions that may have perpetuated, altered,
or hindered student progress or motivation as they navigated their IBS experiences.

In order to assist in gaining access to the information that I would need to answer my overall research question, I crafted five topical questions that were each further supported by four to seven sub-topical questions. I developed my topical and sub-topical questions based on recommendations from Gee’s *An Introduction to Discourse Analysis* (2005) in which he presented strategies for using discourse analysis as an analytic framework to gain access to data and to develop understanding of particular phenomena. In my study, the particular phenomenon to be understood was inquiry-based science. My five topical questions were:

- How can the student social interactions within each case be characterized?
- How does student discourse within each case relate to student interactions and activity?
- How is student motivation characterized within each case?
- How are academic achievements within each case characterized?
- How are the established case profiles characterized and what conclusions can be drawn?

My research was implemented in two eighth grade science classes in a small rural New England town. The study was designed to investigate the IBS experiences of girls and boys. However, the random group selection process, which is described in detail within the methodology section of this dissertation, resulted in two groups of girls being selected as participants; my research participants thus included eight girls aged thirteen to fourteen years old. Despite the cautiousness one might have about investigating the effects of social
interactions with a single gender that is strongly associated with social relations, this research was a worthwhile investigation for several reasons. First, it should be noted that the study was designed to be appropriate for boys and girls; no special accommodations were made, or altered, based on the gender of participants that were ultimately selected. The lessons and activities included in this research were intended to be beneficial to boys and girls, the boys experiences within this IBS unit were not diminished due to my focus on female participants. Second, there is a national push to increase the number of girls pursuing science related careers; insights into how to increase female interest, motivation, and achievement in science classes increases our knowledge of educational strategies that would promote such interest and career pursuits. Third, one could argue that female participants, because of their social nature, would be more naturally engaging in social interactions, and thus I would be observing more naturally occurring events, thus allowing me to investigate differences in social interactions within the two cases resulting from the instructional approach rather than gender. It would potentially have been more difficult to interpret the influences of social interactions within each case from groups consisting of only boys; I would have been less able to determine whether differences in social interactions were due to the IBS approach or from the typically less social nature of boys.

My research occurred during the regularly scheduled implementation of an inquiry-based science unit developed by the Cornell Lab of Ornithology known as “Classroom BirdSleuth: Investigating Evidence.” Although, as a qualitative study
with a small sample size of eight participants limited to a single gender, the results of my research are not generalizable to the broader population, they do contribute to the existing literature about, and our understanding of, inquiry-based science. The results of my research open doors to additional avenues of investigation and ultimately advances our understanding of student experiences with IBS.

**Statement of Research Significance:**

The research I present here advances our understanding of IBS. I provide a more holistic description of student experiences within IBS lessons and an increased understanding of why inquiry-based science lessons are successful. Specifically, I describe how student social interactions during IBS experiences can be related to student achievement and motivation outcomes in science. This broadens our awareness of potential influences to IBS outcomes and assists in our ability to design inquiry-based lessons that address the obstacles mentioned above. Armed with a more comprehensive understanding of IBS, educational practitioners will be better equipped to design and implement inquiry-based lessons that will further increase student achievement and motivation in science.
Chapter 2

LITERATURE REVIEW

Inquiry-based Science (IBS) is an educational strategy that has been employed throughout the history of science education in efforts to increase student achievement and motivation in science as well as to improve scientific literacy within the population. Today, IBS is defined as an educational strategy aimed at fostering student understanding of scientific concepts and the various means in which scientific investigations might be conducted, as well as providing students direct experiences with the implementation of scientific investigations (NRC, 2000). The fact that IBS experiences can improve student achievement, motivation, interest, and persistence in science has been well documented by researchers such as Berg et al. (2003) and Taraban et al. (2007).

Science education philosophers and practitioners tout the positive gains from IBS as being due to the hands-on experiences and opportunities for students to act like scientists that are common to IBS lessons (Chang & Song-Ling, 1999). I argue throughout this dissertation that this view is too narrow and that other aspects, such as student social interactions, may have substantial influence on the successful outcomes witnessed in IBS. My research aimed to expose other possible influences on achievement and motivation outcomes, such
as student social interactions, in efforts to advance our current understanding of IBS. Armed with a more comprehensive understanding of IBS, educational practitioners would be able to develop and implement IBS lessons that are characterized by greater efficiency, effectiveness, and consistency, as well as those that could promote increased achievement and motivation outcomes in science.

Tracing IBS through history reveals how the current interpretations of IBS arose. IBS has oscillated between an instructional strategy used to teach specific content material and one used to promote student pursuits of personal interest. Understanding fluctuations in the intentions of IBS throughout history assists in understanding the current goals of IBS. I, therefore, present next a description of IBS throughout history. This historical perspective is followed by a detailed description of current interpretations of the meaning and goals of IBS and how it is implemented in classrooms today.

**Inquiry-based Science: A Historical Perspective**

The implementation of inquiry-based science within K-12 classrooms is not a new educational practice. A review of the historical perspectives of inquiry in science education traces the origins of IBS as far back as the mid 1800’s and the early work of the British biologist Thomas Huxley (DeBoer, 2006). Huxley advocated that we provide students with direct, hands-on, experiences with nature in order to facilitate scientific investigation, to develop an understanding of scientific processes, and to hone critical thinking skills that would assist an
inquirer in independently evaluating evidence and stated claims (Lyons, 2010). During this time period, science was increasingly included within educational curricula because it was believed that the inductive reasoning required for scientific investigations expanded the learner’s intellect in new ways and assisted in meeting the demands for independent reasoning skills within an ever increasingly modern society (DeBoer, 2006). The push for the inclusion of scientific inquiry in education was continued through the late 1800’s, at which time Herbert Spencer, a social scientist and philosopher, argued that the common educational practices of the time, such as emphasizing the teaching of Greek and Latin, were intended more for the promotion of social status, and thus power as an educated person, and were not adequately promoting practical life skills for the average person (Holmes, 1994). Spencer was a proponent of an educational shift towards an emphasis on biology, chemistry, and physics (Holmes, 1994). He recommended that students have opportunities for independent discovery and believed that teachers should refrain from telling students how to proceed with their investigations and that IBS experiences facilitated a longer retention of the content material learned (Holmes, 1994).

Offering further support for scientific inquiry at this time was the German philosopher Johann Herbart who proclaimed the importance of the conversations and critical discourse that occurred between students and teachers as they navigated through scientific investigations. According to Herbart, conversation allowed students to be exposed to alternative perspectives and ideas that were held by classmates and teachers; the consideration of such alternative ideas, he
argued, could lead to modification of ones own thinking and expand ones knowledge base (McMurry, 1897; DeBoer, 2006).

By the end of the 1800’s, Charles Eliot, who was president of Harvard University at the time, introduced laboratory requirements for science classes at Harvard and also urged for their inclusion at the K-12 grade levels. He believed that laboratory experiences promoted reasoning skills and an ability to independently develop knowledge, qualities that were considered important for the average citizen in a democratic society (Rosen, 2000). During the same time period, Dr. Alexander Smith, professor of chemistry at the University of Chicago, and Dr. Edwin Hall, professor of physics at Harvard University, were arguing specifically for the inclusion of chemistry and physics laboratory requirements and experiences at their respective universities. Smith and Hall claimed that the nature of chemistry and physics facilitated the development and implementation of verification style labs where individuals would develop a greater understanding of the laws under investigation through direct observation. According to Smith, direct experiences with content material, through laboratory exercises, fostered greater conceptual understanding, a longer retention time, and promoted tangible experience with scientific processes (Smith & Hall, 1902). Smith and Hall argued for verification style labs over open-ended, student driven, investigations. They felt that open-ended investigations required too much time, that students generally were ill-prepared to handle the independent nature of open-ended experiences, and that the conclusions drawn by students from such experiences were superficial at best (Smith & Hall, 1902). Hall, however, did express concern
that verification style laboratory experiences encouraged students to simply look for evidence that would support the expected, or correct and often known in advance, answers to investigations (DeBoer, 2006). He, therefore, began advocating for a guided discovery approach. Using this method of discovery, students were given questions to investigate by the teacher, but the results were not readily known or predictable. This fostered the navigation through scientific processes in a more authentic manner than the mere confirmation of known laws and facts, and left some investigative processes open for student creativity.

By the early 1900's, the goals of inquiry-based science education began shifting towards a focus on developing the ability to formulate and investigate meaningful and significant questions of social relevance and to work cooperatively with others in addition to thinking critically; it was believed these goals would help prepare students for participation in a democratic society (DeBoer, 2006). It was at this time that John Dewey introduced his theory of experiential education and the notion that students should be active participants in the learning process (Dewey, 1938). Dewey claimed that students should learn about scientific principles through experiences that were directly relevant, and of interest, to the student's lives (Dewey, 1938). The context of inquiry-based lessons turned largely to projects and problems of student interest and social relevance. There was an increased implementation of inquiry-based science within schools during this era of the Progressive movement in education. It was not, however, met with overwhelming success. As Dewey noted, the lack of success may have been due primarily to a lack of instructional scaffolding that
would adequately equip students with the necessary skills to successfully engage in inquiry-based experiences (Dewey, 1938). Students were encouraged to pursue scientific investigations in which they were interested, but they were not given sufficient training in how to navigate their pursuits. The end results were as Smith and Hall predicted; students were ill prepared and their research culminated in superficial understanding (Dewey, 1938).

During the 1950's, after the successful launch of the Russian Sputnik satellite, many scientists and educational leaders began to see science as key to national security and economic prosperity in the United States (Barrow, 2006). As a result, there was a shift to an emphasis on requiring deeper conceptual understanding of scientific content material across varied disciplines, including physics, chemistry, and biology. This was intended to serve two functions. First, it was intended to adequately prepare students for entrance into scientific careers. Second, it was intended to sufficiently educate the general population about scientific principles and practices in hopes of their being able to understand scientific endeavors; this, it was thought, would assist researchers in garnering the necessary public support for the funding required to continue their scientific research and promote national competency in science (Mathews, 1994). It was then believed that the best way to accomplish these goals was through inquiry-based experiences that authentically represented those of scientists.

Perhaps the greatest proponent of this notion was Joseph Schwab. Schwab, a professor of education and natural sciences at the University of Chicago, believed that the best way to prepare future scientists and educate the
general public sufficiently to understand science was to have them engage in authentic scientific investigations (Barrow, 2006). In his historical overview of inquiry-based science, DeBoer asserts that the educational leaders of this time, including Schwab, claimed that it was "more important to have students conduct their own investigations because it promoted deeper intellectual engagement with the content and more meaningful understanding of the nature of scientific inquiry" (DeBoer, 2006, p. 29). Schwab stated that the discourse taking place between students, as well as with the teacher, was an important component of active engagement and that the exposure to alternative views that such discourse provided was critical to the overall success of inquiry (Barrow, 2006). He also proposed that all investigations should be tied to specific content and contextual situations. He did not support the premise that students conduct investigations of their own personal, or societal, interests; instead, Schwab believed students should conduct detailed investigations that were presented by the teacher based on specific content demands.

In an effort to make science more accessible to all students, in the 1970's there was a swing back towards focusing on investigations that held personal interest and social relevance. In 1971, the National Science Teachers Association (NSTA) claimed that: "The major goal of science education is to develop scientifically literate and personally concerned individuals with a high competence for rational thought and action" (NSTA, 1971, p. 47). The shift back to an emphasis on students' interest and social relevance encouraged science investigations to reach beyond classroom walls and include local communities.
and their resources. Socially relevant science investigations were designed to increase students' sense of purpose and agency as a way to increase their motivation in regards to science (DeBoer, 2006).

This sense of purpose and agency was echoed in the 1989 publication, by the American Association for the Advancement of Science (AAAS), of Project 2061: Science for All Americans in which they presented their basic goals for establishing scientific literacy within a global community. This document was followed, in 1996, by the National Research Council's National Science Education Standards which claimed that the goals of science education were for students to

- experience the richness and excitement of knowing about and understanding the natural world, use appropriate scientific processes and principles in making personal decisions, engage intelligently in public discourse and debate about matters of scientific and technological concern, and increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers (NRC, 1996, p. 13).

A review of both the Science for All Americans and the National Science Education Standards leads one to conclude that the argument for promoting inquiry-based science rests primarily on its potential ability to engage students directly with scientific processes and consequentially to assist students in their ability to develop questions, to think critically, and to take control of their own learning (NRC, 1996).
A review of the history of IBS reveals that its advocates have argued for it on the grounds that it can foster content understanding, increase retention of content, develop critical thinking and reasoning skills, as well as engagement in conversation and critical discourse, cooperation, collaboration, and motivation; motivation being interpreted as having increased interest and likelihood of engaging in science related activities, classes, and careers. The focus of IBS has fluctuated over time between a method used to teach extensive scientific content and one that aimed to provide opportunities for students to investigate topics of personal interest and/or societal relevance. As illustrated through this historical perspective, throughout its long history, IBS has had varying goals and definitions. In the next section, I present the contemporary definition and goals of inquiry-based science.

**Inquiry-based Science: Definition and Goals**

The term "Inquiry-based science," as illustrated in the previous section, has been employed throughout its history with numerous definitions and interpretations. Perhaps the root cause of these variations lies with the term *inquiry* itself. The term has come to mean three different things within the realm of science education (Flick, 2006). First, the term inquiry is meant to refer to the various means of conducting scientific investigations (Flick, 2006). Thus, one goal of inquiry-based science is to have students develop an understanding of how scientists navigate the investigative process. This understanding is meant to inform appropriate processes for student investigations; inquiry-based science
should teach students, preferably through direct experiences, how to inquire (Abrams, Southerland, and Silva, 2008).

Second, the term *inquiry* is meant to reflect an understanding of the nature of science and how knowledge is constructed. A study conducted by Schwartz and Lederman, and reported in: “What Scientists Say: Scientists’ views of nature of science and relation to science context” (2008), investigated the characteristics of knowledge as perceived by practicing scientists. The researchers interviewed twenty-four United States scientists from the disciplines of biology, chemistry, earth/space science, and physics. Data collected from the interviews, as well as open-ended questionnaires, was qualitatively analyzed within, and across disciplinary groups. The results of the study revealed a general consensus among scientists, and across disciplines, that the nature of science, or scientific knowledge, is tentative and subject to change, has its basis in empirical evidence, is subjective due to prevalent scientific perspectives as well as the bias and experiences of practicing researchers, is socioculturally embedded, and is dependent on, and the product of, human creativity (Schwartz & Lederman, 2008). It is critical to point out, however, that the subjectivity described by the scientists is meant to acknowledge potential bias that may enter into investigations, not to insinuate that scientific knowledge is purely subjective. In actuality, scientific knowledge aims to transcend subjectivity and strives for truth and objectivity. As described by D.C. Phillips, in “The Good, the Bad, and the Ugly: The Many Faces of Constructivism” (1995), “knowledge construction is ‘rational’ in that it proceeds deliberately according to
methodological rules and criteria" (p. 404). Scientists strive to continually search for, and correct, inaccurate knowledge claims, thus scientific knowledge is often characterized as self-correcting.

The same characteristics of scientific knowledge that were identified by scientists in the Schwartz and Lederman study (2008) were reported in a study conducted by Wong & Hodson (2008) entitled: "From the Horse's Mouth: What Scientists Say About Scientific Investigation and Scientific Knowledge." In this study, thirteen scientists from around the world, and varied disciplines including astrophysics and microbiology, were interviewed and asked to fill out the same open-ended questionnaire ("Views of the Nature of Science Questionnaire-version c, or VNOS-C"; p. 116) used in the Schwartz study. After analysis of the data, the scientists from this study were found to hold identical views as those from the Schwartz & Lederman study (Wong & Hodson, 2008). Thus a second goal of inquiry-based science that is advanced, is to foster student understanding of the tentative nature of knowledge, the influences of cultural and individual bias, and the dependency of knowledge construction on human creativity.

Finally, the term inquiry is also meant to reflect an instructional strategy for teaching science content (NRC, 1996). The National Science Education Standards defines an inquiry approach as facilitating student participation in making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing
answers, explanations, and predictions; and communicating the results.

Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (NRC, 1996; p. 23).

From this perspective, a third goal of inquiry-based science is for students to learn science content through direct experiences with a variety of investigative processes, opportunities for the critical evaluation of insights and investigative processes, developing and evaluating explanations, and communicating investigative results and insights to broader audiences.

In summary, the three goals of inquiry-based science education about which there is consensus are for students to be able to participate in inquiry experiences as informed through their understanding of the various means in which scientists engage in scientific inquiries — students will be able to do inquiry, to understand how scientific knowledge is constructed through their understanding of the nature of science — students will understand about inquiry, and to learn science content through direct experience with inquiry processes — students will participate in inquiry-based instructional approaches (Flick, 2006).

In 2000, the NRC set forth the more succinct definition of inquiry-based science as an educational approach that facilitates a student’s ability to “learn the principles and concepts of science, acquire the reasoning and procedural skills of scientists, and understand the nature of science as a particular form of human endeavor” (NRC, 2000; p. xiii). This definition of inquiry-based science, stipulated by the NRC, captures each of the three goals discussed above as well as each of
the specific components mentioned earlier in the NRC's 1996 definition of an
inquiry-based approach to teaching science.

Many research studies, such as those conducted by Basaga et al. (1994),
Chang & Son-Ling (1998), Marx et al. (2004), Wilson et al. (2009), and Wolf &
Fraser (2007), offer evidence to show that students learning science through
inquiry-based approaches show greater academic achievements in, and more
positive attitudes towards, science than their peers in more traditional, lecture
based, science classes. Evaluations conducted by the National Research
Council (NRC) also claim that inquiry-based science lessons can increase
student motivation towards, and achievements in, science (NRC, 2000). Inquiry-
based science experiences include opportunities for students to be active
participants in the scientific process. When IBS is fully implemented, students
develop research questions and testable hypotheses, design and implement
experiments, gather and analyze data, make conclusions, and report their
findings to various others such as teachers, classmates, the student body of the
school, as well as the broader community (NRC, 2000). If implemented with
adequate scaffolding of experiences, that encourage students to authentically act
like scientists, IBS experiences can realize the goals set forth in the definition of
IBS established by the NRC.

Inquiry-based science has been described based on different levels of
teacher and student responsibility for the required procedures and decision-
making processes contained within the lessons. Although variations in the
number of levels exist within the literature, they all consistently describe three basic levels. These levels are presented below.

Inquiry-based Science: Characteristics of Three Levels

Three Levels of Inquiry-based Science:

There are three basic levels of inquiry-based science lessons. Although some variations in name and number exist, there are three levels that incorporate each of the variations; these levels are generally recognized as: teacher-directed, teacher-guided, and open-inquiry (Cuevas et al., 2005). Each level represents a delineation of the degree to which students are responsible for generating investigative processes. All three levels are meant to be implemented within science education programs, through proper scaffolding of student experiences along a continuum from teacher directed to open inquiry, and all are meant to incorporate the qualities set forth by the NRC. A discussion of each follows in order to illustrate current practices and the limitations that may be found at each level.

Teacher-Directed Inquiry:

In teacher-directed inquiry, the teacher typically poses the research question to be investigated by the students and designates all, or a substantial part, of the experimental procedures and data collection methods to be followed by the students during the investigation. In these inquiry experiences, students are typically told what to do, and how to do it, by the teacher. Such lessons typically include hands-on laboratory exercises that assist students in gaining
experience with the means for proceeding through scientific investigations and to verify science concepts previously presented by the teacher. This type of inquiry is particularly helpful for initial scaffolding and introducing inquiry-based experiences because students are directly shown the manner in which to proceed (Geier, Blumenfeld, Marx, Krajcik, Fishman, Soloway, and Clay-Chambers, 2008).

A study conducted by Cuevas et al. (2005), entitled "Improving Science Inquiry with Elementary Students of Diverse Backgrounds" offers evidence that teacher-directed IBS experiences can improve student achievement, as measured through student performance on curriculum assignments as well as pre and post student interviews assessing student comprehension of content material and process skills, at the elementary level (Cuevas et al., 2005). Cuevas's study was conducted in order to determine the instructional impact of IBS, specifically among twenty-five third and fourth graders, and to determine whether an IBS approach to teaching science could narrow achievement gaps seen among various subgroups of students including those from varying socioeconomic status, ethnic backgrounds, and proficiencies for speaking English (Cuevas et al., 2005).

The study was conducted between 2001-2002 within six elementary schools in the southeastern United States; the schools were selected based on their reflection of the typical, and varied, demographics existing within the school district. The year prior to their research, the researchers observed a number of teachers in order to identify teachers believed to be effective at teaching science
and meeting the needs of students from diverse backgrounds. Once the teachers were selected, all of which were female, four students from each of their classrooms were selected for participation. The teachers selected the student participants based on achievement levels and gender; one boy and girl were selected from the high achieving students based on the teacher's assessment of overall academic performance in science class, and one lower achieving boy and girl were selected based on the same criteria. In order to control for teaching style and skill, the selected teachers attended a four-day training workshop where the lessons were practiced and standardized for purposes of implementation and comparability. Students participated in third grade during a unit on measurement and matter; the same students were assessed during their fourth grade year during a unit on the water cycle and weather. The third grade unit was entirely guided by the teacher, whereas the fourth grade unit afforded some student responsibility in designing the investigative questions. Each unit spanned approximately three months and had been designed by science educators, scientists, and linguistic specialists (Cuevas et al., 2005). Pre and post interviews with the students were video recorded in order to determine pre and post student understanding of content material and process skills.

During each unit, students were given a problem scenario to consider. For example, in one of the activities, the scenario involved needing to determine which fish bowl would retain enough water for the fish to survive while its owner went away for several days. Once the problem had been presented, students were asked several questions to prompt their consideration of an experiment that
would adequately determine which bowl would be sufficient. In some instances, students simply answered questions posed by the teacher; in others, they participated in experiments. Experiments at the third grade level had specific directions for students to follow; those at the fourth grade level allowed students to be more involved in the design process. Each activity had accommodating questions, such as "what materials were needed," or "what conclusions can you draw;" each activity also had content transference questions such as "How do you think it [the water in the fish bowl] is different from what happens with the oceans, lakes, and rivers?" (Cuevas et al., 2005; p. 354). During each of these units, student responses were given orally and were video taped by the researchers.

Each of the video recordings of student oral responses to questions was coded for content accuracy of the responses as well as conceptual understanding. T-tests were conducted to determine the impact of student's ability to understand and conduct an inquiry investigation as evidenced by the scores on their responses to the posed questions. Due to the small sample size, the statistical significance could not be calculated for demographic subgroups, so gains scores between pre and post interviews were used for comparison purposes. The results of this study indicated that academic gains were made across the spectrum of students regardless of gender, socioeconomic status, ethnic background, and proficiency in English (Cuevas et al., 2005). The study further revealed that students who entered the intervention at the lower end of the achievement scale, as well as those from lower socioeconomic status,
showed greater academic gains than their peers (Cuevas et al., 2005). One limitation to this study, as was noted by the researchers, is that the researcher conclusions for this study were drawn from the oral responses of the students. It remains unclear from this research whether the same level of content understanding would have been expressed by students in a written format; written responses are the more typical, and familiar, manner in which students express their understanding.

This study advanced our understanding of IBS by illustrating the positive outcomes that are possible when teachers are supported in the use of inquiry-based lessons that have been developed by trained personnel, and when teachers are trained in effective implementation strategies, such as scaffolding lessons to meet the cognitive needs of the students. This is illustrated by the fact that fourth grade students showed an increased ability to plan procedures for investigations and make conclusions after they had participated in the experiences in third grade (Cuevas et al., 2005). The success of the lessons also supports the notion that teacher training may be a key element to the success of IBS and thus should be included in any model of ideal IBS.

One gap in this study, and one which my research begins to fill, is that studying the social dynamics that occurred between the students during the unit could lend valuable insight into why the specific results were obtained as well as insight into other factors that influenced each student's experiences and achievements.
Strengths and Limitations of Teacher-Directed Inquiry:

The study mentioned above illustrates that teacher-directed inquiry is able to improve academic achievements in science. This level of inquiry can offer students experience with how to proceed with scientific investigations as well as insight and some experience into designing research questions and procedural methods, but it generally does not provide a strong platform for students independently designing and carrying out investigations, nor for exposing students to the alternative ideas, possibilities, and explanations that their peers might offer. Considering the stated goals of inquiry-based science offered by the NRC, which, stated succinctly, are to “learn the principles and concepts of science, acquire the reasoning and procedural skills of scientists, and understand the nature of science as a particular form of human endeavor” (NRC, 2000; p. xiii), it can be seen that the teacher-directed level of inquiry allows students to gain some acquaintance with the “procedural skills of scientists” (NRC) by following the procedural steps set forth by the instructions of the exercise. We also see that this level of inquiry can increase a students ability to “learn principles and concepts of science” (NRC) as evidenced by increased academic achievements as assessed by measures designed to determine student’s knowledge of scientific principles and concepts. This method of inquiry, however, falls short of realizing the stated goals of assisting students in acquiring “the reasoning skills of scientists” (NRC) and “understanding the nature of science as a particular form of human endeavor” (NRC). These aspects may be better fostered through social interactions and critical discourse as these have been
shown to be important aspects of acting like a scientist and in developing scientific knowledge (Wong & Hodson, 2008). Such limitations within teacher-directed inquiry inherently limit the potential of this approach to reach the farthest goals of IBS education.

Offering students opportunities to devise their own research questions and design their own investigations would appear to better encourage students to wrestle with some of the other important aspects of reasoning and collaborating like scientists. Having to design their own investigations requires students to make decisions and to evaluate the consequences of those decisions. A guided inquiry approach to IBS fosters such opportunities. I turn now to a discussion of guided inquiry.

**Teacher-guided Inquiry:**

In teacher-guided inquiry, students are afforded more control over the specific topic of their investigations. The teacher may present an overarching area of focus in order to contain the possible research directions students will take, but students are then expected to develop their own questions and/or design their own experiments to investigate their questions. Giving students an opportunity to partake in the design of experimental procedures and to make decisions about how to proceed fosters student ownership and interest in the inquiry process; as opportunities for student choice increase, students become more intrinsically motivated to engage (Schunk et al., 2008).

Teacher-guided inquiry experiences begin to move students closer to meeting each of the intended goals of inquiry-based science. These learning
experiences allow students first hand opportunities to consider the intricacies, and wrestle with the struggles, of developing researchable questions and designing experimental procedures that will allow them access to the data they must gather in order to answer their questions. Ideally, students are given opportunities to work more collaboratively with their peers and a chance to discuss and evaluate their research plans. They begin to be exposed to alternative ideas and possibilities. Through these experiences, they are offered an increased opportunity to practice and develop the reasoning skills of scientists and may be more likely to recognize science as a human endeavor through their interactions and conversations with their peers, and teacher, as they navigate through experimental design, data collection, and analysis (NRC, 2000).

In a 2004 study conducted by Marx et al. (2004) entitled "Inquiry-Based Science in the Middle Grades: Assessment of Learning in Urban Systemic Reform," nearly 8000 students in grades six through eight, from fourteen different urban schools, participated in a three year inquiry-based reform effort within the Detroit public schools. This study was part of a larger NSF funded project known as the Center for Learning Technologies in Urban Schools, or LeTUS. The LeTUS project supplied the inquiry-based lessons used in this study and provided training for teachers in order to ensure a common implementation of the curriculum, thus making the results more comparable. Teachers were selected based on their willingness to work with the LeTUS project, the availability of at least one computer for every four students in their class, and whether they had administrative support. One strength of this study, as in the Cuevas et al. (2005)
study, was that the lessons, and the tools available for student use, were
scaffolded across years in order to facilitate student learning and a progression
towards more independent inquiry experiences (Marx et al., 2004). There was
one curriculum unit implemented in grade six, two in grade seven, and one in
grade eight. Each unit took 8-10 weeks to complete.

The study used pre and post-test scores within each unit and across
grade levels to assess the impact of the inquiry-based curriculum on content
understanding and process skills over time. The assessments were comprised of
multiple-choice and open response questions which were categorized as
representing either content knowledge or science process skills (Marx et al.,
2004). Student responses to the questions were rated as either high, medium, or
low based on the depth of conceptual understanding revealed in their answers.
Researcher ratings of student responses were calculated and assigned by teams
of 3-5 researchers; discrepancies in researcher assigned ratings were discussed
until agreement was reached thus establishing consistency and inter-rater
reliability (Marx et al., 2004). The use of pre and post-test scores, however, did
limit the researchers in terms of what types of conclusions could be drawn. For
instance, although the use of consistent and valid measures allowed researchers
to determine whether gains were made, gaps remained in the researchers ability
to understand why gains had been made.

The results of this study did, however, show statistically significant gains
among students who participated in the inquiry-based lessons. The effect sizes
for the gains were stronger for the content knowledge scores than the science
process scores (Marx et al., 2004). The researchers did describe students working together to complete tasks, but they did not investigate whether those interactions could be related, and if so, in what ways, to the noted outcomes. It is quite possible, for example, that the collaborative activities, and the social interactions that ensued, were influential to the overall success of the students.

The researchers also found that the measured gains grew stronger across the three years of student experience with the IBS lessons (Marx et al., 2004). The researchers concluded that an inquiry-based science curriculum, in this case one reflective of the teacher-guided inquiry level, could effectively increase student achievement in both content understanding and process skills (Marx et al., 2004). The researchers also concluded that proper scaffolding of lessons and activities was influential to student success (Marx et al., 2004). This study moves our understanding of IBS forward in that it documents positive gains in student achievements and process skills as a result of IBS experiences, and notes increased gains with increased student experience, but it did not attend specifically to the reasons for those gains.

Another study, conducted by Taraban et al. (2007), shows that teacher-guided inquiry experiences have also been successful at the high school level. The Taraban study was designed to determine the impact that a guided inquiry approach within two high school biology units would have on student understanding of scientific content, the nature of science, and student attitudes towards science (Taraban et al., 2007). Four hundred and eight students from six classrooms in Texas participated in this study; two thirds of the students were
high school sophomores, and one third were freshman. Participating classrooms were selected in order to include a mix of urban and rural schools as well as teachers with varying years of experience. Two units and accompanying lessons were designed and field-tested by teachers and researchers prior to the research; one unit focused on microscopy and the other unit focused on biotechnology. Each unit included researcher designed open-ended questions and statements that were used to assess student understanding of content material, process skills, and attitudes about science.

In order to assess the type, and depth, of content material covered within each class, researchers relied upon daily teacher journal reflections. The researchers acknowledged that one limitation to this study was that some teacher entries were less detailed than others making it difficult to assess how the material was actually taught (Taraban et al., 2007). A second limitation was relevant to this acknowledged concern. Although comparisons were made between designated teacher-directed and guided inquiry classrooms, it was not entirely clear whether the teacher-directed classroom was actually an inquiry-based approach, or if it was more reflective of a more traditional, lecture based, approach; this is admittedly a fine demarcation that is often difficult to recognize.

The results of the study, however, indicated that students who participated in the teacher-guided inquiry approach expressed more positive attitudes towards science, scored significantly higher on curriculum based exams, and showed greater depth of understanding in process skills, as was evidenced by their responses to the short answer questions, than their peers in the teacher-
directed lessons (Taraban et al., 2007). All open-ended responses were scored and coded by two researchers; discrepancies in scores were discussed and resolved in order to achieve inter-rater reliability (Taraban et al., 2007). Questions were broken into three categories; factual content recall, critical thinking skills, and understanding of process skills and the nature of science (Taraban et al., 2007). A multivariate analysis was conducted that used the type of instruction, teacher-guided or teacher-directed, and the type of focus questions, whether they were based on content, critical thinking, or process skills, as determinants (Taraban et al., 2007). The results revealed that students in the teacher-guided approach showed gains within each of the three question types compared to their peers in the teacher-directed approach. The results also showed, however, that the amount of gain fluctuated depending on the question type (Taraban et al., 2007). Significant student gains were measured for both factual content and process skills. Although improvements were observed in the critical thinking skills of students participating in the teacher-guided approach, the gains were not found to be significant (Taraban et al., 2007). The results of the study also indicated, through coding and evaluation of student short answer responses, that students who experienced the teacher-guided inquiry approach were able to describe what they had learned with greater conceptual detail than students experiencing the teacher-directed approach (Taraban et al., 2007).

This study supports the notion that teacher-guided inquiry can promote improvement in achievement and content understanding. It further advances our understanding of IBS by illustrating that students make gains in content
understanding, developing an understanding of the nature of science, and in their overall attitudes towards science (Taraban et al., 2007). However, the researchers are left without an understanding as to precisely why the gains occurred. The researchers were not present, in the field, to observe what actually occurred on a daily basis. Had researchers been present, and able to attend to the actual instruction that took place, rather than relying on teacher self-reflections, and if the researchers had observed how students acted, reacted, and interacted, some reasons for student gains may have been revealed. Attending to the daily actions and interactions may well foster insight into why student gains are often seen through IBS experiences.

Strengths and Limitations of Teacher-guided Inquiry:

The studies mentioned above illustrate how teacher-guided inquiry experiences are able to move students closer to each of the stipulated NRC goals of inquiry-based science. The requirement for students to design and implement their own questions and investigations, to work collaboratively with their peers, and to evaluate the results of their investigations increases the likeliness that students will be exposed to alternative ideas, possibilities and explanations. As such, students begin to be more exposed to experiences that have more potential to realize all three of the stipulated NRC goals; they learn scientific concepts, they develop reasoning and procedural skills, and they experience science as a human endeavor through their interactions with their peers. There are, however, some limitations with this approach to inquiry. Guided inquiry lessons often take longer to complete which may cause lessons to
become rushed. This may, in turn, force students to only shallowly evaluate their results, thus limiting potential learning from the experience. Research, such as the Taraban et al. (2007) study mentioned above, has also shown that although participation in this level of inquiry shows significant gains in content understanding and process skills, it does not always produce significant gains in critical thinking skills. It seems that prior student experience with, and scaffolding of, inquiry may affect whether guided inquiry can realize this intended goal.

The current continuum of IBS from teacher-directed to open inquiry, suggests that the farthest reaches and intended goals of IBS may best be met, assuming proper scaffolding of inquiry experiences and support structures such as skilled teachers are in place, through open inquiry experiences. Open inquiry allows students to engage and wrestle with all aspects of the scientific process. There are also, however, drawbacks and limitations to open inquiry.

Open Inquiry:

Open inquiry offers students the greatest level of individual choice in project options and directions. Students are often encouraged to pursue a direction of personal interest for their investigations. If taken to the farthest extreme, students would have no limitations other than the supplies and resources available to them for their topic of study. Research on open inquiry experiences has been met with mixed reviews. The most successful open inquiry experiences follow from students who have had ample experience with teacher-directed and guided inquiry in order to properly prepare them for the open inquiry experiences (Flick, 1998). As inquiry-based lessons tend to be rare in current
practices, the number of students adequately prepared, and afforded opportunities to participate in open inquiry are few. Research, such as that discussed earlier in this section, has also shown that students participating in inquiry experiences, even without proper preparation, may enjoy the experience more than their typical science class, and thus improve their attitude towards science, but the conceptual understanding of science content, the development of critical thinking skills, and an understanding of scientific process skills are advanced at varying degrees and sometimes the gains are negligible (Settlage, Meadows, Olson, and Blanchard, 2008). Some research, however, such as the studies mentioned below, has shown that if implemented and scaffolded adequately, open inquiry experiences can accommodate significant gains towards meeting NRC goals.

Research, such as that conducted by Flick (1998), has shown that students thrown into open experiences without proper preparation actually become overwhelmed and frustrated by the experience and their positive attitude toward science is actually reduced. Flick's study compared the impact of scaffolding inquiry-based instructional approaches to student engagement. The study compared and analyzed the instructional strategies of two teachers; these teachers were selected based on their level of experience with inquiry and after researcher observation of eight potential teacher candidates for the study. One teacher taught sixth grade science, his focus with inquiry was on creating opportunities for student discussion about the activities within the lessons. The other teacher taught seventh grade science; his focus on inquiry was creating
opportunities for student reflections on the concepts and processes of science. Flick video-recorded and took field notes during six observational sessions and conducted one extended interview with each teacher. All video-recordings and field notes were transcribed and coded. The results indicated that open inquiry experiences can impact student engagement. Open inquiry experiences that have been complimented by instruction that is carefully scaffolded, in terms of conceptual understanding and developing skills necessary for success, can foster student engagement and increase positive attitudes towards science (Flick, 1998).

In addition to investigating the impact of deliberately scaffolded lessons, research has also been conducted to investigate whether student attitudes towards science upon entering inquiry-based experiences influence the outcomes of IBS. In 2003, Berg et al. conducted a study entitled “Benefiting from an open-ended experiment? A comparison of attitudes to, and outcomes of, an expository versus an open-inquiry version of the same experiment” at Umea University in Sweden. This study specifically investigated the effects of open inquiry-based lessons compared to the same lesson taught in a teacher-directed manner. The researchers specifically investigated whether existing student attitudes towards science as they entered the inquiry experience would influence the results of their experiences and their accomplishments within each style of inquiry instruction (Berg et al., 2003). The study included 190 students in their first year of chemistry at Umea University. The study was implemented in two phases; phase one took place in the fall semester and phase two took place in
the spring semester. Researchers first determined student existing attitudes towards science based on a researcher-developed questionnaire that was adapted from one originally designed by Johnstone in 2001 (Berg et al., 2003). The researchers used their modified questionnaire to identify students as having either a positive or negative attitude towards science as they entered the respective classes. Students were evenly distributed between the teacher-directed, or expository, and open inquiry experiences. The equal distribution of student ability level and existing attitude towards science within each approach to inquiry added to the strength of this study; this helped ensure that any obtained results were not skewed by an excess of students with higher ability level, or existing positive attitudes toward science, in one class or the other.

All students in each class completed self-reflection questionnaires about their experiences and the researchers interviewed course instructors in order to assess instructor perceptions of student work and accomplishments as well as the instructor assessments of the teaching approach (Berg et al., 2003). Within each class, and each phase, three students with positive attitudes towards science and three students with negative attitudes towards science, were selected for an additional in-depth researcher interview. These interviews were conducted in order to discover more detailed information about student perceptions of their experiences and their achievements (Berg et al., 2003). All interviews were audio taped, transcribed, and coded by the researchers. Interviews were initially coded independently, then comparisons between codes were made and discrepancies recoded for mutual agreement, thus establishing
inter-rater reliability. The interviews were conducted either the same day, or the day after laboratory experiences so the experiences would be fresh in the students' minds. The interview practices within this study demonstrate both a weakness, and some strengths, to this study. The strengths include the fact that the researchers were able to glean direct insight into student experiences. Conducting the interviews near to the actual time of the experiences also helped to ensure that student memories were not altered by the passing of time nor influenced by other activities. One limitation of the interviews, however, is that the information gleaned from them was representative of only a single experience and only representative of about nine percent of the study group.

In phase one of the research project, 105 students were divided evenly according to their attitudes towards science, as evidenced by their scores on the researcher developed questionnaire, and were placed into one of two classes; one class implemented a teacher-directed inquiry approach and the other implemented an open inquiry approach based on the same curriculum content (Berg et al., 2003). Students in the class with the teacher-directed approach to inquiry were given explicit instructions to follow and questions to answer while conducting their investigations. Students enrolled in the open inquiry approach were told very general information about the materials available to them and instructed to investigate any avenue of interest to them that would allow them to compare any two catalysts for chemical reaction (Berg et al., 2003).

Phase two of the research included 85 students comprised of equal numbers with positive and negative attitudes towards science, all within a revised
open inquiry approach to chemistry. The revised approach included the instructor informing the students, in advance of their inquiries, that the planning and evaluation phases of their experiments would be an important component to the experimental process. A second revision to phase two of the research was that the instructors required students to check in with the instructor in order to discuss their progress mid way through the experience. This modification was implemented because researchers discovered that students who had scored lower on the science attitude questionnaire struggled more in the open inquiry experiences than students who had scored higher on the questionnaire; it was believed that these modifications would support these students and enable them to be more successful during phase two of the study (Berg et al., 2003).

The results of the study revealed that relatively equivalent gains were made in content understanding within all three approaches regardless of student's initial attitudes towards science or the instructional approach used. Substantial gains were made, however, by students within both the open and the revised open inquiry approach in students' ability to synthesize and evaluate experimental results and processes (Berg et al., 2003). The greatest gains were seen within the revised open inquiry approach, followed by successes seen in the initial open inquiry approach. Only nominal gains in student's ability to synthesize and evaluate results were found in the teacher-directed approach. Results also illustrated that while all students in the teacher-directed inquiry performed identical experiments, as per the instructions, that had predetermined results, students in the open inquiry classes conducted a wide variety of
experiments with varying results that were not predictable at the outset (Berg et al., 2003).

An evaluation of the in-depth researcher interviews revealed that students in the open and revised inquiry experiences had substantially better abilities to describe the experiment that had been conducted, could evaluate the experimental results, could identify strange or questionable results and possible sources of error, could evaluate and make suggestions for improving the experiment, and could suggest experiments that would accommodate new experimental objectives. The interviews also revealed that students with more positive attitudes towards science upon entering the class more readily engaged in the activities and that students entering the experience with more negative attitudes towards science required more support (Berg et al., 2003). The results of the revised open inquiry approach indicated that having a check in with the instructor mid way through the class to discuss progress, and having advance notification that evidence of student planning was part of the instructors evaluation, were effective additions to open inquiry and supported learning. Finally, students with both negative and positive attitudes towards science reported, in their self-assessments, an increased ability to synthesize and evaluate experimental results; the self-reported improvements were more substantial within the negative attitude than the positive attitude students (Berg et al., 2003).

As mentioned above, the interviews revealed that students were able to explain the experimental process, identify anomalies and sources of error,
evaluate experimental results, develop conclusions, and design future experiments. The research advanced our understanding of the possible benefits to the open level of IBS experiences. The researchers learned that the open inquiry experiences seemed superior to the teacher directed experiences, but, once again, the researchers are not able to specifically pinpoint, or explain, why the experiences led to greater achievements and understanding of scientific processes. It is quite possible, for instance, that the social interactions that took place in the open inquiry experiences were influential with respect to the level of motivation, and thus to engagement and to achievement. Finally, although the researchers label this study a comparison of teacher directed and open inquiry, it can be argued that the open inquiry experience was actually more reflective of a higher level teacher-guided inquiry as students were limited to studying catalysts for chemical reactions as their topic of study.

The Berg et al. (2003) study investigated whether student attitudes about science upon entering inquiry-based experiences influenced the educational outcomes of IBS. Other research has investigated the opposite affect: whether student participation in IBS experiences could influence student attitudes towards, and interest in, science as a result of their IBS experience. One such study was conducted by Gibson and Chase (2002).

The Gibson and Chase study (2002) investigated the long-term effects of student participation in a two-week inquiry-based summer camp that fostered open inquiry experiences. The goals of the inquiry-based camp were to increase middle school student interests in science and their pursuit of science careers.
This longitudinal study tracked student interest in science over a three year time period. Participants in the study, including two comparison and control groups that did not participate in the summer camp experience, completed the Science Opinion Survey and the Career Decision Making System-Revised in order to determine their attitudes towards science. The Science Opinion Survey was developed by the National Association for Educational Progress and assesses student current interest in, and attitudes towards, science. The Career Decision Making System-Revised assesses student career interests based on a 96-item questionnaire that describes various careers from six broad fields, one of which includes science related careers. The surveys were initially administered on the first day of the camp with follow up surveys being administered two to four years post-camp experience, depending on which year students attended the camp. Interviews were also conducted, audio recorded, transcribed, and coded.

The results from this analysis indicated that students who participated in the open-inquiry camp experience maintained a more positive attitude towards science, and interest in science related careers, over time than their peers in the control groups. The results indicate that the camp experience helped foster positive attitudes, and interest, in science during the experience and participants of the open-inquiry experience maintained a more positive attitude towards science over time (Gibson & Chase, 2002).

Qualitative analysis of participant interviews revealed similar results; students from the open-inquiry group expressed more positive attitudes towards science, and interest in science related careers, than their peers in the control
groups. The results showed seventy percent of the students enjoying the camp experience, with seventy-seven percent claiming it increased their interest in science. One theme that emerged from the student interviews was the importance of communication and interactions with their peers. This is evidenced in comments such as: "you get to talk to people, discuss things, explain your ideas, you have an opinion, you speak about it, and you have freedom" (Gibson & Chase, 2002, p. 701) and "I learned to open up more, to let others know what I think" (Gibson & Chase, 2002, p. 702).

In summary, this study investigated the long-term impact of open IBS experiences and revealed that open inquiry experiences can positively influence student attitudes towards science. One strength of this study is that it offered longitudinal insight into the impact of open inquiry experiences. Two of the previously mentioned studies, Taraban et al. (2007) and Berg et al. (2003) illustrate how IBS lessons can bolster positive student attitudes towards science. This study adds to those investigations in that it illustrates the long-term positive effect IBS can have on student attitudes towards science and sustaining their interest in scientific careers. The study also reveals insight into the importance, as expressed by the students, of social interactions in the IBS experience. Unfortunately, however, the study did not follow up on student comments, such as those mentioned in the previous paragraph, in order to determine what influence, if any, the social interactions had on students. The study reveals that such interactions emerged as important to students, but it does not offer much
insight into why, or to what effect, those interactions may have influenced the experience.

Strengths and Limitations of Open Inquiry:

The strengths of open inquiry-based science include its potential to meet each of the stipulated NRC goals. In order for open inquiry experiences to reach these goals, however, the lessons must be scaffolded effectively. Research discussed above, such as that conducted by Cuervas et al. (2005), Gibson & Chase (2002), and Taraban et al. (2007), has illustrated that prior teacher training, and experience, with an inquiry approach to teaching can be instrumental to the success of open inquiry experiences for students. A second strength to open inquiry is that it offers students the greatest flexibility in pursuing personal interests. An ability to pursue topics of interest can increase the value placed on the experience and can be motivational for students (Schunk et al., 2008).

There can also, however, be several weaknesses with an open-inquiry approach. If students are placed in an open inquiry situation without prior, and adequate, experiences with inquiry-based lessons, it can lead to student frustration and a decreased interest in science (Flick, 1998). Some research, such as that conducted by Taraban et al. (2007), has also shown that open inquiry experiences may be perceived as simply more enjoyable by the students because they have more personal freedoms regarding the topic of investigation and procedures to be followed, but that there may actually be a reduced level of
content understanding; this may be the result of students undertaking superficial investigations.

**Summary of Inquiry-based Science Levels**

IBS has been shown to be an effective teaching approach at all levels of education from kindergarten through college. The previously mentioned studies, have shown that IBS can increase student achievements in science (Berg et al., 2003; Cuevas et al., 2005; Marx et al., 2004; Taraban et al., 2007), conceptual understanding of content material (Berg et al. 2003; Marx et al., 2004; Taraban et al. 2007), positive attitudes towards science (Berg et al. 2003; Taraban et al., 2007) and an awareness of scientific processes and the nature of science (Marx et al, 2004; Taraban et al., 2007). Each level of inquiry has been shown to address the stated goals of inquiry as stipulated by the NRC. Teacher-directed inquiry mainly accentuates the NRC goal of fostering conceptual understanding of content and the procedural steps of scientific investigations. Both teacher-guided and open inquiry lessons can, if implemented effectively, address all three of the NRC goals for IBS. The general characteristics as well as the strengths and weaknesses of each level of inquiry have been analyzed; I turn now to current practices within schools in order to discuss some of the challenges and struggles that may obstruct the effective implementation of IBS lessons.

**Inquiry-based Science: Current Practices and Limitations**

As currently implemented, the majority of IBS lessons conducted in schools are at the teacher-directed level, and even those are rare (Wilson et al.,
Along with the general infrequency of an inquiry-based approach to teaching science, there are several, possibly compounding, factors that interfere with the implementation of IBS lessons and their ability to reach the farthest intentions of IBS. Current barriers to IBS include, but are not limited to: time constraints of daily school schedules which interfere with the longer time required for inquiry-based approaches, pressures around high-stakes standardized testing and the practice of using test scores as the prominent measurement of student success, as well as inexperience of both teachers and students with properly scaffolded activities that could assist in the development of skills needed to increase the level of success met through IBS experiences (Holliday, 2006). The issues mentioned above are common to all levels of inquiry.

**Barriers to IBS:**

Numerous barriers exist that interfere with the successful implementation of IBS. First, there is considerable confusion among educational practitioners about what the term “inquiry-based science” actually means, what it looks like, and how it can best be implemented. As a result, some educators claim to be implementing IBS lessons when, in actuality, they are not, and some educators are so uncertain about how to proceed that they simply opt not to even attempt inquiry-based lessons in the first place.

A second barrier to IBS is the fact that inquiry-based science lessons often take more time to implement. Many teachers struggle to find the time, and feel themselves incompetent, to include the inquiry process within their classes (Holliday, 2006). The additional time required to implement inquiry-based science
lessons is of ever-increasing concern during the current high stakes testing and accountability climate of education. In this era of standardized testing, teachers feel intense pressure to prepare students to be successful on standardized tests. Teachers fear their instructional time may be better spent implementing lessons and activities that more directly prepare students for these tests. As a result, the more time intensive inquiry-based lessons are sacrificed for more traditional skill-and-drill type lessons. Due to time constraints, and standardized testing pressures, teachers often rush students through the inquiry process, thereby reducing the potentially influential interaction and collaboration between students.

Compounding the pressures of preparing for standardized tests is the fact that many teachers have either had, or heard of, experiences with inquiry-based science lessons in which students did not gain sufficient understanding of content material to warrant the length of time spent on the lessons. The known struggles, inconsistent results, and even failures, of IBS lessons further deter teachers from taking the time necessary to attempt such lessons; instead, teachers opt to implement lessons with which they feel more confident of student success. Determining how to more successfully, and efficiently, implement IBS lessons within the class time available would encourage more teachers to utilize this teaching strategy. Complicating this issue even further, the currently accepted notion of what counts as success leads to yet another barrier to IBS.

A third barrier to IBS is the fact that success in science education is currently measured primarily by student performance. Typical evaluations assume that if students score favorable marks on content related tests,
particularly standardized tests, that they have learned the material (Yore, Henriques, Crawford, Smith, Gomez-Zwiep, and Tillotson, 2008). Classroom standards tend to be performance based; students are considered successful if they score high on assessments and if they outperform their peers (Wolters, 2004). Administrators consider students successful if they outperform students in other school districts on standardized tests. Typically, students are considered successful in inquiry-based science if they are able to recognize the procedural steps to the scientific method, are able to identify appropriate scientific equipment necessary for particular tasks, can design and implement experiments, can analyze data and develop conclusions, and can share their results with various audiences through reports and posters. They are considered successful if they can state the scientific facts that emerge, or are supported, through the lesson. Current accounts of success send the message to students that learning means memorizing content material in order to regurgitate information on, and thus pass, a test. Although students might be able to cite the procedural steps of the scientific method and/or identify basic scientific content, they often fall short in demonstrating their ability to engage in critical discourse about the scientific process. They often struggle to explain why they obtained certain results from their investigations, or the significance of those results; they struggle to provide evidence that they actually understand what they have learned (Yore et al., 2008). As described by Yore et al. (2008), "many of these labeled-successful students leave secondary school lacking a deep, conceptual
understanding of scientific concepts and are ill prepared to apply their knowledge of science as citizens or undergraduate students” (p. 72).

This current notion of success negates knowledge gains that can be made through interactions with others, such as knowledge gained through peer review discussions, interviews, or discussions that take place during student investigations. Beginning to acknowledge and include alternative assessments that measure student abilities and tendencies to engage in activities such as reasoning like scientists, collaborating with others, and engaging in critical discourse will assist in exposing currently unrecognized measures of success. Creating more holistic knowledge assessments may reveal that IBS lessons can lead to even more knowledge gains than are currently acknowledged.

A fourth barrier to the implementation of IBS lessons stems from a lack of teacher comfort in relinquishing varying amounts of control of the lesson to the students. During IBS lessons, teachers increasingly take on the role of instructional facilitator rather than the more traditional role of lecturer. Teacher training, however, often does not provide opportunities for teachers to practice skills required for the successful facilitation of student-generated inquiry-based experiences.

A fifth, and perhaps one of the greatest limitations to IBS, however, stems from our current tendency to tout the “hands-on” nature of IBS activities and students “acting like scientists” as the reasoning for any successes seen through IBS. Obstacles and limitations arise from our willingness to not only accept an inadequate interpretation of what it means to act like a scientist, but also from our
efforts to have inquiry-based science experiences reflect that misinterpretation. In
the next section of this dissertation, I discuss the limitations that these notions
impose on IBS and suggest a need to shift our attention to the student
interactions that take place during IBS experiences in order to gain a more
comprehensive understanding of IBS and possible reasons for its success.

**Inquiry-based Science: The Need to Shift Our Attention**

Many research studies, such as those mentioned earlier as well as those
conducted by Basaga et al. (1994), Chang & Song-Ling (1998), Marx et al.
(2003), Wolf & Fraser (2007), and Wilson et al. (2009), provide evidence to show
that students learning science through inquiry-based approaches show greater
academic achievements in, and more positive attitudes towards, science than
their peers in more traditional, lecture based, science classes. Evaluations
conducted by the National Research Council also claim that inquiry-based
science lessons can increase student motivation towards, and achievements in,
science (NRC, 2000).

The existing research, however, claims that IBS lessons increase student
achievement and motivation due to their "hands-on" approach and the
opportunities that exist for students to "act like scientists" (Chang & Song-Ling,
1999). For example, in their 1999 study, Chang & Song-Ling compared the
outcomes of teaching an earth science unit using a traditional, lecture type
approach, to that of an inquiry-based approach. Results of the study indicated
that student achievement scores on the researcher developed pre and post-tests
were significantly higher for the inquiry-based group than the lecture group (Chang & Song-Ling, 1999). The researchers presented the hands-on nature of the investigative activities as the primary reason for the increase in student achievements (Chang & Song-Ling, 1999).

Turning to the research literature in order to clarify the expressed meanings of the terms “hands-on” and “acting like a scientist” reveals that the notion of “hands-on” tends to be equated with the physical manipulation of science materials, such as microscopes or pulleys, during the inquiry experience. The term “acting like a scientist” is equated with navigating through the procedural steps of the scientific method which is described as developing questions and hypotheses, designing and implementing experiments, collecting and analyzing data, making conclusions, and reporting findings to a broader audience. In actuality, however, “acting like a scientist” includes a much broader scope than that seen within the existing literature and current practices of IBS lessons. Some researchers have turned directly to scientists in order to determine the meaning of the term; the scientist’s perceptions are presented below.

**Acting Like a Scientist**

Scientists act in numerous ways; not all are immediately visible within the hands-on navigation through the scientific method that is currently touted as the reason for success in inquiry-based science. Scientists acknowledge that the procedural steps of the scientific method play a substantial role in their research,
but that a multitude of other methods are also used depending on the goal of their investigation and the type of research they are conducting (Schwartz & Lederman, 2008). In fact, scientists argue that not all research questions can be answered through hands-on experimental procedures but sometime require modeling and thought experiments (Schwartz & Lederman, 2008).

**Scientist Perceptions of “Acting Like a Scientist”:**

According to the Schwartz and Lederman (2008) study mentioned earlier, scientists acknowledge engaging in a variety of activities, driven by the context of their investigations, as they attempt to answer their research questions or develop explanations for observed phenomenon. The twenty-four scientists who participated in this study claimed that, as researchers, they design and implement rigorous experiments, or investigations, in search of empirical evidence that will either support or refute their working hypotheses. In such pursuits, they methodically attempt to control for variables that might influence the resulting data. They follow various procedural steps and protocols in order to increase the reliability, and comparability, of the data collected. Scientists critically analyze their data and evaluate potential bias in order to make reliable and accurate conclusions (Schwartz & Lederman, 2008). This study stressed the scientists’ view that not all investigations are compatible with hands-on manipulative experimentation. As an example, scientists described how astrophysicists studying distant galaxies are unable to physically manipulate the galaxies under investigation, and therefore must use alternative investigative measures (Schwartz & Lederman, 2008).
Similarly, the Wong and Hodson study (2008), in which the researchers specifically investigated the perceptions of thirteen prominent scientists regarding scientific processes and scientific knowledge, tried to better clarify what it means to “act like a scientist.” The thirteen scientists in this study shared numerous ways in which they engage in scientific investigation that do not reflect the step-by-step procedures of the scientific method. They described conducting research through alternative methods such as observational studies, literature reviews, and meta-analyses of existing studies (Wong & Hodson, 2008). Scientists claimed to take on many tasks in their role as researchers; they may create or test ideas, conduct research experiments, or offer insight into, and possibly theories for, observations or topics of interest. The participants of the study claimed that some scientists “focus on experimental work, others on theoretical issues. Some scientists use experiments, others may use naturalistic studies, historical reconstructions, or computer simulation and modeling tools” (Wong & Hodson, 2008; 125). The importance of self-reflection during all phases of research as well as engaging in peer reviews with colleagues were also emphasized as important aspects of acting like a scientist by the scientists who participated in this study. Frequent engagement in a variety of kinds of conversations with various others about their work was cited as important. Conversations they deemed vital to their work included: heated debates and critical discourse with fellow scientists, funding agencies, and public organizations; casual conversations with those previously listed, as well as
casual talk with friends, family members, or lay people about their work (Wong & Hodson, 2008).

The scientists from the Wong & Hodson (2008) study agreed overwhelmingly that creativity and imagination are both necessary qualities for scientific investigations. This same sentiment is reflected in the now infamous quote from Albert Einstein: “Imagination is more important than knowledge...it is, strictly speaking, a real factor in scientific research” (Einstein; 1931; p.9). The importance of empiricism, as well as the interconnections between science, technology, and society, were emphasized by the scientists in Wong and Hodson’s study as integral aspects of investigations (Wong & Hodson, 2008).

Scientists shared a recognition of the diverse methods of conducting research and interpreting results as well as an acknowledgment that researcher bias is inescapable and must be uncovered and evaluated (Wong & Hodson, 2008). Data analysis from Wong’s study revealed that the scientists involved identified eight common aspects of science: varied methods of investigation, consideration of existing theories throughout inquiries, recognition of the tentativeness of theories (meaning that theories may be modified as new evidence becomes available), creativity at all stages of the process, social/political/cultural influences on science and researcher bias, funding and ethical issues, collaboration and competition with other researchers, and the importance of peer review (Wong & Hodson, 2008). The scientists in Wong & Hodson’s study acknowledged that:

no experimental method is perfect, so no method can produce perfectly valid and reliable data... even relatively small variations in method can
produce quite large differences in data, and even when the methods are procedurally identical, variations in data can still occur because of differences in the quality (reliability) of the instruments deployed or the bench skills of the technicians (Wong & Hodson, 2008, p. 120).

Scientists continually assess and re-adjust their experimental procedures based on new information and insight; their scientific method is not a linear procedure, but rather a cyclical and morphing process that evolves until a method that is believed to be appropriate and reliable is found. The consideration of multiple perspectives and results ultimately leads to improved understanding of observed phenomenon and the modification, and advancement, of existing scientific theories was found to be crucial to the success of scientists' research (Wong & Hodson, 2008). This is consistent with the aim of scientists to continually strive to expose inaccurate knowledge claims as new information becomes available and to generate new knowledge claims as our understanding evolves.

The importance of collaboration and the consideration of multiple perspectives are reflected in the growing tendency for scientists to work within collaborative teams. Although scientists certainly can, and sometimes do, work in isolation from others, they often, if not typically, work in interdisciplinary or collaborative teams in order to conduct their investigations (Jones, 2010). They constantly assess and reassess their findings and make comparisons with research conducted by other scientists. They give to others, and receive from others, feedback on their ideas, practices, and procedures (Jones, 2010). In a 2010 study, Jones examined recent trends in scientific research and
governmental policies that support research efforts. He documented a significant shift in research efforts from researchers working independently, to research being conducted by research teams with experts from varying disciplines and specialties collaborating together (Jones, 2010). Jones documented a substantial rise in the number of published journal articles written by multiple scientists and a drop in the number of articles with just a single author; Figure #1 illustrates this trend.

![Figure 1](image_url)

Figure 1: The number of published journal articles with multiple authors (from: "As Science Evolves, How can Science Policy?" (Jones, 2010; p. 12).

Jones states that this shift:

suggests fundamental changes in the organization of innovative activity, with innovators not only being more specialized but increasingly working in teams… this documents a major dynamic in science: a general shift to team production and associated rise of teamwork as the locus of higher impact ideas (Jones, 2010, p. 11).
In discussing policy trends that currently support research efforts, Jones noted that policies, and rewards for innovative work, are beginning to shift their recognition criteria to include team efforts rather than individual efforts. Jones credits the increased specializations of scientific disciplines as a main cause for these trends. As scientists become more and more specialized, they also become more and more dependent on other scientists for collaboration in order to develop a comprehensive understanding of all aspects of their investigations (Jones, 2010). Social interactions, therefore, are a substantial component to acting like a scientist. But of course not just any and all social interactions, and so we need to look more closely at exactly the kinds of social interactions involved in “acting like a scientist.”

It is the interaction of all the qualities mentioned above, including social interactions, that makes science a “particular form of human endeavor” (NRC, 2000, p. xiii). There is no single, correct, manner in which to engage in scientific endeavors, scientific knowledge is not acquired merely by the implementation of strict and rigid methods. Scientists value creativity and imagination as critical aspects to all stages of their research and investigations (Wong & Hodson, 2008). Current practices in inquiry-based science education, however, do not emulate all the dimensions of scientific investigation, including those that are acknowledged as important by scientists. Perceptions of science that are perpetuated within the classroom are reflected in student perceptions of science and their understanding of what it means to “act like a scientist.” Student perceptions are presented below.
Student Perceptions of "Acting Like a Scientist":

Student perceptions of "acting like a scientist" are influenced by classroom experiences as well as portrayals that are depicted in textbooks and media (Bybee, 2006). According to Bybee, "many science textbooks...instill the notion that science proceeds as a prescribed method. The scientific method, as presented, is logical, objective, and impersonal... Textbooks leave students with the view that all of science proceeds in much the same way" (Bybee, 2006, p. 2). These views often perpetuate the stereotypical notion of scientists as men wearing white lab coats, working only within the confines of a sterile laboratory, and following rigidly established steps of "the scientific method."

Most science classrooms follow a lecture and verification laboratory exercise format; only about two percent of classroom experiences are inquiry-based and of those, most are of the teacher directed inquiry type (Flick, 1998). In such situations, student choice and creativity is often limited as students are typically expected to follow teacher directed procedural steps or adhere strictly to the linear progression of "the scientific method" (make an observation, generate a research question, establish a hypothesis, design and implement an experiment to test the hypothesis, gather and analyze data, make conclusions and report findings to others). These experiences often leave students with the perception that scientific experimentation is simply a means of proving already known scientific facts; the verification lab exercises only assess students on their ability to arrive at pre-determined results (Alouf & Bentley, 2003).
Although verification style lab experiences can hold a potentially valuable place in science education, for example when students are expected to demonstrate mastery in science content, measuring skills, or the appropriate use of tools, they become limiting when students perceive this format as the only viable option for scientific investigation. When this is the perception, as it is currently, students come to believe that science is "procedural rather than creative" (Wong & Hodson, 2008, p. 126).

Starting to Shift Our Attention:

Following rigidly prescribed procedures often reduces interactions with others; when one is specifically told what to do, there is little need to interact. Interactions with others, however, have been identified by scientists as being integral to authentically acting like a scientist (Schwartz & Lederman, 2008; Wong & Hodson, 2008; Jones, 2010). By attending to student social interactions, including student discourse, we will begin to shift our attention from the procedural steps being followed during IBS investigations to the interactions that unfold. Such a shift in attention may expose currently unrecognized influences to IBS and thus increase our understanding of IBS. Some recent research has begun to make such a shift.

A few recent studies, such as those conducted by Anderson, Zuiker, Taasoobshirazi, and Hickey (2007) and Cross, Taasoobshirazi, Hendricks, and Hickey (2008), have begun investigating the influences of student discourse and provide insight into how student engagement in scientific argumentation effects their academic success in science. In the Cross et al. (2008) study, the
researchers specifically measured each student's level of critical discourse and argumentation skills against their conceptual understanding of content material. The results of the study showed, as evidenced through a comparison of pre and post-tests as well as a final standardized exam, that achievement gains were made by students who engaged in greater levels of argumentation; students with greater participation and skill in argumentation scored higher on the post tests and final exam (Cross et al., 2008). In this study, argumentation was defined as: making claims, using data to support these claims, warranting their claims with scientific evidence, and then further justifying or changing their claims and warrants when presented with additional data. Students also use backings, rebuttals, and qualifiers to further support their reasoning as the arguments become more complex (Cross et al., 2008, p. 839). The researchers determined that a student's argumentation skills, as well as the accuracy of information included in their discourse, was influential to individual learning gains (Cross et al., 2008).

The Cross et al. (2008) study advanced our understanding of science education by revealing the importance of student discourse and argumentation skill to the development of content understanding. There were, however, several limitations to the research. The study spanned a period of only two-weeks; this short amount of time likely limited the type and quality of argumentation skills that developed among students. Potentially even more problematic, however, was that in order to assist students in developing argumentation skills, they were shown a researcher-developed cartoon video demonstrating weak and strong
argumentation qualities. This video could have influenced student discourse practices and resulted more in student mimicry of known researcher approved qualities than those of naturally occurring processes.

Some assumptions were also made by the researchers of the Cross et al. (2008) study as to why students were engaging, or not, in the scientific process. The researchers credited a student's ability and practice of speaking up and sharing their ideas with the larger group as an indication of possessing stronger argumentation skills. The researchers also hypothesized that the quality of student argumentation skills was correlated to their conceptual understanding of content as was evidenced through their test scores. (Cross et al., 2008).

Numerous other factors, however, such as classroom climate, individual achievement goals, perceived value of the activities, and self-efficacy, which have each been shown by studies conducted by Wigfield & Eccles (2000), Elliot (2005), Meece, Anderman, E., and Anderman, L., (2006), Schunk et al. (2008), Ryan & Shim (2008), and Wolters (2004), to be substantially influential on a student's motivation to engage, unknowingly may have influenced the results of the Cross et al. (2008) study. Thus, the measured student conceptual understanding of content may be a result of more complex interactions related to motivation than currently credited. Additional research that can tease out the complexities of the data will assist in more firmly grasping the effects that argumentation and critical discourse have on the interactions that take place, which in turn may impact student motivation and achievement.
The Anderson et al. (2007) study, also investigated the effects of student discourse on academic achievement and conceptual understanding. This case study examined how student participation in scientific discourse influenced students' conceptual understanding of content, as evidenced through their ability to transfer content knowledge to new scenarios, and academic achievement. Academic achievement levels were measured based on scores from curriculum-based and standardized tests. The study specifically investigated the role of critical discourse within four high school astronomy classes. Each class was given identical tasks and questions to answer; students first answered each question individually, and then got into small groups to share their individual responses and come to consensus on a group answer for each question. Each group, however, was also given an "answer rubric" that provided explanations of varying degrees of simplicity or scientific complexity for the questions. The answer rubrics ranged from a simple answer to the posed questions to offering increasingly detailed, yet age and cognitively appropriate, explanatory material. The researchers hypothesized that the more detailed answer rubrics would encourage students to engage in conceptually deeper conversations because the rubrics offered insight into material that students may not have considered. The results of this study indicated that this hypothesis was supported (Anderson et al., 2007). Although some students simply waited for the correct answers to be given to them via the answer rubrics, the majority of students who engaged in discourse consisting of greater insights and scientific information, such as that supplied by the more advanced answer rubrics, outperformed their peers on
assessment tests and reflected deeper conceptual understanding of content material as evidenced through researcher analysis of transcribed conversations (Anderson et al., 2007). This study offers insights into the potential benefits, such as academic achievement gains, that might be obtained if students are given the opportunity to engage in discourse with their peers. A gap in understanding that remains, however, is whether students would need to be given specific information to stimulate their conversations or whether they simply need time, and/or guided support, to develop their own thoughts and arguments.

These studies illustrate that discourse can be related to content understanding, but they did not assess in what manner the social interactions that emerged may have motivated certain discourse to occur which in turn may have influenced student achievement. Further research in assessing the effects of discourse on the success of students participating in inquiry-based science experiences would be helpful.

As illustrated throughout this section, “acting like a scientist” is perceived differently by scientists than the following of procedural steps often described within the community of education. Students see “acting like a scientist” as conducting hands-on investigations that follow the procedural steps of the “scientific method.” However, scientists view “acting like a scientist” to include such things as experiments, observational studies, meta-analyses, critical discourse – including arguments and debates, casual conversations, peer review, collaboration, competition, using various tools and equipment, asking questions, searching for evidence, controlling variables, analyzing data,
assessing for bias, public outreach, imagination and creativity, flexibility, lab
work, desk work, and field work. Due to such discrepancies, it was necessary for
me to enter into my research with some clear account of what I would include as
examples of acting like a scientist. I turn now to a discussion of what my study
included as indications of acting like a scientist.

**Attending to Instances of “Acting Like a Scientist” within my Research:**

Through my research, I compared daily events and student progress, as
well as ultimate outcomes, within two different approaches to the same IBS unit. I
assessed whether, and if so, why, one approach or the other led to greater gains
in student achievement and/or motivation. As IBS is currently believed to be
successful because it encourages students to “act like scientists,” it was
necessary for me to recognize examples of students “acting like scientists” within
each of the two cases. I, therefore, needed to be sensitive to any student
interactions that influenced and/or reflected “acting like a scientist”
characteristics. In order to monitor for such characteristics, I entered the research
with a clear account of what to look for as examples of these qualities. As a
starting point, I established three basic categories within which to look for
examples of students acting like scientists: students engaged in the scientific
process, students demonstrating interactive characteristics of scientists, and
students engaged in establishing a scientific community.

In the category of students engaged in the scientific process, I included
instances, or interactions, in which students engaged in investigation. This
included any part of the conception of the scientific method as discussed in the
Cross et al. (2008), Wong and Hudson (2008) studies cited above (making observations, developing questions and hypotheses, designing and implementing an experiment, analyzing data, making conclusions, and reporting findings to others), or literature reviews, or students learning how to use equipment. These observations, however, were restricted to those that were relevant to student research projects. For example, I included students making various observations that were then discussed with their peers as part of their project. I excluded, however, students simply observing their surroundings without comment to peers, or observations and comments that were seemingly unrelated to specific projects. For example, if a student's project took place in the woods at the nature reserve, I would include student comments about observations relevant to the woods, but not comments such as noticing that the tide had gone out. I remained open to the possibility that I may have initially dismissed a comment that I later realized had greater relevance to the students project than I first thought. Video recording as much student interaction as possible provided an invaluable data source that allowed me to go back and revisit, and reassess, particular events and comments.

I also included instances of students using equipment that was available to them in a manner that was helpful to their research. For example, if students used binoculars to view birds in the distance, I counted that as acting like a scientist because it reflected students carrying out observations. I excluded, however, students simply carrying a pair of binoculars with them, or staring at each other through the binoculars.
In terms of students demonstrating characteristics of scientists, I included instances of students engaged in peer review, offering feedback, questioning, or debating aspects of their projects such as ideas, methods of data collection, meaning of data, or ways to share their project with others. I was particularly sensitive to any student behaviors and/or comments that seemed to stimulate, or dampen, motivation as well as any perception of acting like a scientist that may have sustained or altered behavior and/or activity among the students. For example, I included instances of student discussions about how to proceed with their projects, or any evidence of reasoning in which the students were engaged. I included signs of competition that were relevant to the student research projects. For example, I included instances of students wanting to be the ones to make the most observations or to be first to gain access to a particular piece of equipment. I excluded signs of competition, however, that seemed to stem from a desire that was not relevant to their research; an example was students wanting to be first to get their computers put away so they could be the first to get to lunch. I attempted to identify distinguishing features between scientifically related social interactions and more casual social interactions. Admittedly, there was considerable overlap between these categories. For instance, it was difficult to distinguish whether casual social interactions led to a sense of community that subsequently established the support network for students to be successful with their scientific investigations or whether the collaborations within their investigations led to the development of the scientific community. I looked for evidence of the distinctions between categories as well as what impact those
differences may have had on outcomes. Student journal reflections, as well as formal and informal interviews with students, assisted me in identifying such distinguishing characteristics.

In terms of establishing a community, I included instances of student behaviors and/or comments that either encouraged or discouraged collaboration, creativity, and imagination. I focused on these three aspects because they were each identified by the scientists in the Wong and Hodson (2008) study as being an important component of acting like a scientist. In order to assess these aspects, I took note of the types of discourse that were relevant to student projects, such as discussions about equipment, heated debates, or arguments, which emerged within each case. I looked for behaviors/comments that seemed to influence, or were reflective of, student creativity and imagination. I looked for ways in which the community that was established in each case may have influenced student motivation and achievement. I looked for instances in which student interactions influenced the sense of community within each case. For example, a group of students sharing resources with another group was included in my observations. I took note of how the collective group of students interacted with each other in each case and noted any influences such interaction seemed to have on the sense of community that developed. Observations included whether students interacted with students in other project groups, whether students assisted other groups, or interactions that seemed to sustain or transform behaviors and group cohesiveness.
Concluding Thoughts About Current Practices in Inquiry-based Science:

Our current understanding of inquiry-based science lessons touts the “hands-on” and “acting like a scientist” qualities of such lessons as the explanation for their success. Crediting these characteristics, as currently interpreted and implemented, as the reason for the successes seen in IBS provides an incomplete explanation. It is quite possible that other contributing factors, such as the social interactions that develop during these experiences, also have a substantial influence on the outcomes of these lessons. Ignoring other possible explanations for success leaves our current understanding of inquiry-based science deficient; the full educational potential of these experiences may, therefore, not yet be realized. Shifting our attention to include other dynamics inherent in these experiences, such as social interactions, may bolster our overall understanding of IBS as well as the ability of educators to develop more effective inquiry-based science lessons. Such an understanding of inquiry-based science could augment the existing level of student motivation and achievement in science.

Student social interactions have been shown to be influential in research, such as that conducted by Berndt and Keefe (1996) and Wentzel, Barry, and Caldwell (2004), to student academic achievements. Understanding how social interactions can influence individual and group behavior, as well as group dynamics and an individual's attitude and willingness to engage in activity, is beneficial to understanding how such influences may impact IBS experiences and their outcomes. I therefore turn now to a discussion about how social
interactions have been shown to be influential to academic and motivation outcomes.

**Social Interactions: Peer-Peer Relations**

Research, such as that described in this section, illustrates that children of all ages can be influenced, both positively and negatively, by the behaviors and attitudes of their friends (Berndt & Keefe, 1996). For example, having reciprocated friendships in school can lead to students who are “more sociable, cooperative, self-confident, independent, emotionally supportive, altruistic, prosocial, and less aggressive than those who do not have such friendships” (Wentzel et al., 2004, p. 195). As students transition into adolescence, and as they respond to the corresponding developmental increase in, or longing for, independence, children begin to rely more heavily on their peers for support and are thus potentially more influenced by peer behaviors (Wentzel et al., 2004).

Research in attachment theory has shown that emotional attachments to others foster a sense of well being and belonging which, in turn, fosters adaptive behaviors leading to academic and social achievement (Wentzel et al., 2004).

One study providing evidence that reciprocated friendships foster prosocial behavior and lead to greater academic achievements was conducted by Wentzel and Caldwell (1997). This study investigated whether reciprocated friendships, peer acceptance, and group belonging could be related to academic achievement (Wentzel & Caldwell, 1997). In this study, 213 sixth grade students from a mid-western, working class community were followed through the end of
their eighth grade year; this two-year time span constituted the duration of their middle school experience. Participants were selected by the principal in order to reflect a range of academic ability levels. In order to identify reciprocated friendships, researchers distributed class lists to students; each student received a class list containing only the names of their same sex classmates. Students were asked to identify three classmates from the list that they considered to be their closest friends. Researchers then compared student lists in order to identify reciprocated friendships. One issue with this method of identifying reciprocated friendships, however, may have influenced the results; by asking students to identify three of their best friends from a class list containing only the names of their same gender classmates, researchers may have inadvertently eliminated the names of some student's actual best friends. Based on observations from my own teaching experience, it is quite possible that some students, including - but not limited to - gay or lesbian students, may have been given lists that did not contain the names of any of their closest friends. I have witnessed boys and girls at the middle school level develop stronger friendships with members of the opposite sex than with members of the same sex. Such students within this study would not have been able to circle the names of the students that they actually felt were their closest friends. Admittedly, the percentages of such students could have been small, and perhaps would not have changed the results of the study in any significant manner; it is, however, a point worthy of consideration.

In order to assess peer acceptance within this study, three peer relationship variables, reciprocated friendships, peer acceptance, and group
belonging, were measured against student academic achievements. Academic achievement scores were determined by each student’s cumulative grade-point average (GPA) for their grades in math, science, social studies, and English (Wentzel & Caldwell, 1997). The results of the study, which were determined through univariate and covariant analyses, indicated that significant relationships existed between all three peer relationship variables and academic achievement (Wentzel & Caldwell, 1997). There was some variation between results based on gender. Specifically, in 6th grade, peer acceptance and reciprocated friendships were more predictive of GPA for boys, whereas peer acceptance and group membership were more predictive of GPA for girls. The study also revealed that the three peer relationship variables were significant predictors of GPA through 8th grade (Wentzel & Caldwell, 1997).

This study adds to our understanding of potential peer influences on academic achievement levels by identifying three significant predictors (reciprocated friendships, peer acceptance, and group belonging) of GPA that persist over time. The study reveals that student interactions can, and do, influence overall achievement levels. Although the study identifies factors that influence GPA, it does not offer insight into how the influences manifest themselves on a daily basis. This study, through its illustration of how social interactions unveiled by friendship, peer acceptance, and being part of a group, can positively influence, and be predictors of, educational outcomes, exposes a potential gap in our understanding of IBS. These predictors of student achievement may play a substantial, and as yet relatively unexplored, role in the
positive outcomes witnessed from inquiry-based science experiences.

Understanding these predictors in relation to IBS may reveal insights into how to more predictably, and consistently, achieve positive gains through IBS.

As a follow up to the above study, Wentzel et al. (2004) conducted a study to investigate whether the results of the above study could be replicated and to determine whether factors such as pro and/or anti-social behavior, as well as emotional distress, could assist in explaining obtained results. This two-year study investigated how adolescent friendships and individual levels of emotional distress related to adjustment at the middle school level. A strength of this study is that it investigated, and added to existing literature, the possible longitudinal effects that social behavior and emotional stress had on student friendships and academic outcomes over time. As in the first study, the researchers defined friendship as being a mutually reciprocated relationship that both parties would acknowledge. They defined school adjustment in terms of prosocial behaviors and academic achievement scores (Wentzel et al., 2004). The researchers focused particularly on how a student’s emotional distress related to the student’s friendship status, level of prosocial behavior, and academic outcomes; measures of prosocial behaviors and academic achievements were the determinants of this study (Wentzel et al., 2004).

Participants included 242 students in grades 6-8 from a middle school centrally located on the east coast of the US. Measurements included reciprocated friendships, prosocial behavior, efforts to be prosocial, academic performance, efforts to learn, and emotional distress (Wentzel et al., 2004). In
order to identify reciprocated friendships that persisted throughout the two-year study, researchers asked students to identify three students in class they considered to be their best friends; this was done at the end of both 6th and 8th grade. As in the first study, students were given class lists with names of only their same gender peers from which to select their best friends; students whose best friend selections matched were considered reciprocal friends. Prosocial behavior was rated based on student and teacher nominations from class lists. Sixth grade students were asked to identify, by circling classmate names, which of their peers they would identify as being the most cooperative, helpful, and best at sharing; the prosocial behavior of sixth grade students was then ranked based on the student nomination results. Teachers of the 8th grade students were asked to rank each student on a 5-point scale for their demonstrated level of cooperativeness, consideration of others, and helpfulness towards others. Academic performance was assessed, as in the first study, from each student’s cumulative GPA from the four core subjects (math, science, English, and social studies). Emotional distress of students was assessed, in both 6th and 8th grades, through the self-reported Weinberger Adjustment Inventory-short form (Wentzel et al., 2004).

The results of this study, as revealed through analyses of variance calculations, indicated that students possessing reciprocated friendships scored significantly higher on measures of academic performance and prosocial behavior, as well as significantly lower on measures of emotional distress than their peers without reciprocated friendships (Wentzel et al., 2004). Emotional
distress increased over time for students without reciprocated friendships. Emotional distress, however, could not be directly linked to academic achievement over time; the researchers speculated that this was possibly due to student compensatory behaviors such as studying harder or forming relationships with teachers. The results of a regression analysis did reveal that prosocial behavior increased over time for those students who had friends in 6th grade that were considered more prosocial than themselves and that prosocial behavior decreased over time for students who had friends in 6th grade that were considered less prosocial than themselves (Wentzel et al., 2004).

The results of this research are useful in trying to understand the possible relation that student interactions may have with achievement and motivation. One drawback to this study is that it only assessed the influence of reciprocated friendships on student outcomes; there are far more interactions within a classroom, however, than those limited to reciprocated friendships. The entire peer network may have had an influence on the outcomes of the study. Understanding how the existing peer network influences outcomes may further our understanding of why some experiences, such as those within IBS, lead to gains in student achievement and motivation. Additionally, understanding how the level of emotional distress interfaces with student interactions and thus possible friendships may reveal triggers to student behavior that are currently overlooked. This study measured emotional distress levels, but not what effect, if any, those levels seemed to have on the daily interactions with peers and thus the development, or disintegration, of reciprocal friendships and/or behaviors. It
is quite possible that student emotions have motivational significance on behaviors (Graham, 1996). Understanding this significance may offer insight into best educational practices, including those for IBS.

Attending to Social Interactions within my Research:

Social interactions, however, are ubiquitous in everyday life (Gauvain, 2001). Social interactions play themselves out in an abundance of styles including verbal, non-verbal, physical, and written. Some interactions are overt and some are subtle. Social interactions can stimulate numerous types of exchanges between individuals and groups such as: cooperative, competitive, antagonistic, empathetic, playful, loving, nurturing, accommodating, belittling, hostile, supportive, and non-supportive (CSR, 1997; p. 23). Of particular importance to my research is the fact that the types of social interactions that prevail, or dominate, in a particular environment, such as a classroom, are set in motion by individual self-efficacy levels, achievement goals, and the perceptions of what is required for success within a particular environment (Ryan & Shim, 2008). Social interactions establish, and reflect, the goals and attitudes of a community of learners (Wolters, 2004).

Because social interactions were a focus of my research, and because it was not realistically possible to attend to every social interaction that took place, I had to specify the types of interactions to which I would be most attentive. My research question, in order to be answered, required an understanding of whether, and if so how, social interactions may be related to student motivation and achievement in science. I, therefore, was particularly sensitive to any student
interactions that seemed to influence student progress in, and motivation concerning, the class and/or student projects. Therefore, any verbal or physical exchange between individuals that seemed to perpetuate, alter, or hinder student progress and/or motivation was included in my observations. I looked for exchanges that were cooperative or detrimental to student progress. I excluded exceedingly common exchanges, such as one student lending a pencil to another or one student simply taking a pencil from another, unless they seemed to have some greater meaning to the given situation.

I also included exchanges that seemed relevant to student projects, content material, attitudes towards science, or to the feelings of group members. Verbal exchanges to which I attended included, but were not limited to, comments that revealed student perceptions of the process they experienced, their understanding of the nature of science or what it means to act like a scientist, anything indicative of student emotional states, and anything about grades or judgments of success. Any verbal comments that lent insight into student perceptions of how they thought/felt about how they were doing in science and/or on their project, as well as those that lent insight into student perceptions of task value were also noted. Casual conversations, such as discussing an upcoming school dance or an upcoming surfing trip, were largely excluded unless they seemed to be pertinent to student motivation and/or achievement. Exchanges that offered insights into student emotions during the project were noted. For example, certain student declarations, such as "I hate this," "this is fun," or "why do we have to do this," were included. Excluded
comments included things like “I was so mad at my mother this morning” and “I’m psyched to go surfing tomorrow.” Although I excluded such comments as just described, I remained attentive to the possibility that they may have been indicative of affiliative attachment to group members that may be influential to the student’s sense of community, which may have ultimately influenced student achievement and motivation.

Physical exchanges that are typical of adolescents, such as nudging each other, grabbing pencils from each other, or taking each others food, were largely ignored – unless they seemed to be particularly relevant to a particular instance/situation, provided insights into future student attitudes or actions, or were believed to arise from bullying intentions. Physical exchanges to which I attended included students physically supporting each other or equipment in order to set up their projects, or anything physical that seemed to change the mood or attitude of another student, such as forcefully shoving or knocking something over, as such gestures may have influenced the future involvement of some students. I also remained open to the possibility that some behaviors and/or comments that I initially dismissed may, over time, become recognized as patterned behavior or of more importance than originally believed. Reviewing digitally recorded videotapes assisted in recognizing such patterns that were then included in my analysis.

The research discussed throughout this section illustrates the potential influences of peers on achievement and motivation. Reciprocated friendships, such as those discussed above, as well as peer interactions in general, elicit
interactions that are largely dependent on the behaviors, emotions, and goals that each individual brings to each situation. In order to develop an understanding of the complexity of each situation, it is necessary to understand elements of motivational theory. Because I aimed to better understand the ways in which IBS lessons may relate to motivation and achievements at the individual level, I conducted my research through a social cognitive lens. A discussion follows of Social-Cognitive theory and how Expectancy-Value theory of motivation, and its social-cognitive perspective, was used to inform my research.

A Social Cognitive Stance to my Research

Throughout my research, I looked at social interactions from a social cognitive perspective. I took this stance because of my desire to understand the relational experiences of students within specific contexts. According to Social Cognitive Theory, an individual's actions and achievements are influenced by contextual and relational experiences that exist within "a network of reciprocally interacting influences" (Bandura, 1989, p. 8). Social cognitive theory "favors a model of causation involving triadic reciprocal determinism. In this model of reciprocal causation, behavior, cognition and other personal factors, and environmental influences all operate as interacting determinants that influence each other bidirectionally" (Bandura, 1989, p. 2). Personal, behavioral, and situational factors are influential and interact with differing intensity under different contexts. The figure below illustrates Bandura's interpretation of the bidirectional influence of the three factors (see Figure 2).
Social cognitive theory claims that people are not solely driven by internal or external factors, but rather are driven by the interplay between the various forces under differing circumstances. In this model, the link between person and behavior represents the interplay between ones thoughts and affect, cognition, and behaviors (Bandura, 1989). In this bidirectional interplay, ones thoughts and feelings influence ones behavior, and the expected results of behavior influence thoughts and feelings. The actions, emotions, and emotional reactions that an individual elicits may have substantial influence in this interplay. My research was attentive to the interactions, and the emotions that were elicited, during student experiences within two approaches to IBS.

The interplay between the situation, or the environment, and the person reflects the tension that exists between how one perceives themselves and the situation and their ability to be successful, and feel safe, within that situation. Contextual and social influences of others in the situation become particularly meaningful in this interplay (Bandura, 1989). My research was also attentive to variations in social interactions that may have been due to contextual situations.
Finally, the link between the situation and behavior reflects the influences that each bestows upon the other. This interplay accentuates the fact that individuals are "both products and producers" of their environment (Bandura, 1989, p. 4). As shown through motivation theory, in particular expectancy-value theory (which is discussed in the next section), students are more likely to engage in activities in which they feel likely to be successful, when the tasks are personally meaningful, contain appropriate challenge levels, and elicit personal interest. Activities that are offered by teachers and created by students can be particularly influential in this interplay. My research was, therefore, attentive to variations in student perceptions of available opportunities, student expectancies to be successful, as well as the value students placed on the activities and opportunities that arose within each approach to IBS.

The "triangle of influence" sketched by Bandura is supported by, and relevant to, motivation theory as well as the intended goals of inquiry-based science instruction. As stated previously, one expected outcome of the current progression within IBS is that as students move into teacher-guided and open inquiry experiences they will become more intrinsically motivated because they have opportunity to make decisions and take ownership of their experiences (NRC, 2000). Motivation theory has shown that an individual's intrinsic motivation, that is often spawned by ones expectancy to be successful at a particular task, and the personal value they place on that task can be related to their willingness to engage in the task. Motivation has been related to student achievement levels. A social-cognitive perspective supported a focused
exploration of influences aligned with motivation theory and inquiry-based
science goals that determine how individuals perceive the experience of inquiry-
based science. I investigated the social interactions that took place within two
approaches to IBS and looked, through a social-cognitive lens, for evidence of
motivation and achievement within each approach. Because I approached this
research from a social cognitive stance, because expectancy-value theories
reflect a social-cognitive perspective of motivation, and because contextual
situations and student perceptions of choice and control are influential on the
value and intrinsic interest students place on experiences, my research focused
on expectancy-value measures of motivation. I turn now to a discussion of
motivation as it relates to expectancy-value theory.

Motivation: Expectancy-Value Theory and IBS

Contemporary views of motivation assert that there are motivational
processes that construct behaviors (Wigfield & Eccles, 2000). It is generally
accepted that motivation results from the complex interactions of individual
thoughts such as perceived task value, individual social and achievement goals,
as well as individual beliefs (Wigfield & Eccles, 2000; Schunk et al., 2008).
Motivation can influence outcomes and, in turn, outcomes, or potential outcomes,
can influence motivation. Motivation has been defined as “the process whereby
good-directed activity is instigated and sustained” (Schunk et al., 2008, p. 378). It
is this definition of motivation that I assumed throughout my research.
Student motivation levels are influenced by an individual's judgment of task and expectancy values (Schunk et al., 2008). Measures of expectancy assess the level to which students expect to be capable of performing a particular task with success (Wigfield & Eccles, 2000). Individuals are more likely to engage in tasks in which they feel confident they can succeed; contextual situations can influence student perceptions of their abilities to be successful. Task value refers to the personal value an individual places on a particular task and is related to one's perseverance on that task (Schunk et al., 2008). Measures of value assess the intrinsic, attainment, utility, and cost values individuals associate with engaging in a particular activity. Intrinsic value is considered to be the level of personal interest, or the sense of joy and excitement that arises from engaging in a particular activity, that an individual places on a task. Attainment value refers to the importance an individual places on doing well on a particular task. Attainment values may include such things as striving for good grades in order to increase ones chances of getting into college, or working hard to increase the possibility of getting a better job. Utility value refers to the personal benefit, and usefulness, an individual assigns to a task (Schunk et al., 2008). Finally, cost value refers to a measure of how much effort will need to be expended in order to complete a task and the degree to which this effort might limit engagement in other, more desirable, activities (Schunk et al., 2008). Each of the values that an individual places on a task can be related to ones perseverance on the task (Schunk et al., 2008). Research, such as that described below conducted by Meece et al. (2006) and Berndt and Miller (1990),
has documented that both expectancy and task values have substantial influence on ones motivation to engage and each are predictors of subsequent student behavior, as well as task persistence and achievement levels (Schunk et al., 2008).

The results of the studies described next reflect the claim put forth by Schunk et al. (2008) that “expectancy beliefs are more closely tied to actual achievement and cognitive engagement but value beliefs are more better linked to choice behaviors that provide the student with the opportunity to achieve in the future” (p. 55). Expectancy-value theory has illustrated that individual expectancies of success and values individuals assign to activities and tasks can be influential on an individual’s behavior, emotions and subsequent actions, as well as achievement. The social interactions that develop and take place, including during IBS activities, are influenced by the emotions, individual expectancies of success, and the values that are assigned by students to the activities and tasks. The interactions that take place during IBS activities may be of paramount importance to the values that students assign to IBS experiences and may reveal insights into student expectancies for success within IBS. Interactions taking place between students during IBS lessons, and the contextual situations within which those interactions occur, are thus worthy of closer examination.

Emotions and value assessments have been shown to be influential on student performance (Meece, Wigfield, and Eccles, 1990). For example, a study conducted by Meece et al. (1990) investigated the possible influence that student
ability and performance perceptions, as well as the student's overall value perceptions of math, might have on student anxiety levels regarding math. This study was part of a longitudinal, two-year, study designed to investigate variables in motivation that influenced student decisions to enroll in future, more advanced, math classes. Participants of this study included 250 students in grades 7-9. In the first part of the study, researchers tested whether math anxiety would be negatively related to student expectancy values regarding doing well in the course. In addition, this part of the study investigated whether student's overall value perceptions of math would be predictive of their anxiety levels. The second part of the study investigated longitudinal effects of prior math grades and ability perceptions to student expectancy values in math. The researchers investigated the influences that student expectancy, value, and math anxiety levels would have on student decisions to enroll in additional math courses (Meece et al., 1990).

The researchers assessed student attitudes towards math through the results of the Student Attitude Questionnaire that was completed by participants. Items on this questionnaire measured "student expectancies for success, perceived values, perceived ability, perceived effort, and perceived task difficulty" in math (Meece et al., 1990, p. 63). Participants also completed a nineteen-item questionnaire designed to measure student anxiety levels towards math. Finally, math achievement was assessed through grades in the student's current and previous math classes (Meece et al., 1990).
Statistical analysis of the results revealed that strong negative correlations existed between math anxiety levels and student perceptions of ability in math, expectancy to do well in math, and value perceptions of math; students who held positive expectations regarding math revealed less anxiety towards math. The results also indicated that expectancy levels to perform well in math were predictive of final math grades and that student value perceptions of math were predictive of their likeliness to enroll in subsequent math classes (Meece et al., 1990).

Berndt and Miller (1990) also investigated how student perceptions influenced academic outcomes. In their study, the researchers assessed the relative contributions of expectancy and value to the academic achievements of junior high students. Participants included 153 junior high school seventh graders. A variety of measures were used to assess each student's motivation to be academically successful. Overall student achievement levels in math and English were obtained from teacher rank books; all other measures were obtained from questionnaires completed by the students. To assess levels of student involvement to their schoolwork, students were given a modified version of the Classroom Environment Scale; modifications included altering the language in the questions from inquiring about classmates' behavior to inquiring about student's personal behavior (Berndt & Miller, 1990). Student's assessment of school value was measured through questions about their sense of utility of material learned in school, how important being successful was to students, and their overall interest level in school. Student perceptions of academic ability were
measured through student responses on the Self-Perception Profile for Children questionnaire. Finally, students assigned attributions, such as intelligence, effort, studying, interest, or external influences, to their academic success and/or struggles in school (Berndt & Miller, 1990).

The results revealed that a student's level of school involvement, the tendency to place value on schoolwork, and attributing success or failure to effort or interest rather than ability were strongly correlated to academic achievement. Student perceptions of their academic ability and their attribution of success to ability were strongly correlated to a student's expectation of success. Results also indicated that academic achievement was more strongly correlated to expectancy than to value (Berndt & Miller, 1990). The researchers used a linear structural relations analysis program, LISREL VI, to assess the relative contributions of expectancy and value to academic achievement. The results of this analysis confirmed that student achievement was more strongly correlated to an expectation of success than to the value placed on being successful. Expectancy and value were both significantly related to achievement and were positively correlated to each other (Berndt & Miller, 1990).

The research described thus far has illustrated that properly scaffolded student experiences with IBS can lead to increased academic achievement and motivation in science, that student emotion and sense of reciprocated friendships, as well as levels of expectancy for success and value placed on particular tasks can influence achievement and motivation outcomes. Other aspects, such as place or location, have also been shown to influence
educational outcomes (Membiela et al., 2011). Because part of my research, in particular the implementation phase of the student generated research projects, was conducted in two different locations, it was necessary to take into consideration how the contextual situation and a student's sense of place might influence the results.

**Place-Based Education:**

Student interests in, and value beliefs about, educational content material and activities have been shown, as described throughout this dissertation, to be considerably influential on student motivation and achievement. The context in which lessons and activities occur has been shown to be influential on outcomes (Lattimer & Riordan, 2011). Place-based education uses the environment to forge meaningful connections between students and their learning, particularly when learning environments include local community areas. Place-based education has been defined as the process of using the local community and environment as a starting point to teach concepts in language arts, mathematics, social studies, science and other subjects across the curriculum. Emphasizing hands-on, real-world experiences, this approach to education increases academic achievement, helps students develop stronger ties to their community, enhances students' appreciation for the natural world, and creates a heightened commitment to serving as active, contributing citizens (Sobel, 2005, p. 7).
One group of my research participants conducted their inquiry entirely within school grounds, while the other group had the experience of visiting a local nature reserve. Both locations presented place-based experiences. The class on school grounds afforded students an opportunity to more closely examine their connections with, and increase their awareness of this familiar space. The off-campus class afforded students an opportunity to develop connections with a less familiar space. Aspects of newness, or adventure, that may have been perceived by these participants, may have heightened the sense of place established by the off-campus group of students. Because of the differences in physical location, I was particularly diligent about watching for any signs that indicated the environment was influential on student activities and learning. As will be discussed later in this dissertation, aspects of place led to differences between the two cases.

**Summary of the Literature Review**

My research advances our current understanding of inquiry-based science by focusing on the social interactions that take place between students as they experience IBS lessons. The study advances our current interpretation of “acting like a scientist,” which is typically reduced to providing hands-on activities and having students follow the procedural steps of the scientific method, by including, and evaluating, the potential relation and significance that social interactions have on motivation and achievement outcomes of IBS experiences.
Many previous studies have shown that inquiry-based science experiences increase student achievements in, and motivation towards, science. It is quite possible, however, that IBS as typically implemented, has not yet been allowed to reach its fullest potential. The success seen in IBS may be due to more than the hands-on manipulation of materials and opportunities for students to follow procedural steps of scientific investigation. Through this literature review, I have argued that our currently accepted view of acting like a scientist, one that we emulate in science class and point to as the reasoning for IBS success, is inadequate. In order to claim that success is due to “acting like scientists,” we must allow students to engage in more authentic experiences of “acting like scientists;” this includes fostering, and being attentive to, the social interactions and critical discourse that takes place between and among students engaging in science investigations. My study compared two IBS experiences; one that was reflective of typically implemented IBS lessons taking place within regularly scheduled class time and one that provided extended contact time for student interaction. This study evaluated which types of social interactions, if any, had an impact on student success and motivation as well as why these interactions were potentially significant.

Motivation theory, specifically Expectancy-Value theory, was used to guide this investigation. In order to understand the influences of social interactions on student achievement and motivation, I needed to be attentive to student task-value assessments and the behaviors and emotions that they elicited. A social cognitive stance, which claims that individuals are largely
responsible for creating their contextual situations, was consistent with my interest in discovering the achievements and motivation levels that surfaced during two approaches to IBS. A social cognitive perspective positioned me to remain attentive to the interplay between the personal, behavioral, and situational aspects of the two IBS experiences that were investigated. This perspective asserts that motivation and behavior arises from within the individual. The factors calling for attention in social cognitive theory integrate seamlessly with Expectancy-Value theory and the goals of inquiry-based science.

My research aimed to investigate whether a more comprehensive understanding of the effects of social interactions taking place during inquiry-based science lessons could expose a more comprehensive understanding of the success seen in IBS. With a more comprehensive understanding of IBS, teachers would be able to design and implement lessons which could potentially show even greater gains in student success in, and motivation towards, science.

This qualitative research project was conducted as a case study using an ethnographic approach. Specifically, I used participant observation techniques in order to situate myself in a position to observe, and notice, the complexities of the situation. The compilation of my own observations, transcriptions and coding from formal and informal interviews with participants, and the collection and assessment of artifacts allowed me to evaluate the complexities of each situation. The specific research question asked was:

"Within two approaches to inquiry-based science lessons, how do student social interactions relate to motivation and achievement?"
The answer to this research question has substantial implications for the development, and implementation, of future IBS lessons and could influence students overall success and motivation in science. A detailed description of my research procedure is included in the following "Methodology" chapter.
CHAPTER 3

METHODOLOGY

Inquiry-based science (IBS) has been long touted as a successful instructional strategy that, if scaffolded properly, can increase student achievement and motivation in science. Numerous studies, such as those discussed in Chapter Two conducted by Basaga et al. (1994), Chang & Song-Ling (1998), and Marx et al. (2004), have provided evidence to support this claim. The research conducted to date is ripe with explanations of IBS being successful because it provides students with hands-on experiences and opportunities to act like scientists. However, I have argued that our current interpretation of what it means to act like a scientist eclipses other possible factors influential to the success of IBS, such as student social interactions, and leaves our current understanding of IBS deficient. In an effort to develop a more comprehensive understanding of why IBS lessons are successful, my research investigated whether student social interactions that emerge during IBS lessons could be related to motivation and achievement outcomes.

Student social interactions have been found to be influential on student academic achievements in research such as that conducted by Berndt and Keefe (1996) and Wentzel et al. (2004), but has not yet been extensively investigated in
direct relation to student experiences with IBS. Social interactions may be verbal, non-verbal, physical, or written and may unfold as cooperative, competitive, antagonistic, empathetic, accommodating, belittling, hostile, or supportive, exchanges. Throughout my research, I was particularly attentive to the social interactions that appeared to dominate a contextual situation as well as to those that triggered, perpetuated, altered, or hindered student progress and/or motivation as they navigated their experiences.

My research was conducted as a qualitative case study, made up of two cases, using an ethnographic approach. Specifically, the research question asked was:

"Within two approaches to inquiry-based science, how do student social interactions relate to student motivation and achievement?"

Qualitative research inherently encourages the researcher to "problemitize phenomena to reveal their complexity" and to search for other conceivable explanations for things that are thought to be currently understood (Schram, 2006; p. 24). In this research, I problemitized inquiry-based science by offering two contextually different approaches to the same inquiry-based science unit; I therefore assumed a qualitative stance to my research.

An ethnographic approach to this research positioned me to uncover and identify other feasible explanations that factor into the overall success of IBS. Ethnographic methods situate understanding of events and interactions within specific time and place and draw attention to ordinary, as well as unique, circumstances (Wolcott, 1999). According to Emerson, Fretz, and Shaw (1995),
"ethnographic field research involves the study of groups and people as they go about their everyday lives" (p. 1). I studied student social interactions as they went about their daily experiences with an IBS unit. An ethnographic approach allowed me to focus on, and assess, the interplay between context and meaning that was derived within each individual case. Specifically, I used ethnographic techniques of participant observation.

Participant observation requires the researcher to "observe as much as they can themselves, ask others for their observations, study the records of what has happened and gather artifacts of those happenings" (Stake, 2006; p. 27). In order to develop a detailed understanding of each of my two cases, I situated myself within, and become aware of, the complex dynamics within the contexts of each particular case. I was present in the field so that events, including unanticipated events, got noticed. My immersion in the field facilitated my ability to look for developing circumstances and patterns, those that were common to both cases as well as those that were unique to each case. I examined and evaluated multiple levels of understanding as revealed through multiple data sources. Data was collected, and analyzed, from sources that included my field notes, formal and informal interviews with students, video and audio recordings, as well as from student generated artifacts such as student journals and curriculum assignments.

The two approaches to IBS within my study created "specific and bounded (in time and place) instances of a phenomenon selected for study" (Schwandt, 2007; p. 27). Each case was represented by a different contextual approach, and
each was bounded within a specific space and time, which made it appropriate to
conduct this research as a case study (Schram, 2006). One case, which I called
the “On-Campus” case, included an instructional approach that was bound within
a science classroom and the corresponding school grounds for student-
generated research projects. The second case, which I called the “Off-Campus”
case, included the same instructional approach, of the same curriculum, that was
bound within the same science unit but with the addition of an off campus field
location for the student-generated research projects. Students in the Off-Campus
case were taken to a field location removed from school grounds in order to
facilitate the development of student social interactions in a less interruptive
environment than would typically be experienced in school settings, such as
interruptions from fire drills, interactions with other students during lunches,
recess, hallway exchanges, intercom announcements, as well as other students
and teachers going in and out of their workspace as other classes within the
building went about their day. In order to assess the influences of social
interactions, an environment in which social interactions could develop without
such interruption accommodated my ability to witness the interactions that
emerged and their influences on motivation and achievement. The two cases
allowed me to examine the possible impacts of social interactions to IBS
outcomes. In order to recognize contextual nuances and to ultimately create
accurate case profiles, I was present in the field, on a daily basis, to observe the
overt, as well as subtle, aspects of each case. Ethnographic techniques
facilitated my understanding of each individual case and informed the
development of individual case profiles. The case profiles were integral to the analysis of the particularistic circumstances within each case and for developing an understanding of the complexities within each contextual situation.

**The Specific Research Question and Sub-Questions**

This project had one overarching research question and five supporting topical questions. Each supporting topical question was further broken into sub-topical questions; these sub-topical questions were deliberately crafted to assist me in gaining access to data that would support an ability to answer the main research question. As a reminder, the Main Research Question was:

"**Within two approaches to inquiry-based science, how do student social interactions relate to student motivation and achievement?**"

I used recommendations gleaned from Gee’s *An Introduction to Discourse Analysis* (Gee, 2005) to develop my topical and sub-topical questions; these questions are listed below, beginning on page 109. According to Gee, discourse analysis is an analytic framework that can be used by researchers to inform and guide their inquiries in order to gain access to specific types of data (Gee, 2005). In order to understand the complexities of a phenomenon, such as inquiry-based science, it is necessary to understand all aspects, verbal and non-verbal, of the phenomenon (Gee, 2005). As stated by Gee, it is “not enough to just get the words ‘right’... it is also necessary to get one’s body, clothes, gestures, actions, interactions, symbols, tools, technologies, values, attitudes, beliefs, and emotions ‘right,’ as well, and all at the ‘right’ places and times” (Gee, 2005; p. 7). Although
each of these aspects may factor into the contextual meaning of any given situation, depending on the specific question(s) being asked by a researcher, data from various aspects, or combinations of aspects, may be more meaningful, necessary, or appropriate for answering certain questions. Gee identified seven categories that are influential to understanding the constructed meaning of any situation: significance, activities, identities, relationships, politics, connections, and sign systems and knowledge (Gee, 2005). Gee developed a question framework within each category to assist researchers in targeting appropriate points of entry to the necessary data for answering their specific research question(s) (Gee, 2005).

Although all seven of Gee's categories were relevant to my research question, I isolated four, relationships, significance, activity, and identity, that I felt were the most relevant, and thus the most helpful, in answering my research question. These four categories, with their emphasis on contextual situations, activities, and social interactions were the most directly connected to my specific research question as well as the social cognitive stance to my research. Had I taken a social cultural stance, and needed to understand how social goods, such as power, influenced individual access to materials and learning, the other three may have been a primary focus. I remained open to the possibility that the initially excluded categories may emerge as more relevant than expected as I navigated through my research. My coding methods helped ensure that I captured emergent categories and themes; I used emerging categories and themes to reassess the appropriateness of the selected categories from Gee.
Before I specify the topical and sub-topical questions that I developed for this project, I wish to provide an explanation for how Gee interprets the four categories I selected and how I saw them informing my research. According to Gee, any situation involving people contains a relationship component. Gee's relationship category includes "relationships that people involved enact and contract with each other and recognize as operative and consequential" (Gee, 2005; p. 111). Because I investigated the social interactions that took place in each case, investigating the relationships that existed between students was a substantial part of my research. The interactions that existed, the responses to those interactions, as well as the consequences of those interactions were influential to student motivation and/or achievement. Recognizing what types of relationships were in effect, how they were sustained and/or transformed, as well as the significance of those relationships, was a necessary focus of my research.

Significance, according to Gee, establishes the situated meaning of words, events, places, people, and artifacts; it reveals "how and what different things mean- the sorts of meaning and significance they are given" (Gee, 2005; p. 110). Building the significance of the situation includes assessing the values participants place on the various aspects of the situation (Gee, 2005). In order to develop an understanding of the relation that social interactions may have had with motivation and/or achievement, I needed to understand the value and significance the participants placed on the activities and interchanges that occurred within each case. The perception of ones ability to be successful, as well as the intrinsic, attainment, utility, and cost values that participants assign to
various actions, events, and tasks, may influence their interactions, willingness and motivation to engage, as well as their overall achievement (Schunk et al., 2008). For example, a student that has more personal interest in the topic of their investigation may be more likely to find the experience meaningful and thus invest greater effort, interaction, and perseverance in the tasks (Schunk et al., 2008). Understanding the significance that participants assigned to various aspects of their IBS experience was, therefore, critical to understanding whether the social interactions that emerged could be related to motivation and/or achievement outcomes.

Participants in any given situation also take on various identities throughout their experience; the identities that develop can be influential on the outcomes of the situation (Gee, 2005). Gee's identity category includes "the identities that the people involved in the situation are enacting and recognizing as consequential" (Gee, 2005; p. 111). Several student identities, such as student, scientist, leader, follower, collaborator, saboteur, coach, instigator, and facilitator, were expected to emerge throughout this IBS unit. In order to construct accurate case profiles, I needed to understand what identities, and corresponding roles, played out within each situation and how these identities and roles influenced the outcomes of each case. For example, a student's perception of what it means to act like a scientist, and how they perceived themselves as a scientist, was expected to influence student engagement and understanding of scientific processes. Questions I developed within the identity category assisted me in uncovering this critical information.
Finally, the student actions and activities, such as the use of various equipment or specific student-generated research endeavors that took place within each situation, were indicative, and reflective, of the lived experiences of the participants. In the activity category of Gee's discourse analysis framework, he includes "the specific social activity or activities in which the participants are engaging; activities are, in turn, made up of a sequence of actions" (Gee, 2005; p. 111). Individuals typically act in a manner they feel is necessary, appropriate, beneficial, and/or possible for a given situation (Gee, 2005). Activities that are offered, and those that are perceived to be offered, or possible, may be influential to participant actions. For my study, it was necessary to recognize and understand what activities actually occurred within each case, how each of those activities developed, and what activities and actions were potentially responsible for sustaining and/or transforming the activities. For example, the contextual situations within each case influenced student perceptions of time and their ability to be successful within the allotted time; these perceptions were integral to the work completion strategies, such as dividing and conquering, which emerged within each case. This information was crucial to the development of accurate case profiles for each case.

In summary, the relationships that existed within each case fostered certain interactions that, in turn, fostered certain identities and prompted specific activities to unfold. The significance that participants assigned to those relationships, identities, and activities, bore influence on student motivation and/or achievements as they navigated through their IBS experience. In order to
access data that was needed to assess this influence, I used recommendations from Gee (2005) to develop the topical and sub-topical questions. My developed questions were modified from Gee's list of sample category questions (Gee, 2005; p. 110-112). These questions were also used to establish the specific questions posed within my interview guides; my pre-project formal interview guide is included in Appendix A1 and my post-project formal interview guide is included in Appendix A2. In efforts to answer these questions, my focused attention was on one group of four students within each case. I now list the topical and sub-topical questions; I have placed in parenthesis the discourse analysis category to which I assigned each question.

The Main Research Question was:

"Within two approaches to inquiry-based science, how do student social interactions relate to student motivation and achievement?"

Topical Question #1: How can the student social interactions within each case be characterized?

Sub-Topical questions:

a) What types of social interactions are present within each case?

(relationships)

(such as: verbal, physical, collaborative, adversarial, cooperative, competitive, playful, accommodating, belittling, supportive, one-one, group, peer-peer, student-teacher, overt, subtle, glances, posturing)
b) What factors appear to influence the types of relationships that develop within each case? (relationships, identities, activities) 
(such as: comments, actions, emotions, student research goals, location, time)

c) What social relationships are established and how are they transformed within each case? (relationships, activities) 
(such as: anything that triggers shifts in, or sustainability of, relationships - comments, actions, glances, posturing)

d) What are the various identities/roles depicted by participants within each case? (identities, activities) 
(such as: leader, follower, scientist, student, time manager/progress tracker, procrastinator)

e) How are student emotions characterized within each case? (relationships) 
(such as: excitement, frustration, contentment, anger, happiness – as expressed through language, actions, and reflections; this will be assessed through my observations of apparent student emotions, casual interviews with students, as well as through student journal reflections)

f) How do student emotions influence student interactions within each case? (relationships, activities) 
(such as: seeming to stimulate or suppress behavior, comments; this will be assessed through my observations of apparent student
Topical Question #2: How does student discourse within each case relate to student interactions and activity? (this aimed to get at verbal interactions)

Sub-Topical questions:

a) What types of discourse emerge throughout the participant experience in each case? (relationships, significance)

(such as: casual, content based, purposeful, productive, counterproductive)

b) Under what conditions does each type of discourse emerge in each case? (relationships, significance)

c) What meaning and significance do participants place on the various types of discourse in each case? (significance)

d) In what way does student discourse seem to sustain or transform student interaction? (relationships, significance)

(such as: anything that triggers shifts in, or sustainability of, relationships - comments)

e) In what way does student discourse seem to sustain or transform activity? (relationships, significance, activity)

(such as: anything that triggers shifts in, or sustainability of, relationships - actions, reactions)

Topical Question #3: How is student motivation characterized within each case?
Sub-topical questions:

a) What are student perceptions of their ability to be successful within each case?
   a. At the start of unit – student perceptions about ability in science overall
   b. At the conclusion of the unit – student perceptions of their ability within this specific unit (significance)
   c. What value (intrinsic, attainment, utility, cost) is associated by participants to location, other participants, interactions with other participants, artifacts, activities, and personal contributions within each case? (significance)

b) What opportunities are perceived by participants to be available within each case? (activity)
   (such as: student choice, self-regulation, autonomy, materials / resources)

c) What types of activities do participants engage in within each case? (activity)
   (such as: self-regulatory, self-handicapping, challenge levels attempted, materials manipulation, project work, science based, off-task)

d) How do participants perceive their level of engagement within each case? (activity/significance)
(such as: participation, perseverance, withdrawal, giving up)

Topical Question #4: How are academic achievements within each case characterized?

Sub-Topical Questions:

a) How does student performance on assessments vary within each case? (activity/significance)

(such as: scores on tests/quizzes, field journals, final projects)

b) In what ways is conceptual understanding of content demonstrated within each case? (significance)

(such as: written, expressed verbally, transference)

c) How is the depth and breadth of student-generated research questions characterized within each case? (activity/significance)

(such as: challenge level attempted, skills/data needed to answer selected question - blooms taxonomy scale)

d) How is the depth and breadth of student-generated artifacts (field journals, final projects, presentations) within each case characterized? (activity/significance)

(such as: evidence of conceptual understanding, superficial answers, detailed/synthesized answers - blooms taxonomy scale)

Topical Question #5: How are the established case profiles characterized and what conclusions can be drawn? (all significance)

a) What characteristics are unique to each case?

b) What characteristics are common to both cases?
c) What situated meaning, such as the significance of social interactions that develop within each case, can be assigned to the uniqueness of each case?

d) How do social interactions relate to motivation within and across cases?

e) How do the social interactions within each case relate to achievement within and across cases?

f) How does student discourse within each case relate to social interactions and achievement?

g) How does context relate to social interactions, motivation, and achievement?

Discourse analysis is designed to expose the complexities of a particular situation. I aimed to expose and understand the complexities within IBS, thus discourse analysis assisted my ability to make meaning of the data I collected. The meaning that I constructed from the data was critical to the development of accurate case profiles. I turn now to a discussion of the particular curriculum that was implemented followed by a description of the specific data sources.

The IBS Curriculum Implemented within each Case

This research was conducted through the study of two specific cases of inquiry-based curriculum instruction. As mentioned previously, the On-Campus case took place entirely on school grounds; the Off-Campus case had the added component of an off-campus student research site. In order to ensure
consistency with curriculum content, students in both cases participated in the
"BirdSleuth: Investigating Evidence" curriculum that was developed by the
Cornell Lab of Ornithology; the curriculum can be found at the following website:
http://www.birds.cornell.edu/birdsleuth/about/resources/birdsleuth-modules. This
particular unit was selected for this research because it utilized a field-tested,
guided inquiry approach to IBS. Having students in both cases engage in the
same type of investigation helped establish the comparability of the research
results; for this unit students conducted experimental investigations.

Students in both cases were given the same opportunity to work in groups
of three to four students to proceed through the curriculum lessons and activities,
design original research questions, and conduct original experiments. The same
teacher delivered the same instruction, lessons, and activities to all students in
each of the two cases. I was present, each day, to witness the delivery of all
lessons in both cases and thus was able to observe, and note, any discrepancies
in delivery that occurred. Lessons within the "Classroom BirdSleuth: Investigating
Evidence" curriculum included, but were not limited to, "What is Science,"
"Testing Hypotheses," "Show me the Data," and "Plan My Investigation."
Activities included "Meet a Scientist," "Conduct My Experiment," and "Present My
Inquiry Project." In addition, an activity called "Why Study Birds" was
implemented at the start of this unit. This activity assisted students in
understanding what significance birds may have to humans and the environment
and set the stage for the BirdSleuth unit. This activity also introduced scientific
terms, such as bio-indicators and agents of dispersal, which could provide the context for student research questions.

During this unit, all students were instructed to conduct an inquiry-based investigation around the general theme of wild birds. They were instructed to focus their investigations around the overarching question: “What factors are of influence to birds in the area?” The parameters set by the teacher were that the students must conduct their inquiry only on wild birds (no pet birds were allowed), or some aspect of the immediate environment that may impact at least one species of birds. Students could elect, for example, to study what food sources were available in different habitats for certain birds, what factors impacted those food sources, how water turbidity levels might impact Osprey behavior in the area, or how different sounds may influence bird behavior; the students were responsible for selecting the specific topic for their investigation. Students were not permitted to harm the birds or the environment.

All students, in both cases, had access to the same equipment. Students at the school had access to commonly available science equipment such as hand-lenses, compound light microscopes, and computers. Students also had access to less commonly available equipment such as that listed in Figure 3. The science teacher encouraged students to utilize the less commonly available equipment in order to learn new skills and to take advantage of the equipment’s availability.
<table>
<thead>
<tr>
<th>Equipment</th>
<th>Description</th>
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<tbody>
<tr>
<td>Binoculars</td>
<td>Digital motion detector cameras</td>
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<td>Digital Microscope</td>
<td>Digital sound recorders</td>
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<td>Dissecting Microscope</td>
<td>Parabolic dishes</td>
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<td>Sennheiser recorders</td>
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<td>- Temperature</td>
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<td>- Salinity</td>
<td>Field guides:</td>
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<tr>
<td>- pH</td>
<td>birds</td>
</tr>
<tr>
<td>- Force</td>
<td>trees and shrubs</td>
</tr>
<tr>
<td>- Dissolved Oxygen</td>
<td>flowers</td>
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<tr>
<td>- Motion</td>
<td>pond life</td>
</tr>
<tr>
<td>HOBO Probes</td>
<td>RAVEN Lite software*</td>
</tr>
<tr>
<td>- Temperature</td>
<td>RAVEN Exhibit*</td>
</tr>
<tr>
<td>- Humidity</td>
<td>* explanation below</td>
</tr>
<tr>
<td>- Light</td>
<td></td>
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</table>

Figure 3: Sample equipment that was available to all students

RAVEN Lite is a software program that allows students to convert digital sound recordings into spectrograms for detailed sound analysis. The RAVEN Exhibit* is a dual computer system, developed by the Cornell Lab of Ornithology, that includes professionally recorded sounds and data bases for investigation; one computer displays sound waveforms and spectrograms which can be manipulated and the other computer displays information such as pictures of the organism or object that created the sound, textual information about the creator of the sound, and if the sound is biological in nature, the second screen may also contain range maps for the organism. All students were encouraged to use supplies that were readily at their disposal as well as alternatives that arose from their own ideas and creativity.

A summary of the two cases is illustrated in Figure 4. The differences between the cases are noted in bold type.
**On-Campus Case**

**Content:** "BirdSleuth: Investigating Evidence"

**Number of students:** 15 for overall observations and class-wide activities; 4 for focused observation.

**Location:** Central Middle School and the surrounding school grounds

**Duration of “Field Observations”:**
six 45-60 minute class periods.
Total field work = anticipated 300 min.
(actual field work time: 285 min)

Total IBS Unit Time: 29 hr 50 min

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**Off-Campus Case**

**Content:** "BirdSleuth: Investigating Evidence"

**Number of students:** 16 for overall observations and class-wide activities; 4 for focused observation.

**Location:** Central Middle School and a nearby nature reserve

**Duration of “Field Observations”:**
four day-long (3 hours research time) periods. Total field work anticipated 720 min.
(actual field work time: 555 min)
4 hrs 30 min longer than the On-Campus case

Total IBS Unit Time: 35 hr 45 min
(Total time difference = 5 hr 55 min)

---

**Figure 4: Case study comparison (differences between the two cases are in bold)**

---

**SITE SELECTION:**

A small rural middle school situated in southern NH, comprised of approximately 210 students in grades 6-8, was the primary research site for this project. The pseudonym used for this school is Central Middle School (CMS); all names that are used throughout this dissertation are pseudonyms. The 8th grade science teacher, Mr. Bradford, or Mike, was the cooperating teacher and provided the science instruction and my access to 8th grade students for both cases. Demographic comparisons between the town where CMS is located, and the state of New Hampshire are presented in Table 1. The demographics reveal that town residents, on average, earned higher wages, held a greater number of college degrees, had fewer individuals living below the poverty level, and were
comprised of a higher percentage of Caucasians, than the state average

(\text{http://quickfacts.census.gov/qfd/states/33000.html}).

<table>
<thead>
<tr>
<th></th>
<th>Median Household income</th>
<th>% of population with Bachelors degree or higher</th>
<th>% of population living below poverty level</th>
<th>% Caucasian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Middle School Town</td>
<td>$77,064</td>
<td>56</td>
<td>2</td>
<td>98</td>
</tr>
<tr>
<td>State of NH</td>
<td>$63,277</td>
<td>32.9</td>
<td>7.8</td>
<td>94.6</td>
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Table 1: Demographic summary and comparison to state

Central Middle School was selected as the research site for this project for several reasons. First, I had a longstanding relationship with the school and was quite familiar with the equipment and resources that were available for student use within the school and the science department. Second, the 8th grade team of teachers had expressed a willingness to accommodate a flexible schedule that would allow for the extended field research experiences to take place within the Off-Campus case. Third, the school administration had expressed an interest in this study because student scores on standardized science tests were lower than desired; the administration hoped that the results of this study might be useful to inform future instructional practices, and improvements, within science instruction at the school.

The average standardized test scores seen at Central Middle School were somewhat reflective of national and regional trends in science. Nationally, less than one third of 8th graders are performing at proficient levels on standardized tests (National Academy Press, 2005). In 2005, The Institute for Education Sciences reported that only 4 percent of 8th graders in NH scored at an advanced level and only 41 percent of 8th graders scored at a proficient level on the
National Assessment of Educational Progress tests. In 2008, 0 percent of 8th graders at Central Middle School scored at the “proficient with distinction” level, and only 45 percent scored at the “proficient” level on the NECAP (New England Common Assessment Program) test. In 2009, 0 percent of 8th graders scored at the “proficient with distinction level” and 39% scored at the “proficient” level and in 2010, 1% scored at the “proficient with distinction” level and 58% scored at the “proficient” level (http://reporting.measuredprogress.org/nhprofile/reports.aspx?view=26). These scores, as well as the overall New Hampshire state scores are summarized in Table 2.

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<tbody>
<tr>
<td>CMS</td>
<td>0%</td>
<td>45%</td>
<td>0%</td>
<td>39%</td>
<td>1%</td>
<td>58%</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>0%</td>
<td>26%</td>
<td>&lt;1%</td>
<td>24%</td>
<td>&lt;1%</td>
<td>27%</td>
</tr>
</tbody>
</table>

Table 2: Comparison of CMS and state NECAP Scores

Although the scores for Central Middle School tend to be higher than the NH state scores, and the 2010 scores for CMS showed considerable improvement, fluctuation in scores remains from year to year and clearly illustrate room for overall improvement. The district was interested in discovering educational methods that would support sustained improvement in science education, thus their interest in this project.

A local estuarine research reserve provided the field location for the student research portion of the Off-Campus case. This reserve was selected as
the field location for the Off-Campus case, in part, because the reserve had expressed an interest in actively involving more middle school aged students in science investigations at their site; this research project supported that goal. The site was also selected because the surrounding grounds at the center were well-defined and contained established walkways, paths, and handicapped accessible boardwalks, making access to research sites easier for all students and easier for the cooperating teacher to monitor student progress. Additionally, the site had an established bird feeder similar to the one located at Central Middle School, making student research opportunities available at each site similar.

PARTICIPANTS:

Research participants included 8th grade students from Central Middle School. The 2011 8th grade class consisted of four sections of science containing roughly 16 students in each section. The students were heterogeneously mixed within each class, however the science teacher reported a slight delineation in ability levels. The teacher reported that two sections had slightly higher achievement levels, based on overall grades in science, than the other two. This was suspected to be a result of the math class delineations into two formal algebra and two informal algebra sections. Although the students were re-mixed for science class, due to the small size of the overall 8th grade class - 62 students - there was a slight carry over of the delineation from math class into science classes.
In an attempt to control for the slight variability in the reported ability levels of the science sections, the two classes that were identified, by the teacher, as having higher ability were selected to be the focus of my research study. I attended all classes and field excursions for all four classes. To assure unbiased results, one higher ability group was assigned to each project; this assignment was done randomly. Having the two study groups consist of students with similar ability levels reduced the potential influence of student ability within my study; it helped control the variable of student ability. This group selection process assisted in maintaining the integrity of my research and the comparability of the results.

Once the two participating classes had been selected, I placed a colored piece of paper that represented the name of each class (the classes at Central Middle School were each named a specific color) into separate hands. I then extended both hands, with fists closed in order to hide the colored paper, and asked the classroom teacher to select a hand. It had been predetermined that the selected hand would represent the class that would be traveling to the nature reserve for their student research projects. Based on this process, the On-Campus case consisted of higher ability students and took place entirely on school grounds and the Off-Campus case consisted of higher ability students and took place on school grounds and at the nature reserve.

**Small Group Selection Process within Each Class:**

Once the two classes had been selected, the small groups within each class that my research would focus upon had to be selected. The students within
each class were instructed by the teacher to divide themselves into smaller groups for their inquiry-based projects; the two classes comprising my research study each split into five smaller groups. The teacher explained that these self-selected groups would be their project groups. To select my research participants from the first class, I put the name of one student from each group on a separate piece of paper and put all the papers in a box. I then drew one name from the box and this student's group was selected to be the group for my focused attention in that class. I then noted the gender make-up of this group, which was a group consisting of three boys, and matched it with a similar group from the second participating class. There was only one group of three boys in the second class, so I selected this group as the second group for my focused attention. Upon closer examination, however, I noticed that these selected groups presented a problem. One group of boys consisted of two students who were coded for special education and one student who was on a 504 plan; the boys in this particular group all received some level of extra assistance and special grading accommodations for their work. The group in the second class consisted of three non-coded students. Based on this discrepancy, I decided that these groups would not facilitate a fair comparison for my research, so the group selection process was repeated. The student names that represented the various groups were once again placed into a box and I drew out a new name. The second drawing was for a group of four girls. I was able to match this group with a group of four girls in the second class, so these groups became the two groups for my research focus.
The all female gender make-up of my research group created potential influences for the results of this project. Girls tend to be more social than boys and they tend to be less confident in science than boys (Meece et al., 2006). These factors could have had substantial influences on the way in which these students navigated their experiences and thus on the final outcomes. Although studying a single gender places some limitations and influences on the results of my study, the information obtained is none the less important. Our national science education goals include efforts to increase the number of girls enrolling in advanced-level science classes in high school and college as well as in pursuing science related careers (Lawrence & Mancuso, 2012; Milgram, 2011; National Science Teachers Association, 2010). Information gleaned from my study promotes an understanding of how girls act like scientists and experience IBS opportunities, thus offering insights into how girls might be encouraged to pursue higher-level science classes and careers. Understanding how girls experience science and act like scientists is imperative to our ability to encourage girls to pursue science related careers and to meet our national science education goals.

The girls within each group of my research were individually invited to be participants; all girls in each of the groups eagerly agreed to accommodate my research. The girls from each group submitted the required student, and parental, assent and consent forms which granted permission and agreement to participate in the study. These two groups officially became the groups for this research project.
This participant selection process ensured an evaluation of equal numbers of like-gendered and equivalent ability level students. During the research project, I attached myself to each of the selected groups and observed, recorded, and evaluated student experiences throughout the IBS unit. Staying primarily with one group in each class fostered the promotion of a "heightened sensitivity to subtle understandings...such as how meanings emerge through talk and action and how perspectives change over time" that might have been missed had I flitted about from group to group (Schram, 2006; p. 134). This process ultimately accommodated an in depth evaluation of the inquiry-based science experiences of eight female students.

Although I focused my research efforts on these eight girls, all 8th grade students, that had returned the properly signed consent forms, which are included in Appendix B, were considered participants of the study. Signed consent forms ensured that each student, and their parents, had been informed of the general purpose of the research and that each understood that they could discontinue participation, if so desired, at any time. All but two students in the 8th grade agreed to participate and the two that opted not to participate were not enrolled in either of the classes I observed for this research. All students participated for the duration of the project. I observed whole class dynamics and interactions, including class-wide discussions, as well as interactions that took place within, and between, my study groups and other groups or individuals. A discussion of the specific data sources follows.
SOURCES OF DATA:

In the development of each case profile, I utilized multiple sources for generating data. Having multiple data sources allowed me to acquire multiple layers of understanding that, in turn, assisted me in recognizing what aspects of IBS were common to both cases, as well as those that were unique to each case. Additionally, having multiple data sources assisted me in recognizing patterns that developed, such as certain triggers that led to an increase, or decrease, in student discourse or participation. Data were collected through participant observation techniques which included the recording of researcher field notes, digital video and audio recordings – including of all student interviews, photographs of student activity and artifacts, and the analysis of student-generated artifacts such as field journals, scores on tests/quizzes, curriculum assignments, and final projects produced by students. Details about each particular data source follow.

1) Participant Observation:

Participant observation was the driving method for this research. I entered the classroom two weeks prior to the start of data collection in order to introduce myself to the students, to briefly explain the intentions of the research, to distribute consent forms, and to allow students to become accustomed to my presence. I stated that I was interested in understanding how students experienced inquiry-based science lessons and that I intended to observe their experiences with the inquiry-based unit they were about to begin. I explained that in order to use data from my observations, I would need their, and their parents,
consent to consider them participants in my research. I further explained that the project was part of their regularly scheduled curriculum and as such, if they chose not to participate in my research, I simply would not document comments, pictures, or video/audio recordings that included them. All students, and their parents, granted permission for me to use student comments, pictures, and video/audio recordings.

Prior to my arrival, I set up a video camera and external microphone in the classroom so that students would become accustomed to the presence of the equipment; the camera and microphone were not turned on during these initial two weeks. I attended each class daily. During the initial two weeks prior to the official start of my research, I practiced taking field notes, began evaluating whether the initial areas of intended focus seemed appropriate for what I was observing in the classes, and I practiced transcribing and evaluating my field notes in order to assess their effectiveness at accounting for areas of intended research focus. These initial practice efforts allowed me to assess whether I needed to adjust my note taking style and/or be more attentive to certain types of conversations, or activities that occurred in class. During this time, I became quite comfortable with the note taking and transcribing process.

Due to my past experiences with inquiry-based science lessons as an 8th grade science teacher, I entered this research with some preconceived ideas of what to specifically attend to, as well as some potential data analysis codes, such as acting like a scientist, utility value, cost value, student comments that promote progress, student actions that inhibit progress, and emotions that may emerge. In
order to assist my observation efforts, I created an "Observation Sheet" (see Appendix C) that I modeled after the "OPAL Classroom Observation Manual's" protocol for taking field notes which had been created to assist researchers in guiding their classroom observations (Patrick, Ryan, Anderman, Middleton, Linnenbring, Hruda, Edelin, Kaplan, Midgley, 1997). The OPAL manual directs researchers to use the acronym "TARGET" (standing for Task, Authority, Autonomy, Recognition, Grouping, Evaluation, and Time, and they added Social, Help Seeking, and Messages) to assist field observers in targeting their observations in search of evidence that fit into those categories. As the OPAL manual was geared towards revealing goal structures, I modified the "TARGET" acronym to "ISTREAM," which stood for Identities, Significant or Surprising, Triggers, Relationships, Emotions, Activities & Accomplishments, and Motivation, for my project in order to orient my observations more towards student social interactions, achievements, and motivation.

The categories within my ISTREAM Observation Sheet were modeled after the categories I selected from Gee's framework, and directly targeted information needed to answer my research question. For example, my "Relationship" category referred to the student-student, as well as the student-teacher, interactions. It was intended to target the physical and verbal interactions that emerged throughout the project. My relationship category directly reflected Gee's relationship category that includes: "relationships that people involved enact and contract with each other and recognize as operative and consequential" (Gee, 2005; p. 111). All four categories that I selected from
Gee’s framework (relationships, significance, activity, and identity) are directly, and deliberately, integrated into my ISTREAM Observation Sheet. The “I” reflects Gee’s “Identity” category, the “S” reflects Gee’s “Significance” category, and the “A” reflects Gee’s “Actions and Activities” category.

The additional categories I included in my ISTREAM Observation Sheet, “T” for “Triggers,” “E” for “Emotions,” and “M” for “Motivation,” assisted me in attending to aspects of student interactions that might influence student progress and outcomes. I interpreted triggers to include any action, comment, or gesture that lead to a change in student activity, progress, and/or disposition. I interpreted emotions to include the various feelings and sentiments expressed by students. Additionally, I interpreted motivation to include actions and values that initiated and/or sustained student activity. The values I included in my interpretation included student perceptions of task, intrinsic, attainment, utility, and cost values. Finally, I included surprising and unexpected aspects that emerged within my “S” category; this assisted in identifying unanticipated occurrences.

A complete description of each of these categories is offered in Appendix D. I kept a copy of the “ISTREAM Observation Sheet,” which included the category names as well as targets for observation within each category, in my field journals so I could continually remind myself of the various aspects upon which to focus. The “Significant or Surprising” category was specifically meant to facilitate the inclusion of aspects that were not directly included in my targeted list.
but that may hold potential significance and/or were unanticipated events that may later prove to be worthy of further examination.

As intended through participant observation, I immersed myself in the experience with the participants. This allowed me to be present during all components of the project; I documented and evaluated both the classroom and field experiences of students. I attached myself to the selected research groups of students in each of the two cases. I interacted with the students on a daily basis, participating in both casual conversations as well as conversations about classroom activities or science in general. I provided assistance to the students in the form of holding equipment when an extra pair of hands was helpful or carrying equipment to and from field locations. I did not provide any curriculum instruction, or provide any ideas or insights into content material or requirements for the student projects, during the unit. I was present in the classroom, and field locations, for the entire class period, each day, for the duration of the project.

My field notes were in the form of “jottings” as discussed by Emerson et al. (1995; p. 19-35). My jottings included notes about my impressions, the sequencing of events, seemingly key events, words or phrases used by participants, and brief notes about actions, gestures, and student dialogue; often, I scribed verbatim utterances of students. Jottings also included brief notes about my reactions and feelings about various situations, my thoughts about what may be occurring and/or why, participant’s apparent feelings and reactions, and what participants seemed to be understanding and/or dealing with in various situations. I also jotted notes about questions to incorporate into student
interviews based on what I had seen and/or heard, apparent student emotions, and notes about activities that seemed to engage students. I used the "ISTREAM Observation Sheet" to guide my efforts.

Each jotting included as many details as possible and served as reminders of the daily events that were later incorporated into more detailed narratives. My field jottings were turned into narrative field notes on a daily basis. I used separate notebooks for recording my jottings within each case. Each evening, I typed my field notes into Word documents exactly as they had been written in the field in order to keep an archive of actual, original, field notes. I then made a copy of each of these word documents. One copy was kept as the official archive of my original jottings, the other was used to develop more detailed daily narratives of what had transpired. In these full narratives, I kept the original jottings in regular type and italicized any additional information that I added to these notes. This allowed me to readily identify which information had been directly recorded in the field and which had been added later from memory of events. The narrative field notes thus included additional information and details about events and interactions that I remembered from the day, my own thoughts and feelings about the events of the day, what I suspected participants may had thought or felt about the events of the day and/or what follow up questions I had for participants about specific happenings. Ultimately, the full narrative field notes consisted of detailed descriptions of the day. The full narrative field notes included details of "scenes, settings, objects, people, and actions" that I observed
(Emerson et al., 1995; p. 68). These narratives were later included in the coding and analysis of the project data.

In addition to my field notes, digital video and audio recordings as well as photographs were taken of various classroom and field activities in order to capture overall events as well as subtleties and details that I may have initially overlooked; details about each of these data sources is discussed in more detail below. Such recordings and images were an invaluable record of events to which I returned in order to review activities and/or actions multiple times. They served as historical records of the daily occurrences; if I became aware of an action, or comment, that was initially ignored, but then realized later it may have had some significance to the situation, I had digital record of the event to re-watch and assess the scenario with new insights. The compilation of these recordings provided daily, moment-by-moment, record of what had transpired. I used these data sources to cross check my own observations, to seek out aspects that may have initially been overlooked, and in the overall analysis of events.

Being immersed within the experience with the students each day allowed me to gain a broad view of the student interactions that occurred. I attended all classes and field sessions for two of the 8th grade science sections throughout the duration of the IBS unit (approximately 7 weeks). My researcher field journal, video and audio recordings, and photographs served as record of daily activities and interactions. My observations focused on eight specific students, however interactions with and between other students and the teacher were also included.
2) Interviews:

The purpose of conducting qualitative research interviews is to develop an understanding of participant perceptions about what is going on and why (Seidman; 2006). In order to create accurate case profiles for each case, I needed to understand, from the student's perspective, what aspects of each situation influenced their motivation and achievements. Interviewing the participants assisted me in understanding the meaning participants gave to their experiences and informed me whether my interpretations and conclusions were supported, or refuted, by the student's perspective. I conducted both formal and informal interviews.

Two formal interviews were developed, and are included in Appendix A1 and A2, in order to gain access to the information needed to answer my research questions. Prior to the start of the research, I conducted practice interviews with students from seventh grade science classes that were not part of this research. These practice interviews allowed me to assess how well students understood the posed questions, whether students were able to answer the questions, and whether student responses actually revealed the information sought. Slight modifications to some of the interview questions, based on the results of these practice interviews, were made in order to make the questions more easily understood. For example, I shortened the length of one question, simplified the wording of another question, and rearranged the order of a few questions to maintain a smoother flow and continuity throughout my interviews.
Two formal interviews with each participant were conducted. The first formal interview occurred within the first week of the research and the second occurred during the last two days of the research project. One student from the On-Campus case was gone from school for two weeks during the pre-interview time frame, and thus was not interviewed at the start of the research project. As a result of this student's absence, one other girl, Margaret, from the Off-Campus case was individually interviewed during the pre-interviews. Margaret stated she was completely comfortable with being interviewed individually. During the post interviews, the girl that had been absent for the pre-interviews, Kim, was interviewed in pair with another group-member, Kaylee. I included Kim in a post-interview even though she had missed the pre-interviews because I wanted to gain perspective, from her own words, on how she processed her experiences. All other students were interviewed in pairs, thus there were two pre and two post interviews for each case making a total of eight formal interviews. The girls randomly decided who would be interview with whom.

Although I would have preferred to interview all students individually, so that individual responses would not be influenced by their peer's responses, and I would thus get a more informed understanding of each individual student's feelings and perceptions, I did offer students the choice of being interviewed either individually or in pairs if they would feel more comfortable. The students requested to be interviewed in pairs, so I honored their request. Although they did not seem averse to the idea of interviewing individually, I
was attempting to make them feel as comfortable as possible with my presence, so I quickly agreed to their stated preference of interviewing in pairs. An acknowledged limitation of interviewing students in pairs is the possibility that individuals, in efforts to not appear different than their peers, either held back their true thoughts and feelings and/or made claims that were not completely reflective of their thoughts and feelings (Seidman; 2006). An advantage of interviewing students in pairs, however, is that the increased comfort of having a peer present may actually have encouraged students to share more than they would have individually (Seidman; 2006). All formal interviews were video recorded and conducted in the teachers' work area that adjoined the 7th and 8th grade science classrooms during regularly scheduled class times. This interview location was out of sight from other classmates.

Formal interview number one consisted of eleven scripted questions and was completed in approximately thirty minutes. Each interview question had between two and ten sub-questions that were crafted, and utilized, to draw out more details from student responses. The questions within this interview were designed to facilitate my understanding of what each of the interviewee's perceptions were, at the start of my research, about science class in general, their abilities in science, their perceived opportunities for peer interaction, their feelings about science, their interpretations of the terms "hands-on" and "acting like a scientist," and the value they generally placed on science. A complete list of interview questions and sub-questions, as well as a specification of which research question each was intended to address is
included in Appendix A1. Students enthusiastically shared their thoughts and opinions about their experiences, past and present, in science.

Formal interview number two, which is included in Appendix A2, was conducted at the conclusion of the unit, after students had completed their final presentations. The interview was comprised of ten primary questions, each with between two and ten sub-questions, and was completed within approximately thirty minutes. The questions were deliberately reflective of the questions posed during interview number one in order to facilitate the assessment and comparison of pre and post student perceptions. This interview specifically targeted student perceptions of their experiences during this particular inquiry-based project as well as their interpretation of the terms “hands-on” and “acting like a scientist” upon completion of the inquiry-based unit. This interview allowed me to assess whether student perceptions, both overt and/or subtle, varied between the two cases and whether student perceptions had changed from the start of the project. Just as during formal interview number one, students were excited to share their thoughts and opinions about their experiences.

I navigated the flow of these interviews so I could attend to areas of interest that arose, but also ensure that my intended questions were either asked directly or were answered through student responses to other questions. Although I had created an interview guide for each of these formal interviews, additional questions arose through the interviews based on student responses. For example, I frequently asked students if they could “tell
me more about" whatever their initial response had been. All interview questions were answered either in direct response to questions asked by me or through participant responses to separate questions.

Informal interviews were conducted on a daily basis. Informal interviews took place in the classroom and at field locations; they took place within regularly scheduled class times. Students were asked questions, based on my field observations or based on what I had read in a participant's reflection journal, which would assist in leading me to a better understanding of various situations. Questions such as: "Can you tell me how your group came to that decision," "Can you explain what that means," "How has time influenced your group's progress," and "Can you explain to me why you did that" were asked. I also asked students periodically for their perceptions of how time and location influenced, if at all, their work, the types of research questions they asked and/or the way they went about answering their questions. Informal interviews were audio and/or video recorded. Informal interviews ranged in length from approximately two to ten minutes.

Interviews with participants allowed me to gain direct access to their thoughts and feelings throughout the research process. The interviews also provided access to pre and post project student perceptions of the terms "hands-on" and "acting like a scientist." The compilation of this information facilitated my understanding and awareness of student motivation and their perceptions of their experiences and progress throughout the process. This information was essential to my ability to answer my research question.
Video recordings, audio recordings, and photographs:

Video and audio recordings, as well as photographs, allowed me to capture the subtleties within each situation through repeated viewing; moments of interest were captured as they unfolded. These recordings and images served as a historical record of daily occurrences. They allowed me to review actions, or comments, that had initially been ignored, but that I later realized potentially had some significance to the situation. The compilation of these recordings provided daily, moment-by-moment, record of what had transpired. I used these data sources to cross check my own daily observations, to seek out aspects that may have initially been missed, and in the overall analysis of events. Although I had access to each of these pieces of equipment, the use of the video recorder held the highest priority of the three. My documentation efforts focused on video recordings and taking field notes. Audio recordings and photographs were only taken at times when doing so did not jeopardize my ability to attend to the events that were taking place.

Video recordings:

To capture video recordings of classroom activities, a video camera was initially placed in the front right corner of the room. An external microphone for the video camera was suspended from the ceiling in the center of the classroom, between student desks "B" and "E," in order to more readily capture sounds from all parts of the room (see Figure 5). This position of the microphone worked well for the majority of the time. There were seven
occasions, however, when there was simultaneous student talking that lasted for more than three minutes in which it became impossible to separate out individual comments or conversations from the cacophony. Once students broke into smaller groups for their student-generated research projects, the microphone for the video camera was moved to hang directly above “Student Desk F.” The groups I observed during my research were asked to sit at Student Desk F because this desk facilitated the greatest flexibility for positioning the video camera; hanging the microphone directly above the students work area allowed me to capture clear audio recordings specifically from my research groups. The video camera was moved to various positions around Student Desk F in order to capture as much of the student activity and interaction as possible.

Figure 5: Video camera and microphone positioning (yellow dots indicate the original position of the research microphone and video camera)
In addition to daily classroom activities, and the interviews mentioned in the last section, I also videotaped field excursions and each of the final student presentations. Having a video record of student activities, interactions, and presentations, allowed me to review, multiple times, the subtleties of student experiences as well as the level of conceptual understanding revealed by student actions and comments. I was also able to slow video recordings in order to more accurately evaluate things such as student gestures and expressions; such information was invaluable in assessing triggers to student interactions that might have gone unnoticed at regular speed, or through a single viewing.

I video recorded all classroom sessions without fail. These recordings, however, were not without technical glitches. On two days, I accidently, and unknowingly, plugged the microphone jack into the headphone jack; on these occasions, I captured video images, but no audio was captured. By chance, one of these occasions was on a day when the teacher was reviewing various content materials in his efforts to prepare students for the NH NECAP test; fortunately, this day was not directly relevant to my research. The other occasion, however, occurred on a day that was relevant to my research. It occurred on a day when the teacher was explaining how to perform a statistics test and thus was on a day when there was mostly teacher lecturing and only minimal student interaction. Other video challenges arose when students were conducting their fieldwork. During fieldwork sessions, it was impossible to capture all of the student interactions on video because
students often splintered into two groups; I could only video record whichever of the subgroups I happened to be directly observing. On such occasions, students in the non-video recorded group agreed to record their activities on an audio recorder. A final glitch with the video recordings arose one day when I unknowingly switched off the autofocus mode on the camera. On this day, all but thirty-five seconds of the recording ended up being out of focus. The audio on this day was captured successfully, but not the video.

In order to transcribe video recordings, I previewed video recordings, using the "ISTREAM Observation Sheet" to identify areas of key interest. Areas of interest were then transcribed for exact dialogue taking place between individuals. Once these dialogues had been typed into a word document, I saved these as original transcripts from the selected sections of video. These video transcripts were then included in the coding and analysis of the project.

Audio recordings:

I used a small hand-held digital audio recorder for capturing various moments on audio, as well as for occasionally dictating my thoughts and observations. Use of the audio recorder allowed me to capture sounds from a different location than where the video recorder was located. For example, when the video recorder was positioned to capture the interactions of students as they worked while in the field, but then one or two students moved to another area for some aspect of their work, the audio recorder was taken with the students and used to capture the happenings of the student(s)
that temporarily left the group. This allowed me to more extensively capture student experiences and interactions. As with the video recordings, areas of interest were transcribed for exact dialogue taking place between participants. Once these dialogues had been typed into a word document, I saved these as original transcripts from the selected sections of audio. These audio transcripts were then included in the coding and analysis of the project.

Two issues arose with the audio recorder when students agreed to record their activities while in the field. First, students tended to hang the audio recorder by its lanyard around their necks. The rubbing of the recorder against clothes as students walked and worked caused the recordings to be difficult to decipher. Three audio recordings were indecipherable due to all the extraneous noises. Second, on two occasions, students had clearly turned off the recorder for an indeterminate amount of time. I know this to be true because of the abrupt change in conversation topic within the recordings as well as the abrupt change in volume, and type, of background noise and activity. Students did not volunteer that they had turned the recorder off. When I asked participants why they had turned off the recorder, they stated they had just been walking around and did not think I would want to hear them shuffling about. I am left not knowing what influence any comments or actions during this time may have had on their activities or on my research results.
Photographs:

I used a digital camera to take photographs of student work, set-ups of student research projects, final presentation displays, and spontaneous moments throughout the project. Since the video camera mentioned above was used to capture daily, continuous activities, the camera was used primarily for documenting finished student work, such as capturing a digital image of a poster display. There were also times, however, when a quick snapshot of a moment in time proved invaluable at gaining insight into student interactions, participation, and apparent emotions. For example, I captured the precise moment when the girls in the On-Campus case first witnessed birds landing on their birdfeeder. The image clearly captures the excitement of the girls; one girl has her arm raised into the air in celebration, one has covered her mouth with her hands as if holding herself back from screeching, and a third has her finger over her lips as if telling the others to remain quiet. All three girls in the photo have smiles on their faces and wide-open excited eyes. Although the video camera also captured this moment, from its position on a nearby tripod, the image from the camera was captured from closer range. It was also easier to simply analyze the photograph than to isolate the moment from the video recording. Another valuable image I caught with the camera, which I obtained when I had not yet managed to set up the video camera in a field position, was of the girls in the Off-Campus case when they slumped themselves on a tire located at one of their observation areas; they
were clearly uncomfortable from the heat of the day and not enjoying themselves at that moment.

3) **Artifacts:**

Numerous curriculum and student-generated artifacts, such as curriculum worksheets, student journal reflections, and culminating student research projects, were collected from all participating students for analysis. Ten student journal reflections were completed and collected. One of these journal reflections was directly intended to assist students in keeping on track with their research project; this journal required students to craft their null and alternative hypotheses for their particular research questions and to identify the independent and dependent variables for their project. Two other journals were indirectly intended to keep students on track with their work. One such journal asked students, prior to the start of their data collection, to reflect upon their accomplishments to date; this was intended to not only gain insight into student perceptions and feelings about their progress, but also to assist them in determining if they were truly prepared to begin data collection. The second of the journals indirectly intended to keep students on track was the student reflection completed at the halfway point of data collection. Again, this was intended to gain access to student perceptions of their experiences and progress, but also to assist them in determining if their progress was sufficient for the time remaining.

Student journals provided direct insights into individual student perceptions and feelings about their experiences as they navigated through
the inquiry process. Students shared information in these journals about how they were interacting with others, how they felt about those interactions, what aspects they enjoyed or disliked, as well as what challenges they faced. Insights gleaned from my review of student journals informed the creation of informal, follow-up, interview questions to ask the students. For example, one student commented in a journal that she felt her group was ready to begin data collection, but she did not provide any details about why she felt that way; I was able to follow up with her the next day, with an informal interview, to garner more insight into why she had felt prepared. Student journal responses were also used as member checks to compare my interpretations of what was happening to the students interpretations of what was happening and why. This allowed me to assess whether my perceptions were supported or refuted by student perceptions; this insight was critical to the development of accurate case profiles.

Teacher assessments provided twelve additional artifacts. These artifacts included two quizzes, four worksheets: "What is Science," "Meet a Scientist #1," "Meet a Scientist #2," and "Hypotheses," and four classroom assignments: creating an experimental design, project proposal, graphing data, and conducting a statistics test. Finally, teacher assessments also included the final evaluation of the final projects created by the students. Scores students received on these artifacts offered insights into student self-regulatory behaviors, student progress through the curriculum, and motivation. Student achievement was ranked based on individual scores.
received on the artifacts discussed above. Individual scores were also compared against my field observations and student journal reflections in order to assess if achievement scores were reflective of student perceptions of their work. Scores were also used to assess how student participation and motivation may have been related to individual academic performance as well as to student's perceived performance. Achievement was also assessed through the analysis of student journal and interview responses, as well as student abilities to express depth and breadth of understanding within their culminating projects and presentations.

Artifacts were analyzed for student conceptual understanding based on Blooms Taxonomy scale. For example, assessments were made based on whether student artifacts simply stated what had been done, which reflected lower levels of the Blooms Taxonomy scale, or if student work demonstrated an ability to explain why something had been done and/or analyze what had been done, which reflected higher levels of the Blooms Taxonomy scale. These measures assisted in determining the depth of conceptual understanding displayed by students and rendered greater insight into student achievement than what would be gained from using only teacher assigned grades. These assessments assisted in yielding a more comprehensive understanding of student achievement.

**Summary of Data Sources:**

The data sources discussed above provided multiple layers of insight, from the perspectives of both researcher and students, into the situated
meaning of each case. The data sources provided access to the information necessary to determine whether student social interactions could be related to student achievement and motivation. Teacher assessments provided information from traditional measures about student achievement. Student journal reflections, interviews, and my direct observations provided insights into less traditional measures of student achievement such as levels of content related discourse. Student journal reflections and interviews also provided insight into individual student perceptions and feelings about their progress throughout the process. This allowed me to assess, and track, student perceptions of achievement and motivation throughout the project. The video and audio recordings, as well as the still photographs, provided a historical record that was used to review and assess the overt and subtle occurrences within each contextual situation.

My use of the ISTREAM Observation sheet assisted in focusing on the aspects that were most salient to my ability to answer my research question. I was able to focus on student interactions that occurred, the identities that students revealed, triggers to changes in behaviors, feelings, or progress, the types of relationships and emotions that emerged, as well as student achievements and signs of motivation. The use of the observation sheet assisted in focusing my attention to aspects necessary to answer my research question, but also accommodated the documentation of unanticipated aspects of importance. The multiple layers of insight gleaned from these data sources fostered the development of rich, thick description,
case profiles for each case. This allowed me to identify, and understand, the specifics of each case. The evaluation of the case profiles afforded the opportunity to investigate the complexities of social interactions, motivation, and achievements that occurred within each case. More about each of these aspects is discussed in the following data analysis section.

DATA ANALYSIS:

Data analysis was an ongoing process throughout the duration of this project. Each day, transcripts of my field notes were created and used to develop full narratives depicting the day’s activities and events. These daily narratives were subsequently used to inform areas of potential interest as well as where having additional, follow-up, information might lead to greater insight into, and understanding of, the daily events and student experiences. The perceived benefits of such insights were then used to develop follow up interview questions. Subsequent observation efforts were also informed by the review of the daily narratives. The constant interplay that occurred between data collection and analysis fostered a comprehensive data set that ultimately facilitated the development of a thorough understanding of student experiences within the two approaches to the inquiry-based science unit.

An enormous amount of data was collected throughout this research project. The data consisted of pre and post formal interviews, informal interviews, researcher field notes and daily narratives, video and audio recordings, digital images, as well as student artifacts that included such things as unit
assignments, tests, quizzes, student journals, final products, and final presentations. My initial steps of sorting through the data included coding each data source using "etic" codes. According to Lett (1990), "Etic constructs are accounts, descriptions, and analyses expressed in terms of the conceptual schemes and categories regarded as meaningful and appropriate by the community of scientific observers" (p. 130). As discussed previously in the "Sources of Data" section, I had entered this research with some preconceived notions about specific aspects upon which to attend as well as some potential data codes. In order to facilitate, and focus, my daily observations during the project, as well as my initial etic coding runs, I used the "ISTREAM" observation sheet that I had created and modeled after the "TARGET" observation sheet from the "OPAL Classroom Observation Manual" (Patrick et al., 1997). The "ISTREAM" observation sheet used in my research, which stood for Identities, Significant or Surprising, Triggers, Relationships, Emotions, Activities & Accomplishments, and Motivation, assisted in targeting my field observations towards evidence that might fit into these particular categories, yet also allowed me to remain open to other, emergent, categories. This "ISTREAM" acronym oriented my observations towards student social interactions, achievements, and motivation.

I focused my initial etic coding runs through the data on these "ISTREAM" categories. This data-coding run allowed me to review the data, to begin organizing the data, and to reacquaint myself with each of the data sources and events that had occurred from the start of the research. This was a prudent
analysis strategy; it allowed a valuable comparison between my interpretation and the students' interpretation of their experiences that emerged later through emic coding runs which are discussed below. Through my initial etic coding efforts, I coded the student journals, the pre and post student interviews, the student artifacts such as assignments, tests/quizzes, final products, and presentations, as well as my researcher field notes. I also went through each video and audio recording of the daily activities and noted any sections of video or audio that fit these categories as well as other areas of interest. This etic coding effort allowed me to organize and re-familiarize myself with all of the data. I then felt ready to tackle the "next steps" in my coding efforts.

During subsequent coding runs, I re-coded the entire data set, but focused on creating "emic" codes; I did not, however, re-code my researcher field notes for these emic coding runs because the narratives from my researcher notes expressed my voice rather than the participants voices; all subsequent coding, emic, runs were in search of the student's voices. According to Lett, "Emic constructs are accounts, descriptions, and analyses expressed in terms of the conceptual schemes and categories regarded as meaningful and appropriate by the native members of the culture whose beliefs and behaviors are being studied" (Lett, 1990; p. 130). Using an emic approach allowed me to develop codes that emerged directly from the participant's voices. I used guidelines from The Coding Manual for Qualitative Researchers (Soldana, 2009) to establish "In Vivo Codes" that emerged directly from the words and expressions used by participants (Soldana, 2009; p. 74). These codes were comprised of the actual,
verbatim, words used by participants. This method of coding allowed me to capture, and track, codes that were “participant inspired rather than researcher generated” (Soldana, 2009; p. 75). Using In Vivo coding techniques allowed me to reveal, and preserve, the voice of the participants (Charmaz, 2006).

I worked with a PhD researcher in Anthropology to establish coding consensus at two junctures of the coding process as well as to receive additional training in using NVIVO9 software to conduct more extensive data analysis. This researcher runs a qualitative research consulting business and was recommended by NVIVO personnel as an expert in using NVIVO. First, upon completion of the initial emic coding run, she and I independently coded data sets from two of the formal pre-interviews, two of the student journals, and the final products from each of the cases. She and I reviewed our independently generated codes from each of these data sources and discussed differences until coding consensus was established. I then worked to clean up some of my initial codes using NVIVO in order to eliminate redundancy of similarly coded terms. Once I had completed this clean up task, she and I again reviewed the codes and again came to coding consensus. The researcher and I then worked independently to collapse codes into categories; we then discussed our identified categories until coding consensus was reached. Finally, I collapsed the identified categories into themes. I further worked with the research consultant using NVIVO to assist in conducting a negative case analysis of the data. My work with the PhD researcher assisted me in utilizing two methods, coding consensus and
negative case analysis, to establish the reliability of my coding efforts and my subsequent research conclusions.

In order to identify major themes that emerged from the data, I took the extensive list of emic codes and began collapsing these codes into major theoretical categories. I used the parameters of frequency of occurrence and apparent impact to identify the most pervasive and important themes. The parameter of topic frequency was assessed in two manners. First, if topics appeared within two or more sources, such as within student journals, student responses to various unit assignments, and in final student projects, those topics were considered to appear in high enough frequency to be potentially relevant to understanding student experiences with IBS and were thus included in further examinations of the data. Secondly, if topics repeatedly appeared within a single source, but through the responses of two or more students, those topics were considered to be worthy of closer examination. Topics that repeatedly surfaced from the codes were evaluated for their relevance to answering my overall research questions, as well as for their relevance to establishing a thick description of each case. Topics that were relevant to answering research questions were placed into specific themes. Topics that were more relevant to developing perspective of the contextual situation were placed into side categories and later used for developing case narrative descriptions. For example, students repeatedly made reference to the benefits of having time to engage in conversations with their group mates; this topic seemed to have great importance to the various situations. Codes, therefore, that were relevant to this
topic were placed within the major theme of “Opportunities to engage.” Other
topics that frequently emerged that seemed important, yet seemed more
applicable to the development of a descriptive narrative rather than for
specifically answering my research questions, were placed into side categories.
For example, several students discussed their frustrations with the configuration
of the lab tables. Several students complained about not being able to put their
feet under the tables and thus being less comfortable. This was important to
developing the description of the classroom set-up, yet less important to my
specific research questions.

Table configuration within the classroom, however, also had direct
relevance to my research question. Three of my research participants specifically
claimed to like the table configuration because it made it easier for them to
engage in conversations with their classmates. These conversations were both
beneficial, if conversations were content or project related, and detrimental, if
conversations were off-topic distractions, to student progress and achievement.
As a result of being both directly relevant to my research question and relevant to
the contextual situation, some aspects, such as table configuration, appeared in
more than one category.

Infrequent code occurrences were also assessed for their potential import
to the project. Infrequently occurring topics, such as those that only appeared
within one data source or were only briefly mentioned by one or two students, but
that seemed to have substantial influence to the situations within each case were
included within the major themes. For example, the topic of “fighting” was only
casually mentioned by two students during their post interviews, yet it seemed to have an influence on student behavior and progress at moments within their particular projects. This topic was, therefore, deemed important and included within the major theme of "Social Interactions."

I used tools within NVIVO, such as data organization and query tools, to compare my perceptions of frequently occurring topics with how many times topics were actually coded within each data source. Conducting coding matrix queries within NVIVO, I was able to determine the frequency of particular topics occurring across all data sources. This allowed me to not only quickly see within how many sources a particular topic occurred, but also allowed me to begin triangulation assessments of the data.

Upon completion of the above efforts, the initial 425 codes were collapsed into their most salient themes; five major themes surfaced. The five major themes were labeled as: Outcomes, which included aspects of achievement and motivation; Social Interactions, which included aspects of communication and collaboration; Emotions, which included aspects of feelings and triggers to behaviors; Opportunities to engage, which included activities and opportunities for students to interact and engage in their work; and Acting Like a Scientist, which included student perceptions, both pre and post experience, of what it means to act like a scientist, manners in which they acted like scientists, as well as the meaning of the term hands-on. These themes were in alignment with my ISTREAM categories and my research questions. In order to answer my research questions, I needed to comprehensively understand how students
experienced IBS and how these experiences might be related to motivation and achievement outcomes. The emergent themes of outcomes and social interactions directly mapped to the development of this understanding. Additionally, the ISTREAM categories were also reflected within the emergent themes.

Once the themes had been established, a detailed, thick description narrative was created that depicted student experiences and perspectives within each of the two Cases. This allowed me identify and track emergent patterns and themes over time. These narratives facilitated my understanding of whether, and how, student social interactions were related to student motivation and achievement within each case. They also allowed me to assess whether, and if so, how, student perceptions of the term “acting like a scientist” had changed as a result of their experiences with this inquiry-based experience.

Throughout the coding and theme development process, I maintained researcher memos within NVIVO in which I documented any changes to, and merging of, codes as well as my reasoning for making such changes. These memos provided an audit trail of my thinking and reasoning throughout the process of the identification and development of the final major themes. This audit trail was a valuable record of the “steps taken in the process of the research project from beginning to end and includes decisions made along the way that help illuminate and detail the entire process” (Barusch, Gringeri, George, 2011; p. 13). Upon completion of my coding efforts, I was also left with an extensive, and inclusive, record of both etic and emic codes. I was able to
compare the similarities and differences between what my expectations had been upon entering this research project with what was actually witnessed. I was also able to separate my anticipated results from the actual experiences and results as expressed by the participants.

Validity / Reliability of Conclusions:

Rigorous efforts were made to ensure the reliability, and thus validity, of my research efforts and the drawn conclusions. Numerous strategies and efforts, such as those described by Barusch et al (2011): “prolonged engagement, persistent observation, triangulation, audit trail, and negative case analysis,” contributed to the rigor of my research. Each of these aspects is described below.

Prolonged Engagement and Persistent Observation:

My daily immersion in the field, combined with the constant observations that were assisted by my “ISTREAM” observation sheet, constituted prolonged engagement and persistent observation. I was present each day for the duration of each of the science classes. I intently observed student interactions, activities, and outcomes as they unfolded. My use of video recordings also contributed to my observation efforts. I was able to review videotapes, multiple times, in order to study actions and comments that may have either been missed entirely, or only partially noticed when they originally occurred. The combination of prolonged engagement and persistent observation allowed me to identify the characteristics within each contextual situation that assisted in answering my research question.
Triangulation:

Having multiple data sources allowed me to gain access to student experiences from several angles, including my own perceptions as revealed through direct observations and student perceptions as revealed through student journals, curriculum assessments, interviews, video and audio recordings, photographs, and final projects. The triangulation of these data sources allowed me to deepen my understanding of student lived experiences within this IBS unit; this was invaluable to assessing how student interactions related to motivation and achievement. Triangulation of the data allowed me to: "deepen understanding by collecting a variety of data on the same topic or problem with the aim of combining multiple views or perspectives and producing a stronger account rather than simply achieving consensus or corroboration" (Barusch et al., 2011; p. 12). I used triangulation to not only determine where certain topics appeared, such as within which data sources, but more importantly to investigate the varying layers of patterns that occurred within the data; triangulation efforts facilitated my awareness of "massive over-determination of pattern" that emerged from the data (Agar, 1999; p. 689). The patterns that emerged allowed me to identify the ultimate themes.

Negative Case Analysis:

Conducting a negative case analysis allowed me to "challenge the emerging patterns" (Barusch et al., 2011; p. 13) and to develop more accurate, and thus more reliable, emergent themes; this increased the credibility of my research results. Through the development of individual student and case
narratives, I was able to develop themes of importance that were applicable to both individuals and specific cases. I tested themes that emerged from individuals to assess whether these themes held true within the specific cases. When discrepancies arose, I adjusted the themes representative of each case until all themes used to describe that case were accurately depicted and held true throughout. As described by Charmaz, "if negative cases emerge in the data, ... these cases may indicate the need to refine one's emerging theory" (Charmaz, 2006; p.102). I used negative cases from the data to refine the emergent themes until all themes could be confidently explained and an accurate model for the research results could be developed; in instances when expected results did not emerge, I assessed what factors were present that may have led to unexpected results. For example, I used the student profile of one of my participants, Kim, to refine my characterization of the case to which she belonged; I refined my characterization until it held true for all students, including Kim. I refined the resulting themes until they accurately represented the lived experience of each participant within each case.

Audit Trail:

I created researcher memos that tracked my decision making process throughout the research project, thus providing an audit trail of all such decisions. This technique assisted my ability to trace my actions and to rethink such things as why decisions were made, why code names were modified, and why I collapsed codes into particular categories. The tracking of my decisions throughout the process held me accountable to the research decisions I made.
Once the integrity of each case had been established, and a case profile containing rich description and narrative had been developed, a cross-case analysis was conducted in order to track thematic variations across the cases. Themes that were unique to each case were identified, and themes that were common to both cases were identified. Research conclusions and assertions were drawn from these within-case and cross-case analyses. Assertions were then applied back to each individual case to determine whether they held true in each case. Assertions held across cases, thus increasing the validity of the results and allowing me to speak beyond individual cases to broader, more generalizable discussions.

As a result of such rigorous research and analysis efforts, a reliable depiction of student experiences during this particular inquiry-based science unit was developed. Rich, thick description narratives for each individual, as well as for each case, were developed. These narratives were used to assess, identify, and track thematic variation within and across cases. These themes were used to develop a comprehensive model of student experiences within inquiry-based science.

MANAGING BIAS:

Research questions articulate, and are derived from, the central issue being investigated; they reveal and reflect the main focus of the research. It is critical for researchers to be aware of, and manage, any of their own bias that surrounds the issue under investigation. As such, researchers must rigorously
search for bias' that might be unrecognized at the start of their research. I worked diligently to develop research sub-questions that could assist in managing the influence of my own bias. My sub-questions were designed to assist me in garnering information that would be of assistance to answering the overarching research question and that could push beyond any bias that I brought to the research (Schram, 2006). As stated by Wolcott, one task of qualitative researchers is to

try to get rid of almost everything, of honing the topic and sharpening the focus, so that increasingly there is less to be concerned with, and thus what is of concern can be observed with greater attention (Wolcott, 1988; p. 27).

It was impossible, however, for me, as an individual researcher, to attend to every aspect of occurrences throughout this qualitative research. Attempts to be attentive to everything would have almost assuredly caused my inattention towards something; my focusing on one particular aspect, even temporarily, would have inherently caused other aspects to be missed. If inattentive, subtleties, and/or aspects of the situation that were potentially significant, could have gone unnoticed. It was helpful, therefore, for me to have some tentative areas of focus in order to direct my research attention. My research sub-questions, and the ISTREAM Observation sheet were intended to direct that focus. I acknowledge, however, that by frontloading intended areas of focus, my researcher bias seeped into the process.
It was of the utmost importance, therefore, for me to be aware of the assumptions, and bias, that I held. My assumptions could have easily caused me to attend to aspects of the situation that I assumed to be important to the topic of inquiry, yet such focus may have distracted my research efforts and caused potentially significant insights into the situation to go unnoticed. Awareness of my assumptions was critical, for if “left unexamined, assumptions may lead you to focus on what you think is going on in a setting and prevent you from seeing what is actually happening” (Schram, 2006; p. 83). Assumptions not only influence, particularly if unchecked, what researchers attend to, but also how they make sense of what they witness (Charmaz, 2006). Being aware of my own assumptions, therefore, assisted me in recognizing areas where I held preconceived notions as well as in making meaning of what I witnessed. For example, my perspectives, and subsequent assumptions, from my years of experience as a teacher, a female, a scientist's field assistant, and a student all influenced what I suspected might be influential to student experiences of “acting like a scientist” or engaging in “critical discourse.” Students, however, most likely made meaning of these situations in different manners than I; they may have considered different qualities, actions, or opportunities more important than my preconceived notions afforded. I, therefore, remained open to, and continually searched for, alternative explanations and influences. The use of my ISTREAM Observation Sheet and the analysis of multiple data sources assisted in overriding my biases and becoming aware of what naturally arose from the participants. Without having attended to possible alternative perspectives, my
research would have been rendered less meaningful; I simply would have "discovered" verification of how I viewed things.

The sub questions presented in my research were designed to offer assistance in directing attention to possible areas of significance that would assist in answering the main research question. I entered this research project with an assumption that social interactions were important, and influential, to student motivation and achievement. In order, however, to gather reliable and comprehensive data, I also entered the research with an acknowledgment that other factors may be just as, or even more, important and influential to the situation. For instance, because I understood that the factors of location and time may have substantial influence on outcomes; I was attentive to these factors throughout the project. In addition, although I agreed that the "hands-on" opportunities for students in IBS are significant to the ultimate outcomes, I also believed there may be more to the reasoning for the success that is often seen in IBS. I did acknowledge, however, that it may actually be that the "hands-on" nature of the experiences is all there is behind the success to IBS; I entered the research accepting that possibility. I sought out any and all aspects that may be influential to IBS outcomes.

I also entered my research believing that my goal of understanding whether, and if so how, social interactions within inquiry-based science experiences may be related to student motivation and achievement in IBS would be best assessed at the individual level through a social-cognitive perspective. I was aware, however, that I did hold somewhat of a socio-cultural bias in that I
believed culture would have an influence on student actions. For example, my research project investigated the experiences of 8th grade students from Central Middle School. These students, came mostly from families of middle to upper class socio-economic status, and were white, thus, they entered into the experience with culturally preconceived notions of what science, and school in general, was "supposed to be like." Additionally, my participants were all female. It is possible that the girls entered science class with the cultural stigma of expecting that the boys would be better at science than they would be and/or that they, as girls, were not supposed to be good at science. I also had to attend to any subtle expectation that girls may not produce results of the same sophistication of boys and to not over stress, or credit, the girls' accomplishments. Finally, the fact that my research participants were all female brought additional bias to the research. Girls are often considered to be more socially active than boys. As such, girls might have been more likely to willingly and spontaneously interact than a group of boys would have been. Girls tend to share their thoughts and feelings more openly than boys (Mendez et al., 2006). These notions potentially influenced how students navigated their experiences. Although my unit of analysis was at the individual level, being attentive to "what else is going on" (Schram, 2006), including cultural influences, assisted me in recognizing the actual influences to the situation.

I also recognized that my own field experiences with scientific research teams, such as my work with Dr. Peter Doran and the Long Term Ecological Research Project (LTER) in Antarctica, influenced my value of field research
experiences. My bias led me to suspect that students who conducted their research projects at the nature reserve would be more motivated because they would have extended opportunities to interact and bond as a group; I remained alert to the influences such bonding might have on the ultimate outcomes of the project. Students also, in being exposed to an off-site location, might simply have had more fun, or felt more adventurous. I was, therefore, careful to search rigorously for such signs of motivation within students at the nature reserve, as well as for evidence that those signs might have been lacking within the students remaining at CMS. I remained open to any influences to motivation within each case so that I did not falsely attribute motivation because of, or due to, a preconceived bias or assumption.

My past, and somewhat extensive, experience with implementing IBS lessons also presented a bias towards what I believe to be key factors to its success. My bias towards believing that social interactions play a substantial role in motivation and achievement outcomes in IBS caused me to develop sub-research questions that sought to understand motivation through expectancy-value theory. This means of understanding motivation, through assessing student's intrinsic, attainment, utility, and cost value of their experiences, has a bias towards social influences. I, therefore, remained open to the possibility that location, time, or other aspects may be equally, or more, influential. Searching for evidence, and understanding, of these factors assisted in reducing my researcher bias.
Remaining open to other possible explanations for witnessed outcomes and searching for alternative meaning to those outcomes helped protect against errors resulting from researcher bias. Constantly searching for an understanding of "what else might be going on here?" assisted other possibilities to come into view. Other questions I asked in order to remain open to other possibilities, explanations, or interpretations of the situation included: "What ways might students be interpreting _____ (various actions, comments, etc.)," or "Why might this _____ (action, comment, etc.) have been influential to student motivation," or "How does understanding this _____ (action, comment, etc.) inform my research question?"

As noted above, I entered the research understanding that there may be other, more relevant and influential, things going on in the situations that impacted student motivation, and achievement than those for which I specifically searched. Having several initially targeted focus areas, such as those emanating from my research sub-questions, allowed the investigative process to begin. Remaining open to other possibilities allowed space for other focus areas to emerge and were critical to developing a true understanding of what actually happened during this inquiry-based science unit. The use of video and audio recordings to revisit specific moments in time and/or exchanges between individuals allowed me to search for influences that may have initially been overlooked. These efforts allowed the ultimate attention of what was actually "of concern" to be focused upon and revealed.
LIMITATIONS of the RESEARCH:

There are several limitations to this research. First, the focus on participants from one school, during one seven-week curriculum offered insights into processes of inquiry-based science, but cannot be claimed to definitively reflect all possible examples of inquiry-based science. Further research that includes a greater sample size from a variety of classrooms and schools would be needed for more generalizable claims. The methodology of this project, however, mandated a small sample size in order to develop a rich description of what was taking place during each case. The method of participant observation and the numerous sources of data limited the research to a small sample size. The resulting case profiles, however, allowed meaningful conclusions to be drawn about each case and to make accurate comparisons.

A second limitation is that there were aspects of this project that were difficult to "tease out" of, but that were influential to, the results. For example, the fact that one class participated in off campus experiences inserted the problematic variable of location into the research. The factors of time and location did, most likely, have an influence on the process. Close attention to the influences of time and space needed to be, and were, maintained and evaluated throughout the research process.

In addition, the participant selection process presented two particular limitations to this research. First, the limitation of only one group of students per case and the need to have those groups similarly composed limited the overall understanding of IBS. The students were all of the same gender, thus
conclusions are best reflective of that gender’s experience yet none the less important research results are obtained; understanding how girls experienced IBS is important to our current abilities and efforts to attract more girls to science-related fields. A larger study with a larger sample and equal numbers of girls and boys would make this a stronger study in terms of being able to associate the results to a broader audience. I maintain, however, that my study’s focus on girls also presents the important benefit of developing a greater understanding of how girls experience science and act like scientists during IBS opportunities. The second manner in which the participant selection process was limiting is that my focused research was on students that had been labeled “higher ability.” This labeling presented two potential issues. First, the relation of social interactions to IBS outcomes is not generalizable to all ability level students. A larger study that investigates the social influences on all student ability levels would strengthen this study. Secondly, the label of “higher ability” was assigned to the students by the classroom teacher based on their current academic standing in his science class. It may be, however, that his instructional style may have simply been more suited to those students that were labeled “higher ability” and that the students excluded from the study actually would have demonstrated higher ability levels in this IBS unit.

Finally, the nature of qualitative research has an inherent risk of missing potentially significant aspects of the situation while being attentive to other aspects; it is impossible to attend to all things at all times. Having the ability to review video and audio recordings of much of the activity and student
discussions assisted with grasping a more holistic account of each case. As described in the "managing bias" section, I continually reflected upon "what else might be going on." Another potential limitation to qualitative research is its inherent nature to rely on researcher interpretation of the situation under investigation, the meaning of the collected data, as well as the recognition that "coding is a judgment call" because we "bring our subjectivities, our personalities, our predispositions, and our quirks to the process" (Sipe & Ghiso, 2004; p. 482 & 483). The manner in which I coded the data determined the categories that developed, the eventual themes that evolved, and finally my concluding assertions. The same research, coded by another researcher may have led to different codes, thus leading to different themes and conclusions. In order to protect against this possibility, however, I used student journal reflections and interview responses as member checks to my interpretations. Additionally, I worked extensively with a PhD researcher to establish inter-coder reliability before I collapsed codes into major themes.

Although there are several limitations to this research, much careful attention was given to developing an ethnographic study that can withstand scrutiny and yield meaningful results. Through this dissertation research, I have advanced our understanding of why IBS lessons may increase student achievement in, and motivation towards, science.
ETHICAL CONSIDERATIONS:

There are several ethical considerations with any research project. Aspects of particular importance for qualitative research include the manner in which the researcher presents him/herself to the participants, how much information is disclosed to participants, confidentiality of participants, and how to disengage once the research is completed (Schram, 2006). Here I explain how I attended to each of these concerns.

My role of participant observer required me to engage, and be present, with the participants without divulging too much information about my specific research aims. I disclosed my position as a researcher attempting to better understand how students experience inquiry-based science lessons. I selected not to disclose my specific interest in social interactions that take place because I feared knowing this information may cause students to speak and/or behave in ways they suspected I was seeking rather than what may have naturally occurred. Remaining somewhat general about my research purposes through partial disclosure allowed me to speak truthfully, yet still – as much as possible, “ensure that participants act and respond as naturally as possible” (Schram, 2006; p. 141). I told each class that I was investigating how students experience IBS lessons. They did not ask any questions about my research, so that is all I divulged.

All participants, and their parents, signed informed consent forms that had been approved by the Institutional Review Board (IRB) of the University of New Hampshire. Participants were informed of the general research purpose and
were informed that they could discontinue participation at any time without consequence. Participation in this project exposed students to minimal risk. The majority of students participated in the curriculum within the regularly scheduled class on school grounds. These students were not exposed to any greater risk than would normally have been expected during any school activity. One class of students, however, spent four full days and one half day, within regularly scheduled school hours, at the nature reserve. This experience exposed students to slightly higher risks as they were transported, via school bus, to an off campus location.

As part of IRB requirements, and to protect the confidentiality of participants, all data was kept locked in a secure area and the anonymity of participants was maintained. This was accomplished by assigning pseudonyms for individual participants, small groups, and class names. I also maintained respect and confidentiality of participants by being sensitive to the possibility of students not wanting recordings being made at particular times. I respected the wishes of the groups and individuals.

My eventual disengagement from the classes at the completion of my research coincided with the transition into the end of the year school activities at Central Middle School. My research coincided with an IBS unit that was the final instructional unit to be implemented by the teacher for the school year. As such, the ending of the unit and my research transitioned smoothly into end of the year activities and celebrations. This allowed my termination to go rather unnoticed.
SUMMARY:

This research project challenged the accepted belief that inquiry-based science lessons are primarily successful due to the "hands-on" and "acting like scientist" opportunities that are typically included in such lessons. Multiple data sources were used to construct detailed case profiles of two cases of an inquiry-based science unit. These case profiles were then used to identify themes that held true in both cases and those that were unique to one or the other. A qualitative, ethnographic approach situated me to understand the broader complexities occurring within inquiry-based science lessons and to uncover, and identify, additional explanations for the successes seen in these lessons. Specifically, I attempted to determine if the student social interactions that take place during inquiry-based science lessons and activities could be related, and if so how and why, to motivation and achievement outcomes in science.
CHAPTER 4

RESULTS AND DISCUSSION - Part One

Inquiry-based science (IBS) has long been touted as successfully promoting student achievement and motivation in science because of its tendency to include hands-on experiences and opportunities for students to act like scientists. I have argued that this explanation is inadequate to comprehensively explain the varying and inconsistent results obtained from IBS. I have further argued that other influences, such as student social interactions that develop during IBS lessons, may impact results obtained from IBS. My research investigated whether student social interactions, which are largely ignored within our current understanding of IBS, could be related to achievement and motivation outcomes of IBS.

I conducted a qualitative case study, consisting of two cases, using ethnographic techniques of participant observation. Specifically, I investigated the research question:

"Within two approaches to inquiry-based science, how do student social interactions relate to student motivation and achievement?"
I conducted this research within two eighth grade science classes in a small rural town in New England. A group of four girls, aged thirteen to fourteen years, comprised my research participants in each class, thus my research focused on eight students.

Students participated in the inquiry-based science curriculum known as Classroom Birdsleuth that was designed by the Cornell Lab of Ornithology. Students in both cases received instruction from the same teacher. Students in one case, which I named the “On-Campus” case, participated within the school science classroom as well as outside on school grounds during the implementation of student-generated research projects. Students in the second case, named the “Off-Campus” case, participated within the same science classroom, however students in this case traveled off-campus to a local nature reserve in order to implement the outdoor portion of their student generated research projects. I utilized multiple data sources, such as researcher field notes and observations, formal pre and post student interviews, informal student interviews, video recordings, audio recordings, digital images, and student artifacts which included written journal reflections, curriculum assignments, quizzes, and final projects, as entry points for understanding the lived experiences of the students.

I present the results of my research within four distinct sections that represent four specific time spans; the sections are titled: “The Concurrent Path,” “The Path Begins to Divide,” “The Path Divides Even Further,” and “Final Outcomes.” The Concurrent Path time span is presented here in chapter four, the
remaining three time spans are presented in chapter five. Time spans were differentiated based on the student social interactions and the motivation and achievement outcomes that emerged within each. The four time spans mark specific and notable similarities and differences bound in space and time and provide a means to discuss the progression of student experience as well as a platform from which to make comparisons between the two cases. The themes that emerged, as well as their relevance to IBS and the representative model of IBS that I developed as a result of my research, are discussed within each of the four sections.

Chapter Four Design:

In order to orient readers to the classroom dynamics that were present at the start of my research, I first present a general overview of the science classes I observed, and provide a brief introduction to the student participants. This background information sets the stage for tracking aspects of student social interactions and the contextual situations that led to student motivation and achievement. The background information is followed by an introduction to one of the major themes that emerged from my data. It is necessary for readers to understand this theme in order to comprehensively follow the line of evidence I present to support my final research conclusions. I begin with a general characterization of the science classes that participated in this research.
General Description and Characterization of the Science Class:

General Description:

I conducted this research within two eighth grade science classes at
Central Middle School (CMS). The teacher of these classes, Mr. Bradford or
Mike, was an energetic man in his late twenties and his fourth year of teaching
science. Mike's classroom was relatively neat and organized with clearly marked
areas for various aspects of classroom work; for example, there was a
designated area for classroom supplies, an area where students could pick up
extra handouts that had been distributed in class, and an area for storing student
projects. Student work was prominently displayed throughout the room.

The classroom configuration consisted of six octagon shaped lab tables,
four of which were connected to a perimeter counter area and thus formed
peninsula style tables and two were free standing, island style, tables. There was
seating for up to six students at each table, but Mike requested no more than five
students sit at any one table. Students did not have assigned seats in science
class, however most students tended to sit in the same seat each day; there was
no apparent reason for this other than students opting to sit with their friends.

Characterization of the Science Class:

I characterized Mike's classroom based on four characteristics: the overall
classroom climate, student comfort in class, student choice, and student feelings
about science class. These characteristics were selected because they
supported access to information relevant to my research questions and sub-
questions. These characteristics also aligned with the four categories from Gee,
relationships, significance, activity, and identity, which I utilized to focus my research observations and to understand the social interactions that emerged within each case and their potential influences on student motivation and achievement outcomes.

**Classroom climate:**

Influential to classroom climate is a student's comfort level within the class; students who are more comfortable, feel safe to participate without fear of ridicule or failure, and are more likely to engage in lessons, discussions, and activities (Wentzel et al., 2004). From the first moment of my entering Mike's science classes, I sensed a mutual respect and admiration between Mike and his students. Students entered the room enthusiastically and, although students were typically quite social as they entered class, they settled quite quickly upon indication from Mike that he was ready to begin class. Mike always spoke to the students calmly and typically started each class by asking students how they were doing. Students appreciated his inquiries into their wellbeing. One student, Kaylee, commented to me during our initial interview: "he asks us about our days or weekends. It's nice, it's like someone cares" (Kaylee, 4/12/2011).

Attending to, and understanding, the climate in the classroom throughout the project was imperative to my ability to answer my research question. Using my ISTREAM Observation sheet, which was developed to assist in focusing my observations on aspects of Identities, Significance, Triggers, Relationships, Emotions, Activities and Accomplishments, as well as Motivation, assisted my ability to notice both subtle and overt influences to classroom climate. For
example, I deliberately, and periodically, reviewed my ISTREAM observation sheet during each class to help ensure that I did not become fixated on one particular aspect and thus risked missing other important aspects. I scanned through my ISTREAM observation sheet an average of four times during each forty five minute class period and an average of six times during each sixty minute class period. I put a check mark in the corner of my daily field notes each time I scanned through the ISTREAM sheet in order to keep track and ensure that I reviewed the sheet at least three times per class. Of particular importance to my understanding, and characterization, of classroom climate were the ISTREAM categories of relationships, identities, emotions, and triggers. Each of these aspects influenced student engagement in conversations and activities.

**Student Comfort in Class:**

Several aspects of Mike's classroom fostered student comfort and confidence in class. Mike established a supportive environment for students. He expressed enthusiasm and encouragement whenever students participated in class discussions. Mike frequently posed questions to students during class discussions to assess whether students were grasping topics being discussed, and to encourage deeper probing and further understanding of the topics.

In addition to probing for content understanding, Mike also encouraged participation from each student in class conversations. Mike made a point to call on students who raised their hands to be called upon, but also periodically called upon those who did not. When asked why he deliberately called on students without their hands raised, Mike stated: "I want to assess whether they
understood what was being discussed but also because I want them to know that not only were they welcome to share their thoughts, but that it was safe, and somewhat expected, to do so" (Mike, April 8, 2011). Mike used a variety of strategies, such as rephrasing his questions or providing additional information, to encourage all students, even those with less confidence or who had not had their hand raised, to participate. Mike gently guided students who initially claimed they did not know the answer to a particular question in constructing an appropriate response. Mike was overtly supportive of students as they went about the daily science class activities; he regularly complimented students for their work and for their participation in class activities.

Mike’s practice of posting a daily agenda on the front board also added to student comfort in class. Most students habitually entered the room and checked the agenda to review the plan for the day; the posted daily agenda provided a means of communicating with students. Student comments about the daily agenda postings included: “it gives us an idea of what we’re going to do” (Audrey, April 12, 2011) and, when agenda postings were somewhat cryptically written, students expressed that “it sounds exciting, makes me curious” (Kaylee, April 12, 2011).

Mike created a supportive environment in which student’s felt encouraged, praised, and informed; this fostered student comfort. Such student comfort can trigger a student’s decision, and ability, to engage and participate which in turn can influence student achievement outcomes (Wentzel et al., 2004). In order for me to understand how student social interactions might be related to student
outcomes, I needed to understand how student comfort influenced student engagement and participation. Of the eight categories from my ISTREAM observation sheet, the four specific categories of identities, relationships, emotions, and triggers were used to guide my efforts in targeting my assessment of student comfort throughout the project. Understanding student comfort furthered my ability to answer my research questions, specifically those regarding the characterizations of student social interactions, discourse, and motivation.

Mike also provided opportunities for students to make choices and decisions. Such opportunities not only fostered a sense of comfort in class, but also provided students with a sense of control for their own learning.

**Student Choice:**

Students in Mike’s classes were encouraged, and expected, to make decisions. For example, students could choose where to sit and were sometimes expected to make decisions about how to complete various assignments. Some assignments permitted, or required, students to make decisions about what materials to use for the assignment, other assignments required students to make choices about how to proceed with the assignment. For example, students described a “Bottle Decomposition” lab as an example of when they were expected to make decisions, such as what decomposing materials to include in their “decomposition bottle,” but were expected to follow the teacher-designed procedure. Students described a “Sand-Sugar” lab as an example of when they were expected to make decisions about what procedures to follow.
The ability, and expectation, for students to make choices throughout class facilitated a positive classroom climate and a mutual respect between teacher and students. Through allowing students to make choices, Mike indicated to the students that he trusted them to make appropriate choices and that they had some control in their learning. Research, such as that conducted by Flick (1998), and Berg et al. (2003), has demonstrated that student perceptions of choice, and thus control, can be influential to IBS outcomes. Student choice leads to feelings of responsibility, freedom, and flexibility (Berg et al., 2003). Additionally, student perceptions of choice can lead to intrinsic value and motivation to participate (Schunk et al., 2008). Student perceptions of support and comfort foster positive emotions that further motivate students to engage (Wentzel et al., 2004). The aspect of choice, and student perceptions about choices available to them, was thus integral to my understanding of student engagement, interaction, and outcomes in science. Of the eight categories within my ISTREAM Observation sheet, the four specific categories of identities, triggers, emotion, and motivation, assisted my attentiveness to aspects specific to student choice. Understanding aspects of student choice was particularly helpful in answering my research questions that targeted student social interactions, discourse, and motivation. Student perceptions of classroom climate, comfort in class, and opportunities to make choices influenced student perceptions and overall feelings about class.
Student feelings about science class:

When I asked participants how they felt about science class, the general consensus was that Mr. Bradford's science class was a fun, and comfortable, place in which to be. According to the students, eighth grade science was "fun" (Leigha, April 11, 2011) and they "looked forward to coming to class" (Margaret, April 14, 2011). When asked to explain why they enjoyed science class, participants claimed they had the freedom to try new things without fear of ridicule or failure. One participant stated: "it's like we don't have to get every detail right. We have the freedom to try different things and see what happens" (Paige, April 11, 2011), and Margaret stated: "Everyone's just really supportive" (Margaret, April 14, 2011).

Students described eighth grade science as more enjoyable and interesting than their science experiences in previous years. When asked to describe what was different about their eighth grade science experience, participant explanations included claims that their experiences in eighth grade science were more hands-on and discussion based. They described having whole class discussions that included students sharing their thoughts, ideas, and opinions, while they reviewed, or discussed new, content material. One participant expressed: "it's nice getting to talk with everybody - like hear their feedback too- you know - not just your own opinion" (Lexi, April 13, 2011). This sentiment echoed the beliefs of the German philosopher, Johann Herbart, from the 1800's, who argued that content-related discourse exposed students to alternative viewpoints that ultimately assisted in developing student enjoyment,
and comprehension, of science (DeBoer, 2006). There was unanimous agreement from Mike’s students that eighth grade science provided their most enjoyable science experiences to date.

Understanding student feelings about science class at the start of my research revealed that students felt positive about, and comfortable in, Mike’s class prior to their experiences with this IBS unit. It was important for me to understand this from the start in order to avoid miss-assigning positive student attitudes towards science to be a result of this IBS unit rather than existing student sentiments. My efforts to understand student feelings about science were particularly facilitated by attending to the emotions category within my ISTREAM Observation sheet. Understanding student feelings and emotions was integral to understanding student’s willingness to engage with various lessons and activities, thus attending to the motivation category in my ISTREAM sheet was also important. The insights gleaned from understanding student emotions and feelings about science class provided a more comprehensive understanding of the student interactions and motivation that emerged.

The characterizations of Mike’s classes that are described above provided valuable insight into factors that influenced student engagement, interaction, motivation, and achievement within eighth grade science. In summary, Mike’s classroom provided a supportive and nurturing climate in which students felt safe and comfortable to participate, share ideas, and take risks without fear of failure. Additionally, students recognized that there were numerous opportunities for them to make choices and to take control of their learning. Students felt that
science was a fun and enjoyable class and that they enjoyed their eighth grade experiences more than previous years because there was increased opportunity for hands-on experiences and class discussions.

Understanding these aspects at the start of my research provided a benchmark from which to make evaluations throughout the IBS experience. Specifically, these characterizations, and the use of my ISTREAM observation sheet throughout my research assisted my ability to answer the first three of my posed topical research questions: 1) How can the student social interactions within each case be characterized; 2) How does student discourse within each case relate to student interactions and activity; and 3) How is student motivation characterized within each case?

My research questions were developed based on Gee's recommendations for accessing information needed to comprehensively understand the complexities of a particular phenomenon; in the case of my research, the phenomenon was student relationships and interactions within an IBS experience. My ISTREAM observation sheet was directly, and deliberately, correlated with my research questions. Table 3 specifically identifies how each classroom characterization category aligned with my ISTREAM categories. Table 3 also specifies which ISTREAM category is correlated to which of Gee's categories and to which topical research question. My ISTREAM observation sheet and the topical and sub-topical questions developed from Gee's categories were designed to provide multiple entry points from which to obtain and evaluate data required to answer my research questions. As such, a complete inclusion of
all category correlations would depict the overlap that facilitated evaluation of data from multiple entry points. I have restricted inclusions in Table 3 to be representative of only the most pertinent correlations from each category.

<table>
<thead>
<tr>
<th>ISTREAM Category</th>
<th>Gee Category</th>
<th>Topical Research Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom Climate</td>
<td>Identities Relationships</td>
<td>1- Soc. Int.</td>
</tr>
<tr>
<td></td>
<td>Identities Triggers Relationships Significance</td>
<td>2- Discourse</td>
</tr>
<tr>
<td></td>
<td>Emotions</td>
<td>3 -Motivation</td>
</tr>
<tr>
<td>Student Comfort</td>
<td>Identities Relationships Emotions</td>
<td>3 -Motivation</td>
</tr>
<tr>
<td>Student Choice</td>
<td>Triggers Activities Motivation</td>
<td>1- Soc. Int.</td>
</tr>
<tr>
<td></td>
<td>Triggers Significance</td>
<td>2- Discourse</td>
</tr>
<tr>
<td>Student Feelings about Science Class</td>
<td>Significance Emotions Motivation</td>
<td>3 -Motivation</td>
</tr>
<tr>
<td></td>
<td>Triggers Emotions</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Characterization alignment with ISTREAM and research questions.

The continued use of my ISTREAM observation sheet throughout my research was integral to my ability to remain attentive to areas of interest and pertinence to my research questions, as well as to remaining open to unanticipated areas of interest. Now that Mike’s science class has been characterized, I turn to a description of each participating class and how each class participated in the Classroom Birdscleuth curriculum. Following the description of how the curriculum was implemented within each case, I provide an introduction to my research participants.
The On-Campus Case: An Introduction to the Class

The class that comprised the On-Campus case consisted of fifteen students, eight boys and seven girls, who were thirteen to fourteen years of age. According to Mike, these students were of mid-to-high ability level. Ability levels were categorized by Mike based on previous performance scores in his science class. The class met for 45-60 minutes each day, at varying times throughout the week, for a total clock time of 240 minutes, or 4 hours, each week.

How Classroom Birdsleuth was Implemented in the On-Campus Case:

My research was conducted during the implementation of the inquiry-based science curriculum known as “Classroom Birdsleuth: Investigating Evidence;” I will refer to this as “Classroom Birdsleuth” from this point forward. The curriculum is intended to guide students through the process of designing, implementing, and evaluating, an original, student-generated, scientific investigation.

Following several introductory activities, the class broke into student-selected groups in order to design and implement their own bird-related investigations. Once students had determined their research questions, they created hypotheses and designed experimental procedures that would allow them to test their hypotheses and answer their research questions. They then implemented their experiments, gathered, graphed, and analyzed data, and made conclusions about their experiments and research findings. Finally, each group reported their findings to their classmates; first through a peer review process, and then through formal presentations. The irony of investigating an IBS
unit that followed the typical steps of "the scientific method" when I have argued that this interpretation is too narrow a perspective is not lost on me; this unit is, however, typical of IBS lessons implemented in schools. My research reveals how such applications of IBS can be improved.

Students in the On-Campus case participated in Classroom BirdSleuth during their regularly scheduled science classes. All curriculum activities were conducted within the eighth grade science classroom except for the implementation of, and data collection for, the student-generated research projects; this was completed outside on school grounds. During the time that students were developing their research questions, Mike took them outside to explore the various habitats within school grounds so that they could develop appropriate research questions for the area. Participants in the On-Campus case explored potential research areas during two class periods for a total of eighty minutes. While collecting data for their experiments, students went outside, during regularly scheduled science classes for a total of six class periods out of a total of forty-nine. By the end of the project, students in the On-Campus case worked on this project for a total of thirty-six hours and fifteen minutes. This differed from the Off-Campus participants by five hours and fifty-five minutes. The On-Campus participants ultimately had nearly fifteen percent less time than the Off-Campus participants to work on this project.

A Brief Introduction to the Four Research Participants in the On-Campus Case:

The On-Campus case consisted of four girls: Margaret, Kaylee, Audrey, and Kim. Margaret emerged as the clear leader in the group; if something
needed to get done, she made sure it got done. Kaylee provided the comic relief for the group. It was often Kaylee who noticed, and pointed out, the humorous side of comments or situations in class. Audrey was the quietest group member, but she kept the group organized. When anyone in the group was trying to find something, they turned to Audrey first for assistance. Kim was the dawdler in the group. If there was a slower way to do something, Kim found it. Her engagement in class fluctuated; at times she was clearly engaged and participated in class discussions and activities, and at other times, she was disengaged and withdrawn. Kim's situation, however, was a bit different than her peers. At the start of this project, she was slated to move out of town within a week. Some of her disengagement stemmed from her anticipated move as evidenced by comments such as: "I'm leaving in a couple days, so why should I do this?" (Kim, 4/5/11). Kim did move away after the initial week of this project; her family moved to North Carolina. She was gone for two weeks, but then returned; a job her mother had taken in North Carolina did not materialize as planned, so her family moved back to New Hampshire. Kim, Audrey, and Kaylee all turned to Margaret for direction and approval throughout the entire project.

How the group came to be:

When it came time to divide the class into their research groups, Mike explained that groups needed to consist of three to four students and gave students the choice of either choosing their own groups or having him randomly assign the groups. The class decided to select their own groups. Margaret, Audrey, and Kaylee immediately formed a group of three. Margaret noticed that
Kim had not joined a group so she invited her to join theirs. Kim gladly accepted the invitation.

The Off-Campus Case: An Introduction to the Class

The class that comprised the Off-Campus case for this study consisted of seventeen students, seven boys and ten girls, who were thirteen to fourteen years of age. According to Mike, these students were of mid-to-high ability level. Just as in the On-Campus case, ability levels were categorized by Mike based on student's past performance in science class. This class met each day at varying times for 45-60 minutes for a total clock time of 250 minutes, or four hours and ten minutes.

How Classroom Birdsleuth was Implemented in the Off-Campus Case:

Students in the Off-Campus case participated in the same “Classroom Birdsleuth” curriculum and received instruction from the same teacher as students in the On-Campus case. Like the On-Campus case, all curriculum activities and lessons, except the actual data collection for the student-generated research projects, which occurred outdoors, were taught within the eighth grade science classroom during regularly scheduled science classes. The Off-Campus case differed from the On-Campus case in two manners: 1) the time allotted for the data collection phase of student-generated research projects, and 2) the location in which those projects were executed.

The time allotted for the Off-Campus case to collect data differed from the On-Campus case in two ways. First, the data collection phase of the project
occurred during extended blocks of time rather than within the regularly scheduled class. This was an intentional difference between the two cases that was created in order to allow social interactions, which were the intended variable within my research, to potentially develop differently within the cases. Second, the total amount of time allotted for data collection in the Off-Campus case unintentionally exceeded the time allotted in the On-Campus case by approximately four hours and thirty minutes. The intent had been for both cases to have the same total amount of time to collect data, but that the time in the Off-Campus case would be structured within longer individual blocks of time. Although earnest efforts had been made so that the total amount of time for data collection in each case would be equal, logistical challenges, such as an underestimated calculation of time required to travel to and from the nature reserve as well as one unanticipated assembly prevented this from being the reality. This meant that the Off-Campus participants had four hours and thirty minutes longer to engage in IBS project activities as well as to discuss their work and/or casually socialize.

The location for student project implementation between the two cases also differed. In order to isolate student social interactions from other social influences that typically arise in school, such as lunchtime and recess, announcements, students passing in the hallways, as well as teachers and students going in and out of classrooms, the students in the Off-Campus case were taken to a local nature reserve to implement their projects. In order for students to be able to design research questions that would be appropriate to
conduct at the nature reserve, and to offer students in the Off-Campus case the same opportunity to explore existing habitats first-hand as had been done in the On-Campus case, Mike took the students to the nature reserve one morning specifically to investigate the area. This trip allotted students in the Off-Campus case a total of two and a half hours to explore and discuss potential research sites; the On-Campus case had been allotted one hour and twenty minutes. The ramifications of the differences in location and time between the two cases are discussed extensively throughout this chapter and chapter five.

A Brief Introduction to the Four Research Participants in the Off-Campus Case:

My research participants in the Off-Campus case also consisted of four girls: Lexi, Leigha, Paige, and Jessica. Lexi made sure tasks got completed; she quickly emerged as a strong leader within her research group. She readily took charge of any situation and swiftly delegated tasks. Leigha cared about how things looked, this included the presentation of her work. Although she strove to understand content material and to get good grades, she wanted her work to withstand the judgments of her own critical eye. Paige was easy-going, cheerful, calm, and appreciative of nature. She rarely seemed to get ruffled; when others in the group got anxious about meeting looming due dates, Paige simply picked up the pace with which she worked. The final member of the group, Jessica, struggled to keep pace with the other students in class and struggled to conceptually understand content material. Jessica did precisely what she was asked; she listened intently to directions, and tried just as intently to carry them out. When answering questions, she typically parroted responses she had heard
from her peers. The other girls in the group watched out for Jessica; they checked in with her frequently and assisted her in getting to the right material or task. Jessica, Paige and Leigha all turned to Lexi, however, for final approval; Lexi led the group through the process.

*How the group came to be:*

When it came time to divide the class into research groups, Mike gave students the choice of either choosing their own groups or having him randomly assign the groups. The class decided to select their own groups. When Mike gave the class time to decide on their project partners, this group of four girls simply looked at each other, smiled, and quickly agreed to work together. Lexi, Leigha, Paige, and Jessica became an official group.

Now that Mike's class has been characterized and introductions to participants have been presented, I wish to present the specific results of my research. It would be helpful, however, for readers to first understand one of the major themes that emerged from my research findings. Frontloading this theme here will allow readers to follow, and track, the presented evidence that leads to my research conclusions directly.

While working through the process of coding data and collapsing codes into themes, one particular theme surfaced repeatedly within the Off-Campus case that was noticeably lacking within the On-Campus case; this theme revolved around the notion of "flow." Participants in the Off-Campus case recurrently mentioned their ability to "get into a groove" (Lilly, post interview) or "flow" (Jessica, 5/26/11) with their work. The notion of flow emerged as clearly
influential to student experience, progress, and outcomes. My efforts to understand the influences of "flow" on student experiences and outcomes led me to an in-depth investigation of Flow Theory.

Flow Theory

Mihaly Csikszentmihalyi first described the concept of "flow" and developed what is now known as Flow Theory as a result of watching artists and musicians who were completely engrossed in the tasks of painting or playing music (Csikszentmihalyi, 1996). Csikszentmihalyi defined flow as: "a state of heightened consciousness, sharpened attention, and total immersion in the task at hand, which is accompanied by diminished self-consciousness, distorted perceptions of time, and a feeling of personal control over events" (Csikszentmihalyi, 1999). When one has entered into a flow state, "distractions are minimized and the person attains an enjoyable give and take with his or her activity" (Whalen, 1999). Csikszentmihalyi explained that when there is a balance between challenges presented and skills required to successfully complete those challenges, individuals willingly engage in the task at hand and enter into a flow state. From Csikszentmihalyi's depiction of flow, which is illustrated in Figure 6, it can be seen that if the challenge level exceeds an individual's skill for a particular task or activity, the situation can produce anxiety for the individual. In contrast, if an individual's skill level exceeds the challenge presented by the task or activity, individuals may enter into a state of boredom. In either scenario, whether leading to anxiety or boredom, individuals fall outside the range of conditions for optimal
flow and tend to disengage from the task or activity (Csikszentmihalyi, 1999). However, when skill and challenge level are matched individuals are more likely to enter into a state of flow and remain engaged in the task or activity (Csikszentmihalyi, 1999). Continued engagement, however, depends upon the continuation of optimal flow conditions, as new skills are learned, additional challenges must be presented or the individual falls out of the optimal flow boundary (Csikszentmihalyi, 1996).

Figure 6: Optimal Conditions for Flow as depicted by Csikszentmihalyi (1996)

This depiction of flow has since been used to explain individual engagement, not only in art and music, but also in an abundance of activities, including, but not limited to, dance, sports, such as rock climbing, and games, such as playing chess (Whalen, 1999). More recently, researchers, such as Hektner and Asakawa (2000), and Lerner & Israeloff (2007), have investigated how dimensions of flow influence adolescent behaviors and emotions and have
found that flow experiences can be correlated to concentration levels as well as feelings of enjoyment, motivation and self-esteem (Hanson, 1999).

Much of the existing research on flow has utilized the "Experience Sampling Method," or ESM, in order to access individual experiences with flow. The goal of the ESM is to repeatedly question individuals about the activities in which they are engaged, and their feelings during those activities, at random times (Moneta, 2012). Research participants have typically carried a beeper which sounded an alarm at random times; each time the alarm sounded, the individual completed a questionnaire about the activities they had been engaged in when the alarm sounded. Questions included items such as: When you were beeped, what were you thinking about? What were you doing? How did you feel about the challenge of what you were doing? How did you feel about your skills in the activity? (Moneta, 2012). The results of extensive research on flow led to the realization of several characteristics of being in a flow state and an awareness of what conditions are needed to promote states of flow.

**Conditions Required for Flow:**

Csikszentmihalyi identified three necessary conditions to create dimensions of flow: clear goals throughout the activity or process, immediate feedback, and a balance between challenges and skills (Csikszentmihalyi, 1996). When these conditions are in place, individuals are more likely to elicit characteristics of being in a flow state which include having focused attention, losing track of time, being in control, not worrying about failure, becoming less self-conscious, and enjoying the activity.
Extensive research, such as that conducted by Csikszentmihalyi (1996), Csikszentmihalyi (1997), Cziksentmihalyi & Hunter (2003), Fave, Bassi, and Massimini (2010), and Engeser (2012), has shown that individuals who enter into states of flow have enhanced performance in their artistic, athletic, and cognitive abilities as well as increased enjoyment, perseverance, and dedication towards the activities in which they are engaged (Engeser, 2012). As will be illustrated throughout the remainder of this dissertation, the conditions required for creating flow, those of having clear goals, immediate feedback, and maintaining a balance between presented challenges and skill levels, became integral to the experiences of my research participants as well as the ultimate outcomes of the IBS unit witnessed through my research.

Now that Flow Theory has been briefly explained, readers will be able to trace how flow emerged as a major theme from my research and how it became influential on research outcomes. I can now discuss my specific research results in relation to IBS and Flow Theory and illustrate how Flow Theory could be influential on future, and enhanced, IBS success. I turn now to the specific results of my research; I begin with the time span I named “The Concurrent Path.” All student quotes that are presented throughout the remainder of this dissertation are presented exactly as spoken or written by the students, including spelling and punctuation errors.
Specific Research Results and Discussion

Within each of the time spans, I present a brief description of the types of lessons and activities that were implemented. Having an awareness of the differences in the lessons is important because different social interactions emerged depending on the characteristics of the lesson. I then present detailed descriptions of the most salient lessons from each time span. Selected examples illustrate the typical social interactions that emerged within each case and allow me to illustrate how aspects of Flow Theory were a substantial influence on student outcomes. Other lessons are left out of my discussion only because they would bring an element of redundancy to the discussion.

The presentation of each salient lesson is formatted in a similar manner. I first present a brief description of the lesson. Each description is followed by a discussion of how my research participants engaged and interacted during the lesson. I then present the major emergent themes that related to my research questions and conclude each lesson discussion with a “Take Away Message” in which I summarize the main points I wish readers to understand. Finally, I conclude each time span with a discussion about how the lessons presented inform, and are informed by, IBS practices and Flow Theory.

The Concurrent Path: (April 4-May 3)

Results from this first time span include the first three weeks of the IBS unit; the time span also crossed a one-week school vacation. Lessons and activities during this time span included class discussions, worksheet exercises,
and brainstorming sessions for developing student research questions, hypotheses and for designing experiments. Students learned about, and practiced using, various types of science equipment such as HOBO® probes, Pasco probes, digital motion sensing cameras, electronic balances, and digital sound recording equipment. Students were also reminded of the more familiar equipment available for their use such as microscopes and pan balances.

Some lessons during this time span included hands-on activities and some included written tasks, some lessons included group work and some included independent seatwork. Two lessons that are saliently representative of student social interactions from this time span include “Hypotheses Testing” and “The Equipment Exploration” lessons; I present them below.

Testing Hypotheses: Description of Lesson

The purpose of this lesson was to ensure students understood the meaning of the word “hypothesis” and for students to practice creating hypotheses, both verbally and in writing, based on provided examples of research questions. During the lesson, Mike projected several examples of research questions and the class engaged in discussions that generated plausible hypotheses for each question. He also projected graphs of sample research results and the class discussed which hypotheses might be supported by what was seen in the graphs. The hypothesis lesson ended with Mike distributing a worksheet that included sample research questions and asked students to create appropriate hypotheses for each.
Testing Hypotheses: Research Participant’s Engagement

My research participants, in both cases, were less forthcoming in their contributions to the class discussion during initial conversations about the meaning of the word hypothesis. Once Mike began projecting visual images of the data, each of the girls participated by calling out answers to Mike’s questions.

During the worksheet exercise, all of the girls but Kim in the On-Campus case discussed the questions and compared answers as they worked. Kim reluctantly wrote responses to the worksheet questions only after Mike asked her to complete the work; this was expected to be Kim’s last week at the school and she was not invested in keeping up with what the class was doing. In the Off-Campus case, all the participants engaged in discussing and comparing their answers.

In both cases, the girl’s progress was sporadically interrupted by the interjection of random and irrelevant conversations such as Lexi’s announcement in the Off-Campus case that her hairdryer had broken. These random comments, however, derailed student progress on the hypothesis worksheets for at least two minutes with each interruption. Additionally, once students had completed their worksheets, they began chatting with, and distracting, the other members of their group who were still working. Once other students could be heard moving about in the hallway, students who were still working quickly packed up their materials and left. The sounds of other students in the hallway were not only noticed, but triggered students in Mike’s class to pack up and leave.
Participants were not particularly focused during this lesson; they were easily distracted and some packed up to leave even before they had completed the required worksheet. Participants were keenly aware of the time remaining in class as evidenced by their frequent glances at the classroom clock. Glancing at the clock appeared to be more out of determining how much time remained in class, and thus how much longer they would have to work on the worksheet, than out of an anxiousness to actually complete the worksheet in the time remaining.

Participant concentration and focus was lacking. Participants were easily distracted and acutely aware of how much time remained in class. Participants did not approach, or enter, states of flow.

**Testing Hypotheses: Relevant Themes that Emerged**

**Social Interactions:**

The social interactions that arose during this activity included those that were verbal, collaborative, and supportive. Most research participants verbally interacted with others in class during whole-class discussions about the term hypothesis. They verbally shared their ideas and provided answers to Mike's posed questions. Each of the girls, except Kim, worked on their worksheets and, at some point during the exercise, shared their answers with others in their group. Collaborative interactions included exchanging ideas and suggestions in order to work together in creating appropriate responses to the worksheet questions. The verbal and collaborative interactions provided students with feedback about their work and ideas. The interactions, and the feedback they provided, however, were frequently interrupted; discussions never progressed
past minimally required responses to the questions posed. Participant comments within the conversations were typically supportive, pleasant and positive; no one criticized anyone else's suggested responses.

**Emotions:**

The emotions that arose for participants during this lesson were primarily those of tolerance, perseverance, and boredom. Students tolerated the worksheet assignment; they acquiesced in getting the work completed, but there was little enthusiasm in their efforts. Boredom was evident from the ease with which students became distracted, their frequent glances to check the time on the clock, and their rapid and eager departure from class. Students did not enjoy this particular lesson.

**Discourse:**

My research participants contributed minimally to the whole-class discussions. Discourse that unfolded during this lesson was a mix of content-related and random off-topic comments. Content specific discussions involved the creation of hypotheses, but did not extend beyond what was minimally necessary to develop a response to worksheet questions; once a question was answered, students moved on to the next without further discussion.

**Achievement outcomes:**

By the end of this activity, participants were able to develop appropriate hypothesis statements when given a research question from which to work. Their ability to do this was evidenced by direct observations of them verbally crafting such hypotheses as well as by a review of a student journal reflection in which
students practiced creating hypotheses from given research questions. Additionally, two days after this lesson, students took a quiz that required them to develop hypotheses from sample research questions. In the On-Campus case, Margaret and Audrey both received a “100” on the quiz, Kaylee received a “93,” and Kim received a “70.” In the Off-Campus case, Lexi, Leigha, and Paige all received a “100,” and Jessica received an “83.”

**Testing Hypotheses: Take Away Message**

This lesson successfully met the intended purpose of teaching students how to create hypothesis statements. Students were not, however, particularly engaged with this lesson and they did not act like scientists as described by Wong and Hodson (2008); they had not challenged each other's ideas or engaged in sustained content-related discourse. They simply shared answers and moved on. The lack of physical, hands-on, engagement with material, as well as the more mundane nature of completing a worksheet, noticeably deterred student enthusiasm and interest during the activity. The girls cooperated and completed the work, but they were acutely aware of time remaining in class.

The lesson illustrates a palpable difference between lessons that are "hands-on" and directly engaging to students and those that are based on seatwork and less directly engaging. The outcomes of this activity support the research findings of Taraban et al. (2007) that claim lessons that involve more traditional, seatwork, activities are often less engaging than hands-on experiences that lead to elevated student enjoyment and engagement in science. These outcomes also support the claim that when students do not enjoy an
activity, they are less likely to engage in that activity (Schunk et al., 2008). The frequent glances to check the time on the clock and the quick packing up to leave revealed a lack of student enjoyment.

Another lesson yielding similar results to those of the "Hypothesis Testing" lesson was the "Meet a Scientist" lesson. I only briefly present this lesson here because it provides some additional insights into how social interactions, particularly verbal communications, influenced student interest and understanding of content-related material.

Meet a Scientist: Description of Lesson

The "Meet a Scientist" activity consisted of two worksheet exercises that introduced students to two different scientists and their research. For the first worksheet exercise, students were asked to read an information sheet about the scientist and then answer worksheet questions independently. For the second worksheet exercise, students were asked to read the scientist's information sheet aloud within small groups and then answer the worksheet questions collaboratively. The purpose of this activity was to expose students to authentic research being conducted by scientists and to showcase different research methods being used to conduct the research. Additionally, this activity was intended to illustrate the benefits of collaboration and various ways in which individuals can be contributing members of research teams.
Meet a Scientist: Outcome insights into IBS and Flow Theory

Just as had been seen in the “Testing Hypothesis” lesson, the task of completing worksheets was not inspiring to students. Students became easily distracted and glanced at the clock repeatedly. The benefits of having an opportunity to work together and to discuss the scientist’s work as a group, however, led to enhanced enthusiasm and student understanding.

Following the two worksheet exercises, Mike asked students to complete a journal reflection in which they explained which worksheet activity they had preferred and why. Pervasive comments, from both cases, such as: “I enjoyed doing the “Meet a Scientist” page better with a group” (Margaret, student journal reflection #4), revealed student preference of the group, collaborative, activity. Explanations for why they had preferred the group work included: “It was easier with classmates because they had ideas for answers I didn’t think of. It was easier with different points of views” (Kim, student journal reflection#4) and “With a group we got more opinions and more things were noticed than if we were working on our own” (Leigha; student journal reflection #4). Participants, in both cases, claimed to enjoy, and learn more from, the opportunity to discuss the scientist’s research as a group. For example, in the On-Campus case, Margaret stated:

By working in a group, I understood other peoples perspectives, and I was able to think more in depth about my own answers...reading and discussing the “Meet a Scientist” pages helped me to understand more about how the scientific process works. For example....I learned that
scientists help other scientists in other fields (Margaret; student journal reflection #4).

Similarly, in the Off-Campus case, Lexi declared:

having a chance to discuss the "Meet A Scientist" pages with my classmates helped me to better understand the scientist's work. I think that everyone in the class had a different perspective or take on the papers. It helped to hear them (Lexi; student journal reflection #4).

Margaret's comment about learning that scientists from different fields actually helped each other was the first explicitly expressed realization from participants that scientists collaborate. She realized, and verbalized, that part of what it means to "act like a scientist" includes collaboration. Her comment expanded the typical student interpretation of the term that had been reported in Alouf and Bentley's research (2003) that acting like a scientist meant going through procedural steps of an investigation.

Student written responses to worksheet questions, in both cases, were noticeably more thorough when students had been given the opportunity to discuss the questions with their peers. For example, when asked "What did the scientist wonder?" about a scientist who was involved in elephant research, one student's individual written response had been: "What the low humming of the elephants was" (Paige, Off-Campus case, Journal #2). The same question, however, when posed to a group given the opportunity to discuss the question and collaboratively develop an answer led to the following response: "How many elephants there are, where they live – in order to protect forest elephants and
their habitat from extinction. What other noises they make other [than] what
humans can hear” (On-Campus case, group response, Journal #3). The
opportunity for students to talk to each other and discuss the information had led
to more informative, in-depth, and content specific responses.

The comments from students in both cases supported the research
findings of Anderson et al.’s (2007) research that showed student participation in
scientific discourse increases student understanding of conceptual content.
Students in Mike’s class claimed, and demonstrated, an increased understanding
of content material as a result of their conversations with their peers. These
results also support the findings from Cross et al.’s (2008) research; researchers
from this study found that students who had engaged in content-related
discourse developed an increased enjoyment of the activity as well as increased
comprehension of the material being discussed. The outcomes illustrate that not
only did students enjoy working within a group more than working individually,
but they also were able to craft more detailed responses to questions posed
when they worked collaboratively. Such collaboration also more authentically
approached acting like scientists. Participants were able to express a deeper
conceptual understanding of content material when they had worked in a group.

Insights into IBS and Flow Theory:

The outcomes from these two lessons, “Hypothesis Testing” and “Meet a
Scientist” are important to our understanding of IBS. First, these activities
illustrate how a lack of hands-on involvement can foster student apathy. These
particular activities were not hands-on and student interest and motivation was
low. Although there were moments of enthusiasm and excited discussion, students typically appeared bored and disinterested.

Second, the outcomes illustrate the benefits of providing opportunities for students to engage in content related discourse. Students enjoyed the activity more when they had the opportunity to interact with their peers, they crafted more sophisticated responses to posed questions, and they gained a better conceptual understanding of content material through their discussions; they more authentically acted like scientists. Rather than rushing students directly into student-generated projects, which is what commonly happens in current practices of IBS, providing opportunities to investigate, discuss, and understand how different scientists go about conducting their research may increase student awareness of research possibilities. The “Meet a Scientist” activity helped students, at least to a small degree, to move towards the IBS goal of fostering student understanding that there are different ways for scientists to conduct investigations.

The outcomes of these activities also illustrate how Flow Theory can assist in explaining student achievement and motivation outcomes. According to the criteria set forth by Csikszentmihalyi, the students had never entered into a state of flow in either of these activities. They had fallen outside the range of optimal conditions for flow, had become bored, and had largely disengaged from the activities. Students had not lost track of time, in fact they had become quite aware of time, this was particularly true during independent work. During independent work, students received little immediate feedback from the teacher
or peers; students became bored and turned to stare out windows or packed up their materials. Although the goals, which had been to learn how to write a hypothesis and understand varying ways to conduct scientific research, were fairly clear, only minimal challenges were presented. Some heightened enthusiasm emerged when students engaged in class discussions about the scientists' research. These discussions provided opportunities for students to voice their understandings and ideas and provided at least some immediate feedback to their comments and thoughts. These lessons were at least partially successful in terms of student achievement; students learned how to create hypotheses and gained insights into two different ways in which scientists conduct investigations. The lessons were far less successful, however, in terms of student motivation. Students were largely disengaged; they had not experienced flow.

Two extensions of these activities, the "Exploration of Elephant Listening Project Website" and "Equipment Exploration" lessons, one of which was a hands-on activity, created considerable excitement within each class. A discussion of these activities follows.

**Equipment Exploration: Description of Lesson**

During the equipment exploration lesson, students were given the hands-on opportunity to practice using special sound recording equipment, such as parabolic dish and shotgun-style microphones, which were available for use at CMS. Mike spent about five minutes in each class explaining some of the basic
differences between the recording systems. He then provided time for the
students to simply play with the equipment and to figure out the specific
functionality and capabilities of the equipment through their own explorations. As
soon as Mike stated they could begin their explorations, students jumped out of
their seats and rushed to grab the equipment. Mike took students outside to
investigate the equipment for the entire class period. Students not only learned
how the equipment worked, but also considered how it might be utilized for
collecting data for their own investigations.

**Equipment Exploration: Research Participant’s Engagement**

Participants, in both cases, were completely engaged throughout this
lesson. Upon being given permission from Mike to begin using the equipment,
the girls immediately grabbed a set of equipment for their groups and quickly
walked through the hallways to get outside. Comments, such as “Whoa, that’s so
cool” (Leigha, Off-Campus case, 4/14/11), were common. Participants pointed
the microphones at each other, airplanes, cars passing by, even the ground in
efforts to “see if we can hear worms” (Kaylee, On-Campus case, 4/14/11). They
tested how far across the schoolyard the microphones could pick up the sounds
of classmates whispering. There was tremendous enthusiasm. Margaret, from
the On-Campus case, eagerly watched the expressions of her group-mates as
they put the headphones on and heard the intensity of the sounds for the first
time; there was much laughter at each new listeners reaction.

Participants were completely engrossed in the activity for the duration of
the class. They were actually astonished when Mike announced that class was
over; they had completely lost track of time.

**Equipment Exploration: Relevant Themes that Emerged**

**Social Interactions:**

Student interactions were verbal, physical, playful, collaborative, and cooperative. Physical interactions included rushing and nudging in front of others to be the first to get the equipment as well as collaboratively assisting each other to figure out equipment connections and to untangle chords. Verbal interactions were abundant throughout the activity. The discourse that emerged was both playful and investigative in nature such as suggesting and attempting to hear worms in the ground and to determine how far away from each other they could get and still hear each other's voices with the equipment. Discourse included content-related information such as using the technical names of the equipment, discussing sound waves and the Doppler effect, and suggesting experiment ideas. These discussions emerged from the students without prompting from Mike; he had only suggested they use the time given to explore the equipment.

During this experience, students had clear goals: to learn how to use the equipment and to explore similarities and differences between the microphone types. Students also received immediate feedback: they immediately heard variations in sounds depending on their actions with the microphones and they received feedback from their peers such as suggestions and compliments for creative ideas about what to listen to as well as through reactions to project suggestions.
Emotions:

Student emotions included excitement, enjoyment, contentment, confidence, and frustration. Student comments that indicated excitement and enjoyment included "Oh my God, that's so cool! I just heard myself" (Kaylee, On-Campus case, 4/14/11) and "I can't believe I can still hear them" (Paige, Off-Campus case, 4/14/11). Student actions, such as running across the room to grab the sound recording equipment also revealed enthusiasm and enjoyment. Some frustration surfaced when students were asked to wait until Mike had finished his instructions before handling the equipment.

Participants confidently used the equipment and eagerly engaged in their investigations. Their behavior was consistent with findings from research conducted by Wigfield and Eccles (2000), in which the researchers found that individuals were more likely to engage in activities in which they felt confident in their ability to succeed. Participants enjoyed this activity.

Acting like a scientist:

During the equipment exploration time, participants acted like scientists when they investigated the use of the equipment and manipulated the various buttons on the equipment to learn how the functioning of the equipment changed with each manipulation. Investigating the equipment also encouraged participants to consider and discuss the benefits and drawbacks of each type of microphone. These types of decisions were reflective of qualities that scientists in the study by Wong and Hodson (2008) identified as being integral to what they thought it meant to act like a scientist; scientists identified sharing ideas,
determining the functionality of equipment, and assessing the appropriateness of
its use as imperative to the success of their research.

Achievement outcomes:

Achievement outcomes included students successfully learning how to
use the different equipment, the differences in recording capabilities of the
equipment, and the benefits and limitations of each. For example, in the On-
Campus case, after having the opportunity to try both types of microphones,
Kaylee proclaimed: “I like the parabolic better, I feel like I can hear better”
(Kaylee, 4/14/11). Participants in both cases realized similar outcomes.

Equipment Exploration: Take Away Lessons

Participants, in both cases, enjoyed their hands-on explorations of the
different types of equipment. Similarly to what had been found by Schunk et al.
(2008) in their research, the intrinsic enjoyment of the activity had fostered the
motivation for students to remain engaged for the duration of the activities. The
level of personal interest, joy, and excitement that had arisen from the activity
seemed to increase the value perception of the activity and stimulated motivation
to engage.

Some of the most successful IBS lessons have been shown, by research
such as that conducted by Berg et al. (2003) and Taraban et al. (2007), to
emerge from student-generated projects in which there is student interest and
enthusiasm for the project. Providing students the opportunity to experience
excitement through their investigations of how the equipment worked fostered
interest and enthusiasm to engage. This increased interest could lead to the
continued use of the equipment and the incorporation of the equipment into student-generated projects. IBS lessons currently taught "hands-on" experiences as one reason for the success of IBS. This lesson, and the "hands-on" nature of student experiences, supports that assumption. This lesson also, however, illustrates the potential benefits of simply letting students "play" with the equipment and interact with their peers as they learn the practical capabilities and applications of the equipment.

Participants in this activity had established clear goals, they received immediate feedback, and the challenges presented were well matched with student skills. All three of the conditions necessary for entering flow were present. Students entered positions within the range for optimal flow experiences; students approached, and temporarily experienced, flow states.

I briefly discuss one additional lesson, the "Review of the Elephant Listening Project," because it clearly illustrates how student interest, motivation, engagement, and increased conceptual understanding can be achieved, and students can approach flow states, even without a hands-on component to their experience. This lesson provides another example of how Flow Theory, and setting conditions that encourage flow, can be directly connected to successful outcomes in IBS.

**Review of The ELP Website: Description of Lesson**

During this lesson, the Elephant Listening Project (ELP) website was reviewed because it facilitated a follow-up, more in-depth, discussion of one of
the scientists that had been introduced during the “Meet a Scientist” activity. The review of the ELP website also provided authentic examples of how sound recording equipment, which was available for student use at CMS, could be used for scientific research.

In addition to showcasing scientists research equipment, Mike used the contents of this website to introduce students to how visual displays of audio recordings, known as spectrograms, could be used to interpret sound recordings. CMS had a computer program known as “Raven Lite,” that converted waveform sound recordings into spectrograms, loaded on each of the science lab computers. This particular lesson taught students how to interpret spectrogram images. Spectrograms presented within the website, as well as their respective audio recordings, were used to facilitate Mike’s teaching students how to interpret sounds based on visual spectrogram displays. Mike showed students spectrograms from the website, asked students to interpret what they noticed in the spectrogram and to speculate about what the actual sound might be like; Mike also asked students to make predictions about what animal might have made the sound. He then played the sound for the students and asked them to modify their predictions if warranted based on the new evidence they had received. He then revealed an image of the animal that had actually made the sound.

Review of The Elephant Listening Project Website: Participant's Engagement

Participants in both cases were completely engaged throughout the duration of this lesson. They were intrigued, and determined, to correctly assess
the origins of the sounds. Mike played the sounds several times, much to the
delight of the students, before revealing the sound origins. Once announced,
there were frequent looks of amazement and much laughter amongst the
students. Each sound challenge brought considerable focus and excitement to
the participants. Comments, such as "that is so crazy" (Margaret, 4/8/11), were
common within both cases. Sounds that were familiar to participants brought
enthusiasm, confidence in calling out guesses, and a sense of pride in knowing
what animal, such as a loon or a whale, had made the sound. Even Jessica, in
the Off-Campus case, who tended to be quite reserved and typically only
parroted what she heard others say, excitedly called out original guesses. Her
behavior reflected the research findings of Wigfield and Eccles (2000) in which
the researchers found that an expectancy for success led to student engagement
and willingness to take risks. The familiarity of some of the common and
recognized sounds fostered Jessica's confidence in her ability to be successful
and she engaged, enthusiastically, in the activity.

Successful guesses of sounds motivated, and excited, participants to call
out guesses for less familiar sounds. Each time Mike projected a new
spectrogram, or played a new sound, participants became focused. Audrey and
Margaret, in the On-Campus case, and Paige and Leigha, in the Off-Campus
case, even sat at the edge of their seats. They enjoyed the sound challenges and
attempting to identify the sound origins; they also enjoyed the competition to be
the first to call out a correct answer. Participants remained engaged throughout
the entire class and completely lost track of time. Mike had to announce when
class was over and usher students out the door; students protested and pleaded for him to “play just one more!” (Margaret, 4/8/11).

All three of the conditions for fostering flow were present in this activity: students had clear goals to interpreting spectrograms and determine what animal had made the sounds, students received immediate feedback through the reactions of peers to their guesses and by hearing the audio recordings, and student skills were well matched with the challenges presented. Existing knowledge about sound and waveforms was correlated with spectrogram interpretations and a progression from familiar to less familiar sounds sustained a balance between challenge and skill.

Review of The Elephant Listening Project Website: Themes that Emerged

Social Interactions:

The exploration of the ELP website elicited verbal interactions between participants, classmates, and the teacher. The guesses, discussions, comments, and feedback from others all communicated information to the students. Discourse included primarily content specific information, such as describing details noticed within the spectrograms and the implications of the noticed details. Discussions were focused on the task of interpreting the spectrograms. Some good-natured teasing about some inaccurate guesses arose as well as celebratory cheers, high-fives, and fist pumping when correct guesses were shared. Interactions were playful and supportive.
Emotions:

Participant emotions included excitement, enjoyment, happiness, and some frustration. Concentration and smiles on student faces revealed their excitement and enjoyment with the activity. Some frustration occasionally emerged when a correct answer got called out before another student was able to make their guess; frustrations, however, quickly dissipated as each new challenge was presented.

Acting like a scientist:

Students acted like scientists as they interpreted characteristics of sounds based on what was seen in the spectrograms and by making informed assessments about what organism had made the sound. Once the sounds were played, thus giving students additional information, students reassessed their original answers, and made adjustments as necessary based on the additional information they had received. Students also competed with, and challenged, each other to assess and be the first to correctly interpret the sounds. These student undertakings were reflective of those discussed in the Wong and Hodson (2008) study in which scientists described various actions such as using technology to gather and interpret data as examples of acting like a scientist. The scientists also claimed that evaluating information and reassessing original conclusions based on new evidence, as well as challenging, or competing with, other scientists were indicative of acting like scientists. None of my research participants, however, revealed any recognition that their actions and comments about the spectrograms and sounds had been reflective of acting like scientists.
The lack of student realization that these activities were reflective of scientist's behaviors was consistent with research findings that students perceived acting like a scientist as being primarily "procedural" (Wong & Hodson, 2008).

**Achievement outcomes:**

Participants learned how to interpret spectrograms. As the lesson progressed, participants increasingly realized and came to understand that the structure of the spectrograms visually portrayed specific characteristics of sound such as pitch, volume, and the presence of harmonics. Students became increasingly accurate in interpreting whether the pitch of sounds was high or low, ascending or descending, and whether sounds were continuous or interrupted. Academic achievement gains from the review of the ELP website included an increased understanding of different types of research being conducted by scientists, different research methods and equipment used by scientists, the differences between waveforms and spectrograms, as well as an ability to correctly interpret sound qualities depicted within a spectrogram.

*Review of The Elephant Listening Project Website: Take Away Message*

This lesson further illustrates how setting the conditions required for creating flow can lead to focused concentration, motivation, and academic achievement. The presence of all three conditions for entering states of flow were present and triggered a willingness and enthusiasm to engage. The combination of familiar sounds with unfamiliar sounds had provided comfort and challenge for the participants. Mike had skillfully crafted student exposure to spectrograms in a manner that progressed from initially being unfamiliar to students in order to
spark student curiosity, followed by familiar sounds to foster student success with spectrogram interpretation, followed once again by less familiar sounds in order to challenge students to apply their new and increasing knowledge to the less familiar examples. Students were shown a format of data, spectrograms, with which they were initially unfamiliar, and given opportunities to investigate this new format of information in a non-threatening, enjoyable, and challenging manner.

During this lesson, students had maintained focused concentration, self-consciousness dissipated as evidenced by the ease with which students freely shared their ideas, the experience was intrinsically rewarding, and students lost track of time. They had clear goals, received immediate feedback, and maintained a balance between skills required and challenges presented; the progression of this lesson sustained optimal conditions for flow.

**Insights into IBS and Flow Theory:**

The outcomes of these two lessons, "Equipment Exploration" and "Review of the Elephant Listening Project," are important to our understanding of IBS and how Flow Theory can be used to inform IBS practices in three ways. First, these lessons illustrate that when conditions are created that include those necessary for initiating states of flow, students become motivated and positive achievement gains result. During both of these activities, students had clear goals, received frequent and immediate feedback, and sustained a balance between skills required and challenges presented. Students enjoyed these activities and they remained engaged for the entire class period and lost track of time. Only one
student was noticed checking the clock on the wall for time and these time checks appeared to be more out of concern that class would end too soon rather than it could not end soon enough.

Second, the outcomes of these lessons challenge the commonly accepted notion that a primary reason IBS lessons are successful is because they offer hands-on opportunities for students. One of these lessons included a hands-on component and the other did not, yet both were successful. The “Review of the ELP” lesson did not include any hands-on activity; the students touched nothing, they manipulated nothing. Yet, there was considerable motivation and achievement gains were made. This lesson illustrates that student achievement and motivation can be achieved from lessons that do not involve hands-on experiences. This lesson further illustrates that such motivation and achievement can be fostered through setting the conditions that foster flow.

Third, these lessons challenge limitations presented by our current focus on an IBS continuum that focuses on a progression of student experiences from those that are teacher-directed through those that are teacher-guided and then to open inquiry experiences. The outcomes of these lessons suggest that shifting our focus to an IBS continuum that assesses the frequency and duration in which the conditions necessary for initiating and sustaining flow are included in IBS experiences may more directly foster enhanced outcomes from IBS lessons. These activities illustrate the desirable outcomes of enhanced student motivation, participation, interest, knowledge, and skills, which emerge from instructional efforts that include setting the conditions necessary for entering states of flow.
Before presenting a summary of this time span, I wish to discuss two factors that were of concern throughout my research because of their potential influences to student outcomes. These factors of concern were location and time; I introduce them here so readers can track their influence on student outcomes.

**The Influence of Location:**

During this time span, all instruction occurred at CMS. Location did not have any substantial influence on student participation in the lessons or activities. Near the start of the unit, Mike announced to the students which class had been randomly selected to be the one to travel to the local nature reserve in order to implement their actual experiment. When the announcement was made, there was no discernable reaction from the students in the On-Campus case. One student expressed relief to be staying at school and claimed that it would be easier to stay on track in all of their other classes. Two students did express some dismay, but this was short-lived; students quickly moved on with other activities. There was similarly minimal reaction to the announcement from participants in the Off-Campus case. Within this group, a slight sense of good fortune amongst the participants was emitted as indicated by their smiles and focused attention while Mike explained the situation to the class. There was not, however, any additional reaction or outward response to the announcement.

Although there was minimal outward reaction to the announcement that the Off-Campus case would be the class traveling to the nature reserve to implement their experiments, this knowledge did become an influence to the project idea that ultimately was developed by the research participants in the Off-
Campus case. The extended time that would be available while at the reserve did ultimately factor into student decisions.

The Influence of Time:

During this time span, the classes received nearly identical amounts of class time and instruction. At the end of this three-week period, the On-Campus case had received 760 minutes, and Off-Campus case had received 755 minutes of instruction; only a five-minute difference existed in total time between the two cases. However, on three different occasions during conversations among participants in the Off-Campus case, the girls mentioned an awareness, and potential influence, of time. For example, while discussing how they would collect the necessary data for their intended experiment, Lexi commented: “we’ll have all day over there [the nature reserve] to collect data” (4/19/11). The realization that they would have extended time while at the nature reserve to implement their projects and gather data potentially influenced their confidence in their ability to be successful. Their awareness of extended time also potentially influenced their commitment to an investigation involving the use of the sound recording equipment; they felt they had adequate time to successfully complete such a research challenge.

The results from the four lessons described from this time span were typical of other lessons presented during this time. A summary of these lessons and their relation to IBS and Flow Theory follows.

The Concurrent Path: Time Span Summary:

At the end of the initial three weeks, the participants in both the On-
Campus and Off-campus cases were on similar paths in terms of their experiences, their progression through the curriculum lessons, motivation levels, and academic achievements. Overall, lessons in which there were written worksheet requirements and less direct interaction with peers led to higher levels of boredom and more frequent distractions and interruptions to student progress. Although students had clear goals throughout the lessons, they received little immediate feedback, and the skills required to complete the challenges presented were minimal. Students did not approach or enter states of flow during such lessons and their level of engagement was low. During such lessons, students were acutely aware of time remaining in class. In contrast, lessons in which students had clear goals as well as immediate feedback and experienced a balance between skills required and challenges presented stimulated student interest and engagement. During these lessons, students elicited focused attention, enthusiastic participation, and lost track of time.

A summary of the lessons from this time span as they relate to the conditions required for flow is depicted in Table 4. When all three conditions for flow were present, participants entered into states of flow. Table 4 also reveals the importance of sustaining a balance between the skills required to successfully complete in order to sustain flow. For example, one can see that during the "Hypothesis Testing" activity, although all three conditions for flow were initially present, once students learned the skill of creating a hypothesis, only minimal challenge was present and students never entered a flow state. One can also see that presenting different or increasing challenges throughout
the experience assisted in maintaining a balance between skill and challenge and fostered students approaching and temporarily entering states of flow.

<table>
<thead>
<tr>
<th>Conditions for flow:</th>
<th>Hypothesis Testing</th>
<th>Meet a Scientist Equipment Exploration</th>
<th>Review of ELP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear Goals</td>
<td>Stated by teacher at start of lesson Complete worksheet</td>
<td>Stated by teacher at start of lesson Complete worksheet</td>
<td>Stated by teacher at start of lesson</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Immediate Feedback</th>
<th>Immediate from peers</th>
<th>None during solo work Immediate during group work from peers</th>
<th>Immediate and frequent from peers</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Balance Between Skill and Challenge</th>
<th>Once skill was mastered, no new challenge presented. Balance not sustained; fell below optimal range for flow</th>
<th>Minimal challenge presented (pull information from text) Balance not sustained; fell below optimal range for flow</th>
<th>Multiple challenges presented and skills required Balance sustained Different challenges required different skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of Flow:</td>
<td>No</td>
<td>No – during solo work</td>
<td>Yes - extensive</td>
</tr>
<tr>
<td></td>
<td>No - during solo work</td>
<td>Yes - extensive</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Representative Lessons and Conditions for Flow

In Table 5, I present a summary of the frequency in which participant engagement was evident or lacking, positive feelings or actions were expressed, the number of content specific conversations that emerged, as well as the number of instances in which participants clearly acted like scientists within each case. Although many more instances of each occurred, for the comparisons.
within this table, I included only those instances that were clearly distinct examples of each category. As can be seen from Table 4, the frequency of occurrence for each of the categories, as well as the number of sources in which each category emerged from the data, were nearly identical across the two cases.

<table>
<thead>
<tr>
<th></th>
<th>Frequency of Occurrence in the On-Campus case</th>
<th>Frequency of Occurrence in the Off-Campus case</th>
<th>Number of Sources in which evidence appeared in the On-Campus case</th>
<th>Number of Sources in which evidence appeared in the Off-Campus case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant engagement was evident for the duration of class (flow present)</td>
<td>5</td>
<td>5</td>
<td>2 (researcher field notes, video)</td>
<td>2 (researcher field notes, video)</td>
</tr>
<tr>
<td>Participant engagement was lacking or waned through class (flow lacking)</td>
<td>10</td>
<td>10</td>
<td>2 (researcher field notes, video)</td>
<td>2 (researcher field notes, video)</td>
</tr>
<tr>
<td>Positive emotions, feelings or actions</td>
<td>27</td>
<td>33</td>
<td>4 (researcher field notes, video, 2 student journals)</td>
<td>4 (researcher field notes, video, 3 student journals)</td>
</tr>
<tr>
<td>Content related discourse</td>
<td>17</td>
<td>14</td>
<td>2 (researcher field notes, video)</td>
<td>2 (researcher field notes, video)</td>
</tr>
<tr>
<td>Acting like a scientist</td>
<td>12</td>
<td>11</td>
<td>4 (researcher field notes, video, 3 student journals)</td>
<td>4 (researcher field notes, video, 2 student journals)</td>
</tr>
</tbody>
</table>

Table 5: Category Frequency and Occurrence Across Cases

Making comparisons within the table reveals that both cases had equivalent experiences with states of flow; flow emerged consistently across cases and was dependent upon the type of lesson. The table also reveals that expressions of positive feelings were roughly equivalent between the two cases, with the Off-Campus case expressing slightly more instances than the On-
Campus case. The On-Campus case, however, slightly exceeded the Off-Campus case in their engagement in content-related discussion. One can also see, from Tables 4 and 5, that participants in both cases demonstrated a propensity towards flow when the conditions for flow had been set.

Although both cases ended this time span with similar experiences and outcomes, it is important for readers to understand the outcomes of this time span for two reasons. First, the results illustrate that participants in both cases were equally responsive to conditions of flow. Participants in both cases approached and temporarily entered into states of flow, in which they sustained focused attention, were less self-conscious, enjoyed the activity, and lost track of time, when the conditions for flow had been set.

Second, participants in both cases were able to experience states of flow within the regularly scheduled 45-60 minute classes. This demonstrates that, although there may be clear advantages to having longer class periods in which to experience flow, it is possible to enter into flow states within the forty-five to sixty minute class periods that are typical of most school schedules.

By the end of the first three-week time span, participants in the On-Campus and Off-Campus cases were on concurrent paths. The amount of class time had been nearly identical. The contextual situation and opportunities to engage within each case had led to similar student interactions, student emotions, levels of intrinsic motivation, and achievement outcomes. When activities included opportunities for students to interact, student enjoyment was enhanced, discourse included content discussions, students approached and
entered flow states, and enhanced motivation ensued. This pathway, which is illustrated within Figure 7, led to similar student outcomes.

Figure 7: Pathway of common outcomes from the Concurrent Path Time Span (Blue/dark arrows represent the On-Campus case; Red/light arrows represent the Off-Campus case).

Within each case, conditions for flow consistently influenced student outcomes. When the conditions for flow were present, students became more intrinsically motivated to actively engage in the lessons and lost track of time. Students, in both cases, also more authentically acted like scientists; they shared ideas, experimented with scientific equipment, they wrestled with analyzing data, and they challenged each other’s suggestions. When the conditions for flow were absent, students became disengaged and acutely aware of time. Achievement outcomes were consistent across cases. Dimensions of flow were influential on student outcomes in both cases. By the end of this time span, students experienced states of flow with equivalent frequency and duration; motivation and achievement outcomes were comparable across cases. Student experiences with flow in each case began to differ, however, as the unit progressed; student outcomes also began to differ. Chapter five illustrates this divergence.
CHAPTER 5

RESULTS AND DISCUSSION – PART TWO

The research results that are presented in Chapter Five begin when differences between the On-Campus and Off-Campus cases began to surface. Once participants began their field experiences, initially to explore potential research sites and then to implement their student-generated experiments, the paths between the cases began to diverge. Throughout this chapter, I present evidence that illustrates how Flow Theory can be used to enhance and explain student achievement and motivation outcomes in IBS experiences and how it can be used to improve IBS practices.

Chapter Five Design:

I divide Chapter Five into three distinct sections entitled: “The Paths Begin to Divide,” “The Paths Divide Further,” and “Ultimate Outcomes.” These sections are delineated based on differences in student interactions and/or achievements that emerged within each; they mark specific and notable differences between cases that were bound within space and time. Within each section, I describe a salient example of the student social interactions that emerged. I present my findings in a similar format to that used in chapter four, presenting first a brief
description of the main lesson or activity, followed by a discussion of participant engagement during the lesson or activity and the major themes that emerged. Each section also includes a “Take Away Message” in which I summarize the main points from the section and make connections between the results obtained, IBS, and Flow Theory.

Throughout the chapter, I track the evidence that led to my research conclusions and to the model I ultimately created to represent how students experienced this inquiry-based science curriculum. I begin with the time frame called “The Paths Begin to Divide.”

The Path Begins to Divide: (May 4- May 12; an eight-day time-span)

During this time span, participants in the On-Campus case explored potential research sites on school grounds as well as neighboring woods and fields; participants in the Off-Campus case explored a local nature reserve. In this section, I present student experiences during these explorations and discuss how emergent themes inform, and are informed by, IBS and Flow Theory.

Exploration of Research Sites: Description of Activity

The purpose of the research site explorations was to increase participant awareness of the various habitats that existed in the areas where students would be implementing their investigations. During these explorations, Mike deliberately took students to areas with similar habitats; students in each case explored areas around and within a woodland, a field, a transition zone between woods and field, a wetland area, and a parking lot. Upon arriving at each area, Mike first asked
students to make general observations of the area and then engaged each class in a conversation about what they had noticed. He consistently complimented students for sharing their observations and asked students to discuss what types of experiments could be conducted within each area.

Students in the On-Campus case conducted their explorations within eighty minutes, spanned across two class periods. Students in the Off-Campus case were allotted one hundred and fifty minutes, during one morning visit to the nature reserve. The influences of this seventy-minute time difference, as well as influences relevant to location, are discussed following a description of student experiences during two activities and the themes that emerged. I begin with participant experiences from the On-Campus case.

On-Campus Case: Research Participant Experience

Upon arrival at each potential research site, students were given approximately thirty to forty-five seconds to make their initial observations of the area. The class then spent between five and eight minutes discussing possible research projects that could be conducted within each area. These discussions continued as the group walked from one site to the next; as a result, only students who happened to be close to Mike engaged in, or heard, Mike's comments and peer suggestions for potential research topics. During one such walk to a subsequent site, Mike pointed out invasive bittersweet vines and explained how the vines may have been dispersed to the area; only a small group of students heard his comments. Additionally, as the class moved between locations, small groups of students staggered along at different rates, breaking
the class into splintered factions. Once back in the classroom, Mike allotted the remaining class time, which in the On-Campus case was twelve minutes, to brainstorm project ideas within their groups and to begin settling on two possible research questions.

**On-Campus Case: Research Participant’s Engagement**

My research participants were intermittently engaged during their explorations of potential research sites. During the discussions that unfolded at each site, Margaret and Kaylee shared their observations of the area, but none of my research participants shared any ideas for potential research projects. As the class walked between each potential research area, my participants chatted amongst themselves about random topics such as the clothes they had on and movies they wanted to see. During the class time given to brainstorm project ideas, they chatted sporadically about ideas, such as investigating whether more birds would be found in a wooded area or an open field, but primarily about irrelevant and random topics. The limited time remaining in class triggered a sentiment among participants that there was not enough time remaining to discuss ideas in any detail, so why bother. The girls did not discuss, or commit to, any research question or idea; class ended. The experience for Off-Campus participants, however, was quite different.

**Off-Campus Case: Research Participant Experience**

Students in this class had originally displayed little reaction to the announcement that they had been selected to conduct their investigations at the nature reserve. On the day of the student’s initial trip to the reserve, however,
student excitement and enthusiasm for the trip was palpable before they left school grounds. Students entered the classroom with tremendous enthusiasm and energy. One student excitedly asked Mike if they would be allowed to walk off the designated trails while at the reserve. Mike replied: “Yes. In fact, you have been given special privileges. Most visitors have to stay on the boardwalks, but since you are doing research, the reserve is allowing you to go off the trails into other areas” (Mike, 5/4/11). Students were visibly pleased with this announcement and the special status that had been awarded to them by the nature reserve staff; they smiled and nodded their heads, in a swaggering manner, as if in agreement and approval of their special status. This sense of privilege elevated student enthusiasm about going to the nature reserve.

Additionally, as the group prepared to go, there was notable excitement as participants gathered supplies and passed equipment from group to group; they even excitedly announced what snacks they had brought and were willing to share with the group. A sense of increased camaraderie began to form. This class began to form an identity; they were the class that got to go to the nature reserve and had been granted special privileges.

While at each potential research site at the nature reserve, Mike permitted nearly three minutes for students to make their initial observations of the area. The class discussed their observations at each site as a group before moving on to the next area. Rather than pointing out and explaining any prominent features of the area, such as noting invasive phragmites reeds that existed in the marsh, Mike encouraged students to discuss and come up with explanations on their
own. As a result of this discussion strategy, students engaged in content related discourse. Students also shared ideas and both Mike and their peers provided feedback about the ideas that were shared. Students ultimately developed reasonable, and plausible, explanations for why certain conditions, such as the presence of invasive reeds, had evolved.

Just as Anderson et al. (2007) had found in their research, the opportunity to engage in content-related discourse increased student understanding of the content related material. In the study conducted by Anderson et al. (2007), the researchers investigated the relation between content-related discourse and student achievement. Students in high school astronomy classes were asked to respond to content-related worksheet questions based on content information they were given within an answer rubric. The researchers found that the students who had been given more detailed answer rubrics engaged in more in-depth and content-specific discussions and created more conceptually sound responses to the posed worksheet questions than their peers who had been given less information; these students also outperformed their peers on classroom and standardized tests (Anderson et al., 2007). An unknown that remained after Anderson et al.'s study was an understanding of whether students needed to be provided with information in order to stimulate discussion and develop conceptually sound responses or whether they could develop such responses on their own. The results of my research indicate that opportunities to discuss thoughts and ideas and receiving immediate feedback about such thoughts and ideas can move students towards conceptually detailed, and sound, responses to
questions and understanding of content-specific material. Students in my study had not been given additional, content-specific, information from the teacher; they had simply been given the opportunity to discuss, provide feedback, and collaboratively develop sound explanations and understanding.

At each potential research location, Mike also facilitated a group discussion about potential project ideas that could be implemented in that area. These discussions were inclusive of the entire class; the group remained gathered together and everyone was able to hear the conversation. The length of these discussions averaged approximately twelve minutes.

Additionally, at the conclusion of their site explorations, Mike conducted a debrief circle with the class in which they shared their observations from the day as well as their project ideas. This gave students another opportunity to share research ideas and to receive feedback from both their peers and Mike; no such debrief circle had taken place within the On-Campus case. The debrief conversations provided students from the Off-Campus case a chance to formulate and verbalize their research ideas. In so doing, students not only were able to assess the feasibility of their project ideas, but also received immediate feedback about their ideas. Students were able, at least partially, to act like scientists as described by scientists themselves in a study conducted by Wong and Hodson (2008). In this study, one aspect of acting like a scientist, as described by scientists, was to engage in discussions with other scientists in order to evaluate ideas, information, and research plans, and to make adjustments to their ideas and plans based on the outcomes of such discussions.
(Wong & Hodson, 2008). Students in my research shared and discussed possible research ideas with their peers, they reassessed original ideas and research plans based on peer feedback; they adjusted their ideas, thoughts, and plans based on insights gained just as the scientists in the Wong and Hodson (2008) study claimed was reflective of acting like a scientist. Students in the Off-Campus case also began settling on project ideas during this debrief circle.

**Off-Campus Case: Research Participant's Engagement**

My research participants eagerly engaged in the day's activities. They enthusiastically gathered supplies before leaving school, they participated in conversations while at the nature reserve, and they eagerly shared their potential research ideas with the entire class during the debrief circle. As students walked from site to site, the girls in my research group also engaged in random conversations, such as softball practice and complaining about the humidity. Although the girls had not decided on a specific research question by the end of their visit to the reserve, they had definitively decided to conduct an investigation that would somehow incorporate sounds of birds into their project.

**Exploration of Research Sites: Relevant Themes that Emerged**

**Social Interactions:**

Throughout my research, I attended specifically to student social interactions that seemed to positively or negatively influence student progress within, and/or motivation towards, their projects. During this activity, verbal and physical interactions were noted within each case. In both cases, students engaged in content-related conversations as well as random, off-topic
conversations. Content-related discourse emerged with greater frequency within the Off-Campus case. In both cases, playful physical interactions, such as kicking rocks and bouncing on logs were seen; participants in both cases enjoyed their explorations. In general, however, the interactions within the On-Campus case were subdued and in the Off-Campus case were lively and enthusiastic.

The interactions noted were typical of those that emerge during IBS lessons in several ways. Students investigated possible research sites and, at least to some extent, discussed possible research ideas. The On-Campus case experiences were reflective of many IBS lessons in that they were rushed from site to site and not allotted much time or encouragement to delve into in-depth conversations. The On-Campus participants had clear goals throughout the activity; they were to make observations of each site, notice characteristics of each site, and consider possible research questions. During the discussion that did take place, there was little opportunity to give or receive feedback to observations and ideas shared. Only minimal challenges were presented as the teacher either told students information or answered their questions rather than having them wrestle with developing an answer of their own.

The Off-Campus participants, however, experienced all three of the conditions necessary for initiating flow. They shared the same goals as the On-Campus participants. At each site though, they engaged in more in-depth discussion about their observations and research ideas. They gave and received immediate feedback from both the teacher and their peers. They also
experienced the greater challenge of having to develop answers to their questions amongst themselves; new ideas and comments that were shared prompted continued and more in-depth analysis of the comments and suggestions made. Positive emotions were also more prevalently expressed in the Off-Campus case.

**Emotions:**

Throughout my research, I attended to any emotion, such as joy, sadness, excitement, or frustration, which either promoted or hindered student progress with their projects. During this activity, participants from both cases expressed enjoyment that stemmed from the opportunity to simply socialize with their friends; such enjoyment was evident in the smiles, laughter, and student participation in random conversations that arose.

Participant emotions within the On-Campus case included some excitement and enjoyment, but in general, an air of indifference. Although enjoyment was evident at times, boredom and indifference were also evident in the manner in which some students, such as Kaylee, lacked focus on the conversation and stared off towards other areas. In the Off-Campus case, however, enthusiasm and enjoyment were prevalent throughout the morning. Participants excitedly pointed out things that they noticed at the various sites. Students in the Off-Campus case exuded happiness and a sense of having fun.

**Acting Like a Scientist:**

Throughout my research, I interpreted acting like a scientist to include three basic categories: students engaged in scientific processes, students
demonstrating characteristics of scientists, and students engaged in creating a scientific community. As such, I included instances such as when students engaged in an investigative activity relevant to their research question, students using equipment that would assist in their research, instances of content-related discourse, offering or considering feedback, questioning ideas or methods, and collaborating with others, as acting like a scientist.

Participants in both cases elicited aspects of acting like scientists during this activity. The girls in both cases made observations and identified differences in habitat characteristics at each site. Participants in both cases also brainstormed potential research questions. These activities, making observations and developing research questions, reflected additional characteristics of acting like a scientist that had been identified by the scientists within the Wong and Hodson study (2008). These scientists reported their perception that acting like a scientist included making thorough observations and developing research questions based on careful consideration and evaluation of those observations (Wong & Hodson, 2008). Participants in both cases made, discussed, and evaluated, at least minimally, their observations. Participants from the Off-Campus case developed, evaluated, and adjusted their research ideas to a greater extent than was witnessed within the On-Campus case. The feedback received from peers and the teacher in the Off-Campus case sustained more in-depth and focused discussions. At one point, during such discussion, Lexi turned to her group-mates and stated: "I think our idea's good; don't you? I mean like we have three different areas, or like habitats to use" (5/4/11). Leigha added:
especially since we'll have like all day" (5/4/11). These two comments illustrate the girl's consideration of the feasibility of implementing their project idea, as well as their awareness of time that would be available to implement their project; time began to surface as an influence on student progress.

**Exploration of Research Sites: Take Away Message**

The perceived time constraints of the class periods within the On-Campus case had caused Mike to rush the class from one research area to the next. As a result, there were only fleeting moments for students to explore and discuss each area; discussions had also taken place within fractured groups. Although the class had expressed some interest, and had proclaimed three research ideas, there was a general sense of indifference within the class. Little direct feedback had been given or received by students. Participant enthusiasm within the On-Campus case was marginal.

Participant enthusiasm within the Off-Campus case was primarily higher than that seen in the On-Campus case. Traveling to the off-campus location had triggered excitement, participants spent longer durations of time engaged in content related discourse, and conversations included the entire class at each of the research sites and during the debrief circle. Students shared their ideas and gave, and received, immediate feedback about their research ideas. Student interest in, and commitment to, their project ideas became apparent as students proudly shared their research ideas with the group and beamed from positive compliments that were received from Mike and their peers. A sense of community and camaraderie began to form; students were comfortable and
eager to openly share their ideas.

Implications for student experiences with IBS were witnessed through this activity. The manner in which Mike guided students through the experience influenced student participation and outcomes. In the On-Campus case, Mike had rushed, due to time pressures he had felt, students through their observations and discussions at each potential research site. Specific differences between the two cases in terms of time spent making observations and engaged in conversation at each site are presented in Table 6. As can be seen from the table, the time to make observations and discuss each area in the Off-Campus case was roughly double what was experienced in the On-Campus case. The increased time and more in-depth discussions fostered, in the Off-Campus case, conditions necessary for flow; Off-Campus participants approached states of flow, On-Campus participants did not.

<table>
<thead>
<tr>
<th></th>
<th>Time given to make initial observations at each habitat:</th>
<th>Average time spent discussing habitats and research ideas:</th>
<th>Group discussion about research ideas:</th>
<th>Total time to explore potential research areas:</th>
<th>Debrief circle Conducted:</th>
<th>Conditions for Flow:</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Campus case</td>
<td>~30-45 seconds</td>
<td>~Six minutes</td>
<td>Brief-small group only</td>
<td>80 minutes</td>
<td>No</td>
<td>Clear goals = No flow</td>
</tr>
<tr>
<td>Off-Campus case</td>
<td>~2-3 minutes</td>
<td>~Twelve minutes</td>
<td>Extensive - small and large group</td>
<td>150 minutes</td>
<td>Yes</td>
<td>Clear goals; Immediate feedback; Balance of challenge and skills = Yes flow</td>
</tr>
</tbody>
</table>

Table 6: Summary of Research Site Explorations

Time for students to make observations and engage in conversation was
one influential factor in the differences noted between the two groups; location was another. Before explicitly discussing the influences of time and location, however, I wish to present how students developed their research questions. Aspects of time and location also influenced the outcomes of this activity, so I will hold my comments about time and location until after a description of how students developed their research questions.

**Students Develop Their Research Questions: Description of Activity**

During the class following the explorations of potential research sites, Mike visited with each group so they could share their intended research questions with him. Differences in the manner in which participants presented their research questions to Mike illustrate differences in participant confidence and progress at this point in the unit.

**Students Share Their Research Questions with Mike:**

Mike visited with each group and asked students to clearly state their research question to him. He explained that he would randomly pick one student from each group to be the group's spokesperson; it would be that person's responsibility to state their intended research question. When Mike visited the On-Campus case participants, he asked if anyone wanted to volunteer to be the spokesperson for the group. Each of the girls looked sheepishly at the others and avoided eye contact with Mike. They did not exude confidence in their ability to state their intended research question to Mike. He randomly selected a student, Audrey, to be the group's spokesperson. She threw her head back and exclaimed “No!” and glanced nervously at her group-mates. Audrey was typically
quite confident when she spoke; this nervous reaction was uncharacteristic of her behavior. Additionally, although she was able to somewhat concisely state their research question, she stated it in very basic terms, leaving out specific details. Audrey stated: "It's about testing different types of genre to see if it affects birds" (Audrey, 5/5/11). More specifically, her group was interested in determining whether playing certain genres of music near a birdfeeder would affect the number of birds that visited the feeder while that genre of music was being played. The group had been in the midst of discussing specifically what would be measured during their previous class period, but class time had ended and the conversation had been dropped.

In contrast, when Mike visited with participants in the Off-Campus case and asked if there was anyone who wanted to be the spokesperson for their group, three of the four girls immediately raised their hands and smiled enthusiastically. These three girls exuded confidence, comfort, and an eagerness to share their research question. Paige was randomly selected to be the spokesperson for the group, to which she applauded and quietly cheered "yeah!" She stated: "Our project is to determine whether the habitat or the environment of the birds has an affect on the pitch of their noise" (Paige, 5/5/11). She was asked to clarify what she meant by noise, to which she replied: "their chirp." During their discussion at the nature reserve, they had been able to definitively identify pitch as their intended measured variable.

Upon completion of the 'state your research question' challenge from Mike, students were given time to discuss and decide how they would carry out
their research project and to begin developing hypotheses and experimental designs for their projects. Differences in the conversations and the types of research questions being asked emerged between the two cases.

**Students Develop Their Research Questions: Participant Engagement**

During the time given for students to develop their research questions, conversations among participants in the On-Campus case primarily revolved around what type of music the group would include in their experiment. The group discussed how many genres should be included and which songs should be placed on the playlist they would create. Upon deciding that yodeling would be included in their experiment, they spent nearly twelve minutes just searching for yodeling songs. They became quite excited, and distracted, when they stumbled upon “The Lonely Goatherd” song from the Sound of Music. Ultimately, the girls spent over twenty minutes just listening to music as they worked to finalize their playlist. They were quite distracted by the music selection process; very little progress on developing their methodology was made.

Within the final few minutes of class, Margaret managed to refocus the group to the task of writing an experimental procedure. The girls did discuss, and made adjustments to, their procedure. For example, at one point the group had written: “Fill the tube feeder with sunflower bird seed.” This was later adjusted, in order to be more specific, to: “Fill the tube feeder with equal amounts of sunflower hearts, thistle, and mixed bird seed.”

Participants in the Off-Campus case were more focused. Upon completing the ‘state your research question’ challenge, the girls in the Off-Campus case
were complimented by Mike for the research question they had developed. He told them that no one at the school had ever researched their particular question. The girls were pleased and proud to have an original idea and to have been complimented by Mike as evidenced by their smiles and their sitting taller in their seats. This positive feedback was motivating to the group; they immediately, and excitedly, got to work on their procedure.

Conversations among participants in this group were quite focused on the specific details of their research plan. For example, while discussing their overall procedure, Leigha questioned how they should best capture the sounds they needed to record. The group discussed whether they should stay in one spot and see what birds just happened to come by or whether they should walk around looking for specific birds to record in each habitat. They discussed whether they would try to determine the pitch of a specific species of bird within each habitat or just the highest pitch, of any bird, that was recorded. Lexi pointed out that if they had to determine the pitch of specific species of birds, then they would also have to be able to correctly identify each bird. They spent two minutes reviewing and discussing their intended research question and determined that they did not need to be able to identify specific species of birds to answer their question. They also discussed whether they could use the Raven Lite program on the school computers to determine the pitch of sounds they captured.

Additionally, the girls in the Off-Campus case discussed whether it would be better to use a SoundCache recorder, or a parabolic dish sound recorder to capture the sounds they desired. The girls quite excitedly discussed the
challenges, and possible benefits, that the use of the different equipment would present. Leigha pointed out that “if we leave the SoundCache out 24/7, it’s gonna be a lot of stuff to look over” (5/5/11). The group talked further about differences between the SoundCache and parabolic dish recording systems, such as the need to program the SoundCache to start and stop recording at desired times. The group decided to use the parabolic dish system instead of the SoundCache and they reviewed how they would record birds.

The Off-Campus participants were intrinsically interested in their research idea and persisted in sorting through the challenges that would be presented by their project. The actions and discussions among the Off-Campus participants reflected the claims of Schunk et al. (2008) who stated that the intrinsic value and interest that students have in regards to a particular assignment fosters motivation and sustained engagement. According to Schunk et al., having an ability to pursue topics of interest increases the value an individual places on their efforts to investigate the topic further as well as the motivation to persist in the investigation (Schunk et al., 2008). Participants in the Off-Campus case had a genuine interest in their research topic, they were motivated to investigate the topic, and they persisted through challenges such as determining how to gather their data and how to use the necessary equipment.

Students Develop Their Research Questions: Relevant Themes that Emerged

Social Interactions:

The social interactions, within both cases, that developed during this activity were primarily verbal. As can be seen from the descriptions above, the
On-Campus participants engaged in very little content-specific discussion whereas the discussions in the Off-Campus were extensively content-specific. Participants in the On-Campus case were easily distracted by their attempts to select music for their project. Participants in the Off-Campus case were focused and engaged in more content-specific discussions.

*Emotions:*

Student emotions common to both cases included excitement, enjoyment, determination, and pride. Students in both groups engaged in enthusiastic discussions about their projects. Students in the On-Campus case laughed and joked about their song selections for their project and students in the Off-Campus case laughed and joked about their inability to identify individual species of birds.

Emotions that were unique to one case or the other included anxiety and confidence, as well as a sense of feeling lucky and special. Only participants in the On-Campus case were anxious during Mike's challenge to state their research question; participants in the Off-Campus case confidently shared their research question with Mike. Additionally, the Off-Campus participants displayed an air of feeling special and lucky as a result of the special privileges granted them by the nature reserve staff. Pride, although evident in both cases, was evident to a greater degree within the Off-Campus case. One moment in particular, when Mike complimented the Off-Campus group for developing an original research question, elevated the noticeable pride within the Off-Campus case. This pride, from having created an original research question, may have influenced the girl's commitment to their research question.
Participants in each case also felt positive about the progress they had made within their projects. When asked how they felt about their group's accomplishments to this point, responses from the On-Campus case participants included: "I feel good about what we have accomplished because we are ready to start our experiment and not rushing" (Audrey, student journal #7) and "I think we have accomplished everything we had wanted to this week and we are ready to collect data. I think we have accomplished so much because we work hard and we used time wisely" (Kayley, student journal #7). Responses to the same question from the Off-Campus case participants include: "I think that my group has accomplished a lot of really good things. I feel confident about our work because we seem to be on a pretty steady path" (Lexi, student journal #7) and "I feel good because we're on time and on task" (Leigha, student journal #7).

*Acting Like a Scientist:*

Participants in both cases acted like scientists, in the sense that the term is typically interpreted within IBS; they finalized their research questions and began developing their research designs. Participants in the On-Campus case, considered music selections based on genre and length of song as well as how, and where, they would set up their project; they determined how far away from a tree they would place their iPod music station. Participants in the Off-Campus case began to expand the manner in which they acted like scientists. They engaged in more extensive, in-depth, and specifically content-based discussions about their project.
Achievement Outcomes:

Achievement outcomes also began to differentiate during this time span. Although the girls in both cases were meeting each project requirement successfully, as determined by the teacher's summative assessments, the girls in the Off-Campus case began to face more sophisticated challenges. The level of challenge and data assessment efforts that would be required from participants in the Off-Campus case was higher than those in the On-Campus case; this was largely due to the nature of their research question that had been developed during their previous discussions. For example, the girls in the On-Campus case would simply have to set up a bird feeder and tally the number of birds that visited that feeder while playing different genres of music; these activities required only basic skills. The girls in the Off-Campus case, however, had to capture recordings of bird calls within three different habitats using fairly sophisticated recording equipment, transfer the recordings to a computer, import the sound files into the Raven Lite program, analyze spectrograms in order to determine which sounds were bird calls, and determine which of the sounds that were bird calls had the highest pitch. Perceptions of available time influenced their selection of a more sophisticated question; this was also witnessed within the other Off-Campus groups.

The research questions generated by participants in each case presented different challenge levels to the students and required different skills and uses of technology in order to be answered. To assess the complexity level of each generated question, and to assess whether the increased complexity of the research question developed by the Off-Campus participants was unique to that
group of girls or to the Off-Campus case in general, I evaluated the research questions generated by each of the groups within both cases. I assessed the overall complexity of each research question, the technology that would be required to answer each question, as well as how the data collected would need to be assessed by the students. I found that the differences witnessed between my two research groups were consistent across groups in both cases. I used the process described below to evaluate the student-generated research questions.

Determining Sophistication Level of Student Research Questions:

I considered two criteria in order to designate a level of sophistication to the student-generated research questions. First, I considered the cognitive level of the posed student research questions based on Grasser and Person's taxonomy of question types (Grasser & Person, 1994). Questions that required the quantification of data were aligned with Grasser and Person's taxonomy scale as lower-level cognitive questions. Questions that required comparisons, beyond quantification comparisons, were aligned with Grasser and Person's taxonomy scale as higher-level cognitive questions. For example, questions that required only the tallying of data to answer the research question were considered lower-level questions. Questions that required students to first interpret the data and then to make comparisons or evaluations of the data were considered higher-level questions.

Second, I assessed the level of technology that was used throughout the student's experiments on a scale ranging from "no tech" to "high tech" based on the criteria listed below. Higher technology ratings were considered more
complex and more reflective of authentically acting like a scientist. Although not all scientists use technology to answer their research questions, the use of technology can often assist in the acquisition of more complex data, thus higher ratings of technology were considered more sophisticated. Although the use of technology is not necessarily equated with, or necessary for, quality scientific investigations, the additional challenges that might be created by its inclusion in student research warranted recognition within the characterization of question types. Additional consideration was given to the data analysis efforts required with the use of various technologies, such as whether students would be required to simply record data points, such as temperatures, or whether they would first have to interpret the data points and then make comparisons before drawing research conclusions.

Criteria for Technology Designation Level:
- If only basic materials or equipment were used, such as bird feeders, rope, and standard measuring devices, such as measuring cups or meter sticks, the project was considered “No Tech.”
- If only common technology was used, such as binoculars, spotting scopes, iPods/speakers, and digital cameras, the project was considered “Low Tech.”
- If slightly more complex technology was used, such as electronic scales, simple sound recording equipment (tape recorders, MP3 players), digiscoping, or motion sensing cameras, the project was considered “Medium Tech.”
- If complex technology was used such as Pasco probes, HOBO® Probes, bio-acoustic sound recording equipment (parabolic dish/shotgun microphones, SoundCache), computer program/analysis tools (Raven Lite), or Raven Exhibit, the project was considered “High Tech.”
- If projects required additional analysis of the data collected (such as having to interpret data before making conclusions), or required additional skills in order to collect the data (such as having to distinguish between male and female birds), they were considered more complex questions than those that required tallying numbers (such as counting the number of birds in an area). Questions requiring more complex data analysis were given a ranking that indicated a slightly higher level of complexity. For
example, if a question would have been ranked "Low Tech" based on the equipment used, but the project required additional analysis or skills, they were ranked "Low-medium Tech."

Based on the above criteria, the groups from the On-Campus case were assigned the following levels of technology and sophistication for their research questions: one group was considered "no tech, low sophistication" two groups were considered "low tech, low sophistication" 1 group was considered "low-medium tech, medium sophistication" and one group was considered "high tech, high sophistication;" these designations are presented in Table 7.

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of Students:</th>
<th>Research Question Asked:</th>
<th>Equipment Used:</th>
<th>Cognitive Level</th>
<th>Technology Designation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – My research group (all girls)</td>
<td>4</td>
<td>What genre of music attracts the most birds?</td>
<td>1 bird feeder, mix seed, iPod, speakers</td>
<td>Low Quantitative low tech</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Does playing music affect the number of birds that visit a feeder?</td>
<td>School feeders, school seed, iPod, speakers</td>
<td>Low Quantitative low tech</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Does the height of a feeder affect the number of birds it attracts?</td>
<td>3 feeders, seed, rope, measuring cup</td>
<td>Low Quantitative no tech</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>Does playing male bird songs attract more male or female birds?</td>
<td>CD bird sounds, iPod, speakers, spotting scope, binoculars</td>
<td>High Comparative low-medium tech extra ID skills required high tech</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>Do two birds of the same species have identical calls?</td>
<td>Parabolic dish system, binoculars, Raven Lite software, Raven Exhibit</td>
<td>High Comparative</td>
<td></td>
</tr>
</tbody>
</table>

Table 7: Summary of Student Research Questions from the On-Campus case

Using the same criteria for determining the level of technology and sophistication of the student-generated research questions for the Off-Campus
case yielded the following results: one group was considered “low tech, low sophistication,” one group was considered “medium tech, medium sophistication,” and three groups were considered “high tech, high sophistication.” A summary of the student-generated research questions and sophistication levels for the Off-Campus case is displayed in Table 8.

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of Students:</th>
<th>Research Question Asked:</th>
<th>Equipment Used:</th>
<th>Cognitive Level</th>
<th>Technology Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – My research group</td>
<td>4 (all girls)</td>
<td>Does the environment a bird is in have an affect on the pitch of its chirp?</td>
<td>Parabolic dish microphone, Marantz recorder, headphones, computer, Raven Lite software, binoculars</td>
<td>High</td>
<td>High tech (Comparitive)</td>
</tr>
<tr>
<td>2</td>
<td>3 (all boys)</td>
<td>What variation in temperature exists in, near, and surrounding a birds nest?</td>
<td>Hobo temp probe (4 sensors), computer, Box Car software</td>
<td>High</td>
<td>High tech (Comparitive)</td>
</tr>
<tr>
<td>3</td>
<td>3 (all boys)</td>
<td>Does the size of a bird affect the pitch of its call?</td>
<td>Parabolic dish microphone, Marantz recorder, computer, Raven Lite software, Raven Exhibit, Binoculars, Digital Camera</td>
<td>High</td>
<td>High tech (Comparitive)</td>
</tr>
<tr>
<td>4</td>
<td>4 (all girls)</td>
<td>Does the habitat affect the number of birds seen?</td>
<td>3 bird feeders, bird seed, binoculars, motion sensing camera</td>
<td>Low</td>
<td>Med tech (Quantitative)</td>
</tr>
<tr>
<td>5</td>
<td>3 (1 boy, 2 girls)</td>
<td>Does the depth of the water affect where an Osprey will fish?</td>
<td>Binoculars, Spotting scope, depth chart</td>
<td>Low</td>
<td>Low tech (Quantitative)</td>
</tr>
</tbody>
</table>

Table 8: Summary of Student Research Questions from the Off-Campus case

A shift to higher levels of technology and more sophisticated questioning was seen within the Off-Campus case. If the differences in generated research questions between the On-Campus and Off-Campus cases had been due solely
to social dynamics that were unique to these two groups, then similar results would not have been expected across cases. Yet, as seen in Tables 7 and 8 above, there was a general shift to more sophisticated student-generated research questions within the Off-Campus case. The phenomenon was not unique to my two research groups; it occurred across both cases.

**Students Develop Their Research Questions: Take Away Message**

Differences between the two cases clearly began to emerge during this activity. Evidence of this includes both the level of student confidence displayed while stating intended research questions to Mike as well as the depth of content related discourse spoken within each group. On-Campus participants had to make only fairly simple decisions such as: how long their music play list should be, how to adjust the length of the songs so they would be equal in length, how far from their bird feeder to place the speakers, and what type and quantity of birdseed to place in their feeder. Although these were all important decisions for ensuring consistency within their experiment, they each required only basic discussion and skill; the ramifications for each decision were minimal. For example, it did not particularly matter how far away the speakers were placed from the feeder as long as it was a reasonable distance and the speakers were consistently placed at the same distance during each experimental trial, and it did not matter what type of birdseed was used as long as it was consistently used.

In comparison, Off-Campus participants had to make more complex decisions for their research plan such as: which equipment to use, whether to make traveling or stationary recordings, whether to record specific species or bird
sounds in general, as well as what characteristics separated one habitat from another. These decisions were not only important for maintaining consistent research efforts during their project, but each also had ramifications for the effort that would be required to conduct their experiment and to successfully be able to answer their research question.

The Off-Campus participants engaged in more in-depth content related discussions and developed a more complex research question that would ultimately demand higher-level skills, such as in programming and analysis, to implement and evaluate their project. The increased challenges presented by the plan in the Off-Campus case required higher-level skills for the students to meet those challenges. The students continued to develop new skills and understanding as their project progressed; they learned more about how the equipment worked, how to troubleshoot issues that arose from the equipment, and how to use the computer software required to determine the highest pitch of birdcalls. These higher-level challenges required higher-level skills. Participants in the Off-Campus case experienced a sustained balance between the challenges they faced and the skills required to manage the challenges; their experiences progressed within the optimal range for states of flow to develop.

During this time span, aspects of both time and location influenced participant experiences. Before leaving this time span, I wish to specifically discuss each of these factors.
Influence of Time:

Although the Off-Campus case had initially received two hours and thirty minutes longer to explore their research sites, by the end of this time span, the Off-Campus class had only fifty-five minutes of additional class time than the On-Campus class; this was equivalent to a single class period. Other schedule changes and class interruptions that had occurred within the regular school schedule had reduced the overall time differences between the two groups to fifty-five minutes.

Important differences in time between the two cases included the total time spent visiting each potential research site as well as the amount of time engaged in content related discourse at each site. Site visitations in the On-Campus case had been rushed and conversations occurred within fractured groups; site visits in the Off-Campus case had been unhurried and conversations included the entire class. Students in the Off-Campus case had been afforded time to think through, and verbalize, questions and ideas they had; they were given time which provided opportunity to hear, consider, and provide feedback to each other's ideas, at each location before moving on to the next.

When I later asked Mike why he had only spent a few minutes at each research site with the On-Campus case, Mike replied: "I wanted the group to see each of the different areas, so I felt like I had to move quickly because we didn't have much class time" (Mike, 4/12/11). Time pressures felt by Mike had caused him to rush the group discussions at each site. Mike's actions perfectly illustrated typical teacher tendencies in IBS. According to Flick (2006), teachers often rush
students through the planning stages of the inquiry process in order to hurry them into the data collection phase of the experience. Mike had felt so pressured by time constraints that he had limited student discussions and experiences as a result.

While at the nature reserve, students in the Off-Campus case had experienced uninterrupted time to engage in content related discourse and had become aware of the length of time they would have available to implement their projects. What emerged as a result of this awareness was a sense of confidence about, and commitment to, their research ideas. Participants left the reserve feeling confident that they would have ample time to successfully complete their investigations as evidenced by Leigha’s comment: “especially since we’ll have like all day” (Leigha, 5/4/11). This awareness of time not only fostered confidence in their ability to be successful, but also indirectly encouraged participants to pursue a project idea that presented higher-level challenges. Their research question had sparked participant interest in their selected topic as revealed in comments such as: “we have a hard project but I can’t wait to see what happens” (Leigha; Student Journal #7). The willingness, and enthusiasm, with which participants engaged in their work reflected Wigfield and Eccles’ (2000) claim that student perceptions of their ability to be successful in a particular task was a predictor of their likeliness, and willingness, to engage. Participants in the Off-Campus case were interested, and felt confident of success, in their research topic; they were excited to engage with their experiment.

An awareness of time among Off-Campus participants was also reflected
in a group journal reflection in which Mike asked students to explain what factors had entered into their selection of particular research topics. Participants responded: "some factors that altered our decision were....the amount of time we had to conduct our experiment" (Off-Campus case, Student Journal #6). The response from the On-Campus participants to the same question had been: "we all like music and wanted to learn how to yodel in the process" (Journal #6); time was not mentioned as a factor. When asked whether time had impacted their group's progress to date, the On-Campus participants replied: "We had enough time to think of a good experiment and create good details" (Journal #6). From the On-Campus participant's perception, time had not yet become an influence on their progress.

Time had, however, enabled Mike to facilitate the debrief discussion circle with the Off-Campus students. The time spent within the Off-Campus debrief circle enabled students to verbalize their ideas and provided opportunity for them to receive feedback and support from the teacher and their peers. Acknowledgment from others that their suggested research ideas were good and manageable elevated student confidence in their ability to successfully complete their intended projects. Lexi expressed evidence of this in a journal reflection in which she wrote that "we have a good project idea. I think we will be able to get everything organized" (Lexi, Student Journal Reflection #7). Students from the Off-Campus case left the reserve motivated and excited about, as well as committed to, their project ideas.
Influence of Location:

The on-campus and off-campus locations provided similar habitats for students to explore and utilize in their experiments. Participants in the On-Campus case were quite familiar with the habitats on and near school grounds. Although most students in the Off-Campus case had visited the local nature reserve previously, it still provided a sense of novelty and privilege for the students. Participants in the Off-Campus case expressed the benefits and privileges of "having all day" (Leigha, 5/4/11) and being able to "go off the boardwalk" (Paige, 5/4/11). These realizations fostered positive emotions, confidence, and commitment to their project ideas; these benefits had been promoted by location. Traveling to the nature reserve also isolated these students from outside interruptions.

This sense of privilege and physical isolation experienced by the Off-Campus participants echoed the contextual influences of location that were found to influence the productivity of scientists in a study conducted by Parker and Hackett (2012). Before discussing further results from my research, I wish to interject a description of "Hot Spots," as described by Parker and Hackett (2012) because this construct emerged as directly relevant to the influences of location within my research. The construct of hot spots bridges connections between IBS and Flow Theory.

Hot Spots and Hot Moments of Collaboration:

Contextual situations are known to be influential to individual and group achievement outcomes (Pintrich, Marx, Boyle, 1993). Context, which includes
location or place, has been shown by researchers such as Sobel (2005), Lattimer & Riordan (2011), and Membiela et al. (2011), to be influential on student learning. Researchers, including Parker & Hackett (2012), have also shown that the contextual factor of location can positively influence the productivity outcomes of scientists. According to such research, scientists who meet for extended periods of time within isolated settings increase their productivity as a result of experiencing what Parker and Hackett (2012) refer to as “hot spots and hot moments of collaboration” (p. 21).

Affective influences, such as emotion, affect productivity within groups as well as scientific communities (Pintrich et al., 1993; Sinatra, 2005; Parker & Hackett, 2012). The study conducted by Parker and Hackett (2012) investigated the largely unexamined influences of emotions on the productivity of scientists. They focused their research on a group of scientists known as the Resilience Alliance (RA). The RA is comprised of expert scientists whose aim is to resolve conflicts and challenges that arise from environmental pressures that are created by human resource consumption, sustainability pressures, and ecosystem dynamics (http://www.resalliance.org). The group meets annually in various exotic and isolated locations, such as the Kruger National Park in South Africa and Gabriola Island in British Columbia, in order to facilitate coherent and collaborative meetings with little outside influence or interruption. The purpose of the meetings is for participating scientists to evaluate, and develop resolutions for, identified environmental and resource management issues (Parker & Hackett, 2012).
According to the authors, collaborative groups of scientists within the RA routinely establish “hot spots and hot moments” which cultivate innovative contributions to the scientific community. Hot spots and hot moments are considered to be: “brief but intense periods of collaboration undertaken in remote and isolated settings” (Parker & Hackett, 2012, p. 21). Parker and Hackett investigated whether participant affect and emotion influenced scientific processes and productivity outcomes of scientists.

The results of Parker and Hackett’s research revealed that the remote and isolated meeting locations accommodated the development of “intellectual identity, group solidarity, and emotional energy” and that this emotional energy further led to the production of scientific knowledge (Parker & Hackett, 2012, p. 10). They found that extended time in these settings, which the researchers called:

island time: strengthens group bonds, motivates productivity, catalyzes creativity, and builds emotional commitment to the group’s ideas, fostering a culture of receptivity and originality, while quieting skepticism and criticism. This structure, and the socio-emotional processes it engenders, facilitate knowledge production and help the group build and maintain momentum (Parker & Hackett, 2012, p. 7).

Key to the success of the annual meetings was the ability of the participants to enter into a “collaborative flow, which facilitates highly focused discussions” (Parker & Hackett, 2012, p. 9). Such flow was instrumental to the development of new ideas and the ultimate testing of the ideas.
Additionally, the researchers discovered considerable resistance from the participating scientists towards outside criticism of their work. The bonds that were created among RA meeting participants provided support from like-minded individuals who understood each other’s perspectives. Ultimately, however, the collaboration and support of RA members also encouraged scientists to adjust their perspectives and ideas if sufficient evidence existed to warrant such a shift. In essence, the collaboration of the RA members facilitated conceptual growth and change.

Parker and Hackett found five salient influences from emotion upon group performance. They found that emotions influence interactions and collaborations, promote creativity through fostering collaborative flow for work being done, promote trust and an ability to openly share ideas, promote individual and group commitment to ideas, and they promote resistance to outside criticism. According to Parker and Hackett, "Emotions are essential but little understood components of research; they catalyze and sustain creative scientific work and fuel the scientific and intellectual social movements that propel scientific change" (Parker & Hackett, 2012, p. 1).

My research results reflect much of what Parker and Hackett described in their study. Student emotions that surfaced from their interactions influenced subsequent interactions and fueled student engagement in a manner that more authentically reflected acting like scientists, such as engaging in content-specific discourse; such emotions and interactions were more prevalent within the Off-Campus case. The effects of experiencing “hot spots and hot moments,” as
described by Parker and Hackett (2012), also emerged within the Off-Campus case. Emotions that emerged among students engaged in, and wrestling with, scientific content created moments of intense discussion and collaboration. The personal interests, motivation, and social interactions that occur within contextual situations drive such moments (Parker & Hackett, 2012). The results of my research suggest that characteristics of hot spots can be influential on student motivation and achievement outcomes within IBS.

The hot spots described by Parker and Hackett referred to the isolated and remote settings where the researchers convened to engage in discussions and investigations. These locations were influential to the productivity of the scientists. The nature reserve visited by the Off-Campus case became representative of such a hot spot for my research participants.

**Insights into IBS and Flow Theory:**

The outcomes of these two activities, the “Exploration of Research Sites” and “Developing a Research Question,” provide insights into how characteristics of Flow Theory and hot spots can inform and explain my research participant’s experiences. First, as is typical within IBS experiences, participants in both cases brainstormed and discussed, at least briefly, project ideas and potential research questions. As documented by many researchers, including Flick (1998), Marx et al. (2004), and Taraban et al. (2007), one of the procedural steps within “the scientific method” that is typically followed in schools, and credited for the success of IBS, includes the student development and sharing of research questions. Students in both cases went through this process; what was less
typical, however, was the extensive sharing and discussing of project ideas that occurred within the Off-Campus case. These discussions provided time and opportunity for students to give and receive feedback about their ideas; the immediate feedback prompted continued and more in-depth discussions. As claimed by Csikszentmihalyi (1996), immediate feedback is one condition required for individuals to enter into states of flow. Off-Campus participant experiences with such feedback primed them for approaching states of flow.

Participants in the Off-Campus case also developed a more complex investigation that required more complex and skillful analysis efforts than participants in the On-Campus case. The elevated challenge and skills required, as well as the development of new skills as the project progressed, sustained the Off-Campus participants position within the optimal condition parameters for flow depicted and described by Csikszentmihalyi. Participants in the On-Campus case fell below the optimal condition parameters that primed this group for states of boredom and reduced engagement. The Off-Campus participants more frequently experienced conditions that promote entering states of flow.

Second, the nature reserve location began to represent characteristics of a hot spot as described by Parker and Hackett (2012). The nature reserve provided an isolated location where students were free from interruptions and outside influences. Students began to display an air of privilege and camaraderie. The class as a whole began to form an identity as the class that was fortunate to go to the reserve; smaller groups within the class, including my research participant group, also began to take on unique group identities.
During this time span, participants in both cases were well aware of the goals set forth by the teacher. The awareness of goals, provision of immediate feedback, and having a balance between skill and challenge exposed the Off-Campus participants to all three of the criteria required for initiating flow. The On-Campus participants were exposed to just one, an awareness of goals.

The Path Begins to Divide: Time Span Summary

During this eight-day period, differences in student interactions, emotions, and content discourse arose. The most notable differences emerged within three data sources: my field observations, student journal reflections, and video recordings of student behaviors. For example, through direct observations and reviewing video recordings, I noticed that the girls in the On-Campus case became distracted and off task more frequently than the girls in the Off-Campus case. Upon averaging the number of distractions lasting more than three minutes that surfaced within each group for the same two-day period, I counted eleven distractions within the On-Campus case and six within the Off-Campus case.

Through reviewing video and audio recordings, I was able to assess that the girls in the Off-Campus case had engaged in more content-based discourse for longer periods of time than those in the On-Campus case. For example, assessments from one day revealed students in the On-Campus case engaged in three content specific discussions that lasted more than five minutes in length and students in the Off-Campus case, on the same day, engaged in five content specific discussions that lasted more than five minutes in length. A review of Table 9, which summarizes a comparison between the two cases, reveals that
participants in the Off-Campus case were engaged in content-related discourse with more than twice the frequency and duration of participants in the On-Campus case. The table also reveals that On-Campus participants were distracted with nearly twice the frequency of the Off-Campus case. In order to determine the durations of distractions and content related discourse, I reviewed video recordings from the same days in which I had complete, uninterrupted, video for the entire class period from both cases. Table 9 also reveals that although participants in both cases felt positive about their experiences and felt they had been given sufficient time to prepare their projects, the outcomes of the time span revealed that participants in the Off-Campus case had been able to develop a more sophisticated research question.

<table>
<thead>
<tr>
<th>Case</th>
<th>Distractions lasting longer than 3 minutes (2 day observation)</th>
<th>Science content related discourse lasting longer than 3 minutes (1 day observation)</th>
<th>Sophistication level of research question</th>
<th>Students felt they had sufficient time to prepare their project</th>
<th>Students felt positive about their progress to this point</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Campus</td>
<td>11</td>
<td>2</td>
<td>Low</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Off-Campus</td>
<td>6</td>
<td>5</td>
<td>High</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 9: Comparisons between the On-Campus case and the Off-Campus case

By the end of this time span, patterns and themes began to emerge from the data. When student social interactions included opportunities for students to discuss tasks and goals as well as to provide feedback to their peers about ideas and suggestions, student motivation and content related discourse increased. Opportunities for such discussions were subjected to variations in time and location; students in the Off-Campus case, by nature of their having extended
time to engage in discussions while at the nature reserve, elicited increased motivation and engaged in more content related discourse than their On-Campus peers. Additionally, students in the Off-Campus case developed a research question that was more balanced between the skills required to investigate the question and the challenges that would be faced than their peers in the On-Campus case; their research question was more cognitively challenging and demanded higher level skills to implement. Patterns that developed were consistent with conditions required to enter into flow, as students discussed goals and ideas, and gave and received feedback with their peers, they more readily approached states of flow. Students that developed a more cognitively challenging research question engaged in more complex discussions and more authentically acted like scientists. These patterns, which developed with stronger prevalence within the Off-Campus case, are illustrated in Figure 8.
In addition to supporting characteristics consistent with Flow Theory, the data also began to reveal that as student awareness and content specific discussions about goals, feedback, and challenges to be faced became more rigorous and content specific, student motivation, concentration towards their research projects, and enthusiasm was enhanced. It began to become apparent that simply having and discussing goals and receiving feedback may be conditions required to enter flow states, but that particular contextual experiences and motivation, such as receiving feedback from peers, having a sense of time to accomplish tasks, and feeling special privileges about having access to special

Figure 8: Social interaction patterns leading to flow and enhanced outcomes.
locations, that acted as a catalyst to encourage acting like a scientist and approaching states of flow.

At the conclusion of this time span, participants from both cases expressed that they had ample time to implement their projects. This sentiment changed, however, once the data collection process began. Perceptions about the influence of time, as well as the types of student interactions, emotions, and content discourse that emerged within each case diverged even further as students actually implemented their projects and collected their data. This continued divergence is described in the next section.

**The Path Divides Even Further: (May 13-May 26: two week time span)**

This time span includes the data collection phase of the student-generated research projects. Six regularly scheduled class periods were delegated for the On-Campus case to implement their projects and four days were delegated to the Off-Campus case at the nature reserve to implement their projects.

At the start of this time span, participants felt equally positive about their group's progress and felt ready to begin collecting data. When asked how invested they were in their particular research projects, responses from participants in the On-Campus case included: "I am very interested in our project and can't wait to find out what happens. I am very excited to start collecting data tomorrow" (Kaylee, Student Journal Reflection #7). Comments from participants in the Off-Campus case included: "I'm very invested because...I think ours is an interesting experiment" (Leigha, Student Journal Reflection #7). As can be seen
from these journal responses, participants in both cases were invested in, and excited to start, their projects. I describe their experiences with data collection below.

**Data Collection: Description of Activity**

During this phase of the project, students implemented their experiments within their respective locations. Students were responsible for managing their time, and activities, to ensure that all the data that would be required to answer their research questions were collected within the allotted time. Although Mike visited with each group daily to check on their group's progress, students primarily worked independently.

**The On-Campus Case: Research Participant’s Engagement**

The students in the On-Campus case entered class on the first day of data collection chatting excitedly about the start of their projects. Mike asked the class if they were ready to get started to which Margaret excitedly replied: “Oh, we're ready!” (Margaret, 5/13/11). The class sprang into action. My research participants leapt out of their chairs, grabbed their data table, and hurried outside to their research area. They sat on the ground and intently watched the bird feeder they had set up the day before. No birds came to their feeder during their first trial, but the girls did not become discouraged.

After they completed their first trial, Margaret turned to the group and said: “we have exactly fifteen minutes; not enough time to do another trial...let's just play music” (Margaret, 5/13/11). This suggestion triggered the group to abandon their project for the day; instead of continuing to work, they listened to music and
then left their project site and jumped track hurdles in the field. During this first
day of data collection, the girls had noticed a problematic time constraint that had
prevented them from getting a second trial completed. However, rather than
making adjustments to their project plan, they abandoned their efforts for the day.

On the second day of data collection, the girls became quite excited when
birds visited their feeder; they smiled, nudged each other, and hushed each other
to not startle the birds. They excitedly tallied the birds as each landed on the
feeder. Audrey did the recording; each time she went to mark the data sheet, the
other girls huddled closely and peered over her shoulder anxiously checking to
be sure she accurately recorded each bird. Upon returning to the classroom, they
excitedly announced to Mike: “we got five birds!” (Audrey, 5/16/11). The girls then
discussed whether they should continue working on their project. Margaret
announced there were only five minutes left in class and this was not enough
time to get anything done. Rather than spending their time discussing more
efficient ways to collect their data, or working on other parts of the project, they
spent the remaining time, which was actually seven minutes, chatting about
random non-related topics. The impending end of class derailed them from
making any effort to continue working on the project.

On the third day, they planned to get two data trials completed. After
watching their feeder for two minutes, Margaret suggested: “Maybe we should
split into two groups. Like two of us stay here and two go inside to work on like
the introduction or something” (Margaret, 5/17/11). The others agreed and the
group split. When the group later reconvened, they noticed that their bird feeder
was broken and was spilling seed. After two minutes of debating how to fix the problem, Kaylee suggested stuffing leaves into the bottom to plug the hole; they fixed, at least temporarily, the problem of leaking seeds. Upon returning to class, they realized they were two minutes late for their next class; they frantically put their supplies away and hurried off to their next class.

The group strategy of “dividing and conquering” persisted throughout the remainder of the data collection phase. The group decided to create a poster, so students working inside worked on components of the poster, such as creating a title, introduction, and displaying their experimental design. They decided they would swap roles each day after the first observation had been completed. The exchanges between the two groups as they swapped roles were consistently frantic and uninformative. For example, during one of the exchanges, the girls rushed passed each other in the hallway and Margaret frantically said to Audrey “we worked on the introduction. It’s on the computer, just go, you’ll find it” (Margaret, 5/17/11).

On the last day of data collection, the group agreed to conduct their final observation as a group. The girls were extremely distracted during this final observation; they chatted continually about non-related and random topics, yelled across the field to other students, sang songs, and danced around. They were not focused on data collection. At one point, Kaylee announced: “there are no birds out here” (Kaylee, 5/20/11). Margaret asked: “why didn't we do like five minute trials” (Margaret, 5/20/11); she had lost patience, and interest, in tallying the number of birds for twenty minute trials. Upon returning to class after their
final observation, even though there were nearly fifteen minutes of class time remaining, the girls simply continued chatting about random topics. They did not engage in any discourse related to their project. This lack of engagement supported the findings from Wigfield and Eccles (2000) discussed previously, in which the researchers found that aspects of motivation, such as personal interest, construct behaviors; when interest is lacking, engagement dissipates. My research participants had lost interest in their project. Their reduced engagement reflected their dissipating interest and motivation. The data collection experience for students in the Off-Campus case was considerably different.

The Off-Campus Case: Research Participant’s Engagement

Students in the Off-Campus case entered class on the first day of data collection with an air of enthusiasm. When Mike asked if the groups were ready to go, there was a resounding “yes!” (5/23/11). Once at the nature reserve, the education director greeted the class; she complimented students for their research ideas. The compliments from this outside audience pleased the students; they smiled and shuffled about where they were standing. As soon as Mike and the staff at the nature reserve gave the students permission to begin their projects, the groups gathered their supplies and rushed out the barn doors into the field. They were excited to begin.

My research group walked quickly directly to the wigwam located in the woods. Once there, they sat and discussed their strategy for the morning. They decided to split into two groups and that one pair of them would go to the first
data collection area, which was in the woods, and record the sounds for fifteen minutes and then return to the wigwam. Then, the two that had waited in the wigwam would take the equipment to the second data collection area, which was in the marsh, and record for fifteen minutes. Their reason to split into two groups differed from the On-Campus case reasoning. This group decided to split into two groups because there was only one microphone, sound recorder, and headphone set that could be used at a time, thus they would take turns recording. After these recordings were completed, they would all complete their final recording, near a stream, together. The girls explained that even though only two people could participate in the actual recording at one time, it would “be more fun to all be together” (Leigha, 5/23/11) and that “it balanced out the work evenly” (Lexi, 5/23/11). Following the third recording, they would return to the barn, have lunch, and then repeat the same procedure in the afternoon.

On the first day of data collection, they spent nearly twelve minutes sitting in the wigwam discussing their strategy and then split into their two groups. Although each group that was recording took time to bounce on logs or splash in mud puddles as they walked to their recording sites, once they arrived, they quickly got settled and began recording. My research participants enjoyed their work and remained enthusiastically engaged. Their enthusiasm illustrated and supported the claims from Schunk et al. (2008) that the intrinsic enjoyment of an activity fostered sustained engagement. The girls were engaged for the duration of the activity.
In the afternoon, they swapped which pair went to the woods and who went to the marsh. They explained that “this would give everyone the chance to experience all of the environments for themselves” (Leigha, 5/23/11) and “it lets us each get a sense of each area and gives us some variety during the day” (Paige, 5/23/11). Jessica added that one person might notice something that the others did not notice.

While sitting in the wigwam, waiting for their turn to record, Lexi announced: “I like being out here; this is so much better than being in school” (Lexi, 5/23/11). I asked her to explain why she thought that and she replied: “we have more, like, independence” (Lexi, 5/23/11). She went on to explain that she felt more responsible for her work. Jessica added: “We can be in the mindset of science. It’s better than 45 minute classes” (Jessica, 5/23/11). Jessica explained that with the uninterrupted time, she felt they could focus more on a single subject and really get into that subject, that they could get in a “mindset and get on a roll” with their work (Jessica, 5/23/11).

Approximately twenty minutes prior to leaving the nature reserve, Mike asked the entire class to sit in a circle to share their experiences from the day. Students shared their successes as well as problems they had encountered. My research participants shared that their troubles had included running out of battery power and having to return to the barn just to get batteries and falling off the boardwalk “like twenty times” (Paige, 5/23/11); Paige had repeatedly walked along the raised edge of the boardwalk and repeatedly fallen off the edge scraping her ankle each time. They also shared that “it [recording] got annoying
because we could hear like other people talking" (Leigha, 5/23/11). Paige shared her observation that "It sounded like all the pitches were higher just from like the marsh" (Paige, 5/23/11). Other comments around the circle included that the day had been: "better than school" (Brad, 5/23/11). When Mike asked why, students responded: "cause we can like focus on one class" (Kathy, 5/23/11) and "yeah, that's true, cause once you start like working, for as long as you want, it's not gonna, the class isn't going to end and then you lose your momentum on it" (Seth, 5/23/11).

The remaining three days went much like the first. On the second day I asked Lexi and Jessica, while they waited in the wigwam, what they were thinking of creating for their final product. Jessica claimed they were: "Thinking about a poster, or the RavenLite – Exhibit Thing" (Jessica, 5/24/11). Lexi added: "yeah we're thinking that would be cool cause it's like different. But, we have to talk it over with Leigha and Paige" (Jessica, 5/24/11). I also asked them how they liked working at the reserve. They both stated that they liked it because they could get their work organized and completed. Lexi stated that she could: "get in a zone" and explained that she found this helpful because she could just keep going, keep thinking, and move forward in the process (Lexi, 5/25/11). She said that it helped her think more clearly. I asked what she meant by this; she explained that she could organize her thoughts better, rather than just "throwing something together to get it done quickly" (Lexi, 5/25/11). Jessica added that the time gave her "frame of mind; time to think" (Jessica, 5/25/11). When I asked her
what she meant, she explained that she could “decide if the plan makes sense or if they should do something different” (Jessica, 5/25/11).

While walking back to the barn, the girls discussed their data. Lexi announced: “132-135 are all mine” (Lexi, 5/24/11) in reference to the recording file numbers stored within the recorder. The girls discussed the different sound files and made a plan to sort through them and delete files they did not need, such as ones when they “I accidentally recorded ourselves talking” (Lexi, 5/24/11). They discussed having the entire group involved in making the decision to delete or keep a file.

During one of their walks back to the barn, they came across a garter snake and excitedly said: “let’s record it!” (Leigha, 5/24/11). They spent seven minutes listening to and recording the snake slithering through the leaves. They were excited and amazed by what they heard and excitedly encouraged other students that happened to walk by their group to listen to the recordings they had made of the snake.

On the third day, Paige announced: “I wish this was school everyday!” (Paige, 5/24/11). I asked her to explain why and she replied that she enjoyed being outside and felt she had time to really focus on what they were doing. The girls completed their recordings efficiently; they had the process down to a smooth routine. I watched Paige and Leigha, halfway through their recording time, swap who was listening through the headphones and who was holding the recorder; they did not utter a word. Instead, they simply made eye contact, nodded at each other, and made the desired exchange.
During the debrief circle on the third day, one of the boys expressed similar sentiments to what my research participants had been expressing; he stated that he preferred doing work at the reserve. Mike asked him why and the boy replied: "I prefer it – A LOT. I can get more done in a long time – get on a roll – like you don’t just get going and have to stop" (Brad, 5/25/11). He added: “I feel like I get on a roll and I don’t want to stop” (Brad, 5/25/11).

During this debrief discussion, the class also shared observations about their research from the day. For example, Paige shared: “there were like a lot less birds today, like just around in general” (Paige, 5/25/11). She added: “we think maybe because it’s so hot. And like yesterday there were so many birds in the morning, like they were everywhere. And then like in the afternoon there was like none” (Paige, 5/25/11). This comment sparked a conversation about the bird activity; students from all of the groups discussed their observations and possible explanations. The sharing of similar observations and opinions built confidence within groups that their noted observations had been reasonable and accurate.

On the way to the wigwam, on the last day of data collection, my research participant’s conversation was particularly scattered. As soon as they arrived at the wigwam, however, their conversation immediately became focused on their project; the arrival at the wigwam triggered focus. Leigha grabbed the recorder and announced: “we’re off to the lump!” (Leigha, 5/26/11), they had nicknamed the woods location “the lump” because a small mound of dirt in the woods marked their precise recording location. As Leigha and Paige walked out to their
designated spot, a tufted titmouse called its notorious ‘Peter, Peter, Peter’ call.
Leigha proclaimed: “It sound’s like it’s saying ‘Data, Data, Data’” (Leigh, 5/26/11).

These two comments, “we’re off to the lump!” and “It sound’s like it’s saying Data, Data, Data” were expressions that became meaningful to this group. They laughed each time someone proclaimed they were “off to the lump” and giggled as they sorted through spectrogram files saying: “data, data, data.” These expressions were unique to this group; they had become symbolic and helped to congeal their solidarity and identification as a group. Such group specific identity markers were reflective of what Parker and Hackett had described as positively influential to productivity among scientists (Parker & Hackett, 2012). These researchers had found that groups of scientists who developed unique, group identifying, expressions had elevated solidarity and positive emotions which in turn increased their scientific productivity (Parker & Hackett, 2012). The group expressions developed by my research participants brought smiles of acknowledgement to the girls; it was as if they were sharing an “inside joke” and they were among the ones “in the know.” Positive emotions emerged and their work continued with determination.

Paige described how she felt the aspect of time had influenced their project. She compared her experiences with a typical day in school and explained that at school: “It takes a certain amount of time to get started and get yourself all focused and, but then by the time you get focused, like you’re completely focused for like fifteen minutes and then the class is – over” (Paige, 5/26/11). She described her experience at the reserve as being able to get into a
concentrated rhythm with her work and her team. Her description echoed the notion of collaborative flow that Parker and Hackett (2012) had described as influential to the productivity of scientists.

During the debrief circle on the last day, Mike asked students to share their thoughts about what had been the best and worst part about their time at the reserve. Seth shared first, he commented: “The best part was being able to learn about like science in a real situation. Like in the classroom, a lot of stuff is like theoretical, but then we came out here and we actually like did a lot of stuff” (Seth, 5/26/11). Leigha described a least favorite moment, and frustration, as a time when she was recording and there were no sounds at all; she said she was frustrated and bored by the silence. She described her favorite part, however as: “like yesterday, when we went out and were doing the marsh recording and I just laid down and listened to everything, and it was really peaceful out there” (Leigha, 5/26/11). She had been able to be in the moment and fully appreciate her surroundings and the activity in which she was engaged.

Lexi added that she had felt frustrated when she felt they had nothing to do between their morning and afternoon recordings. In actuality, this would have been a good time to begin analyzing data the group had already collected; the group chose to work on other schoolwork, such as language arts, instead. Jessica also shared that a frustration for her had been running out of batteries. The different groups empathized with each other as they shared their frustrations. Students chuckled, nodded their heads in agreement, and acknowledged similar frustrations and experiences.
Students also shared additional questions that had emerged as a result of their research and their general observations. For example, Lexi shared that she wondered whether the seasons would have an influence on the pitch of bird’s calls within the various habitats. The debrief circle gave students a chance to share and reflect upon their experiences and to be acknowledged by their peers who had shared similar experiences within their groups. The sharing triggered a sense of empathy and understanding.

Before discussing the specific themes that emerged from my data, I wish to present student responses to questions that were posed within student journal reflections mid-way through the data collection process. Differences in responses between the two cases illustrate divergences between student experiences and feelings within each case.

**Participant Reflections Mid-way Through the Data Collection Process:**

Halfway through the data collection process, students were asked to complete an individual journal reflection in which six questions were posed. Student responses illustrated emerging differences between the two cases. When asked what obstacles the groups had run into and how they had resolved their problems, Kaylee from the On-Campus case responded:

One obstacle we ran into was the birds would break the holes that opened and closed the bird feeder which would cause the bird seed to fall out. We resolved this by stuffing leaves into the few that were broken. Therefore it stopped the seeds from falling out (Student Journal Reflection #8).
Another problem that was mentioned was that the iPod speakers they were using could not project the music to the volume they had anticipated without sounding full of static. Responses to the same question from the Off-Campus participants included: “WE accidentally recorded some random conversations. We listened to them and sorted through them” (Lexi, Student Journal Reflection #8) and: “So far this week, we’ve ran out of batteries, and fallen off of the boardwalk. To resolve these problems we brought extra batteries and walked closer to the middle of the boardwalk” (Paige, Student Journal Reflection #8).

Participants in the On-Campus case faced minor challenges that were easily resolved; they fixed a broken bird feeder peg by stuffing leaves in a hole and their static ridden speakers by turning down the volume on their iPod. Some challenges faced by the Off-Campus participants were equally minor, such as having to remember to bring extra batteries, but the Off-Campus participants also faced challenges that required more effort and thought to resolve. For example, they had to learn how to use the recording equipment more efficiently and how to salvage sound files that were poor quality because the girls had either recorded themselves or other groups talking.

When asked what obstacles still remained for their group and how they could resolve these obstacles, Audrey, from the On-Campus case, responded: “Obstacles that still remain are the time to get trials, but that can be resolved by making our class time observations quicker transitions” (Student Journal Reflection #8). Paige, from the Off-Campus case, replied: “Unfortunately, we are still having some problems with the recording unit, but we are learning how to
use it better" (Student Journal Reflection #8). When asked how having time to talk to their group-mates had affected their ability to collect data, Margaret, from the On-Campus case, responded: "Now we divide and conquer our tasks" (Student Journal Reflection #8). Jessica, from the Off-Campus case responded: "The time is ideal as it allows us to be able to talk to each other on how we collect data" (Student Journal Reflection #8).

Finally, when asked how class time had affected their group’s progress, Audrey from the On-Campus case responded: "some classes we don’t have enough time to get two trials, so we won’t have as much data as we might need" (Student Journal Reflection #8). Lexi, from the Off-Campus case responded: "I think that we can take our time with the uninterrupted schedule. This allows us to be able to check for mistakes and make sure our work is as good as it can be" (Student Journal Reflection #8).

Participant responses provide insights into student perceptions of how time was influencing their progress. The On-Campus participants noted pressures from time constraints and a concern about their ability to successfully collect an adequate amount of data. The group also recognized that in order for them to deal with the time challenges, they had divided tasks within the group and hurried their transitions between role swapping. The Off-Campus participants, however, expressed having adequate time to not only conduct their experiment, but also to assess their progress along the way. They felt they had been able to discuss what was going well and what needed to be improved.
Now that the participant experiences for both the On-Campus and Off-Campus cases have been presented, I turn to a discussion about the themes that emerged within each case. I discuss how my findings support existing literature on IBS as well as how Flow Theory illuminates my results and aspects of IBS.

**Data Collection: Relevant Themes That Emerged**

**Social Interactions:**

Student social interactions within both cases included those that were verbal, physical, collaborative, cooperative, and playful. In both cases, verbal interactions included research-related discussions as well as random tangents about non-related topics. The frequency and duration of content-related conversations was three times greater in the Off-Campus case. These conversations were also more conceptually complex within the Off-Campus case. For example, project-specific discussions within the On-Campus case included telling each other what work still needed to be completed and suggesting how to repair the broken bird feeder. Such discussions within the Off-Campus case included planning their data collection strategy each day, discussing how to use the equipment and troubleshoot equipment problems, as well as how to determine the highest pitch across a sound file within the Raven Lite computer program. Verbal interactions in the Off-Campus case also included giving, receiving, and discussing, feedback about their observations and project progress; such discussions were largely lacking within the On-Campus case.

Some competitive interactions emerged within the On-Campus case. Competitive interactions included competing to see which pair of participants
observed the greatest number of birds during their observation session. The competitiveness, although good-natured, also perpetuated a fracture within the group; each pair attempted to outdo the other.

**Emotions:**

Participants in both cases expressed excitement, enjoyment, pride, and frustration during this time span. Excited participants in the On-Campus case eagerly looked over each other's shoulders as data was recorded and celebrated birds landing on their feeder with high-fives. Pride was evident in Kaylee's comment:

> Audrey noticed the leaf I put in the place of a broken hole so the seed wouldn't fall out and it was still there and she said 'Hey your leaf idea worked!' And I thought that was cool because I felt like I helped even though I just took a leaf from the ground and stuffed it in the feeder (Kaylee, Student Journal #8).

Kaylee's resolution to the feeder problem had been recognized and complimented by her peer; this recognition and sense of accomplishment triggered her pride. Frustration surfaced in the On-Campus case from the repeated need to repair their bird feeder and when birds did not come to their feeder during observation sessions.

In the Off-Campus case, excitement was evident in the manner in which participants walked quickly out to the wigwam each day and when they recorded the snake slithering in the leaves. Participant enjoyment was evident as they chatted cheerfully, playfully teased each other, and played in mud puddles. This
group also expressed frustration, however, such as when they repeatedly ran out of battery power without having spare batteries in the field.

An emotion that surfaced within only one case during this time span was stress. Participants in the On-Campus case became visibly stressed as they frantically swapped roles; their actions and words were hurried and fleeting. Kaylee’s comment: "sometimes we cut it too close and we are outside for the entire 45 minutes and we might be late getting to our next class" (Student Journal #8) indicated feeling stressed, and concerned, about being late to subsequent classes. Stress was also revealed by Audrey’s comment that her group “won’t have as much data as we might need” (Student Journal #8).

**Acting Like a Scientist:**

Participants in both cases also acted like scientists; they set up controlled experiments, made decisions about data collection methods, and gathered data. Participants also made adjustments to their work and solved equipment problems and challenges as they went about the data collection process.

Participants in the Off-Campus case, however, expanded the authenticity with which they acted like scientists. These participants coordinated data collection and observations from multiple field locations, they assessed the quality of the data they were collecting, they designed strategies to successfully acquire recordings needed for their project, and they learned how to operate the less familiar features of the sound recording equipment. The Off-Campus participants also discussed and considered plausible explanations for their data results, such as suggesting their hypothesis that there were fewer birds calling in
the afternoon because of the increased heat in the afternoon. Off-Campus participants shared, and discussed, data results and research efforts with their peers and the teacher. Much of the student’s ability to engage in such discussions could be traced to aspects of time.

Influence of Time:

Time became an influence on student progress during this time span. The On-Campus participants became aware of time constraints as evidenced by Margaret’s comment that “the 45 minute classes are just a tiny bit too short” (Student Journal #8). Role exchanges between the pairs were always frenzied; the two pairs would scramble past each other and only briefly, and hurriedly, tell each other what they had accomplished. During my post interviews with students, Margaret described one of these exchanges. She mimicked, in a rushed and frantic sounding voice, that: “it was more of a quick like ‘oh, I was working on that, the blahblahblah, intro, intro, go, go work on the intro it's already on the computer, so nananana’ it was like that kind of talking” (Margaret, post interview). There was little communication between the two groups during the data collection phase of their project. Any potential flow was interrupted; either by frantic role exchanges, the end of class, or by students deciding that there was not enough time remaining to make further engagement worth their effort. During such interruptions, conversations and work efforts were dropped and progress and momentum were lost.

Time was also a definite, although positive, influence on progress within the Off-Campus case. Students claimed, during interviews, within student journal
reflections, and within class debrief sessions, that having extended time allowed them to "get into a flow" (Lexi, 5/24/11). Students expressed that such flow assisted them in thinking through their projects, assessing data that was collected, and problem solving. Lexi explained that it had been "nice to really be able to gather our thoughts, allowing us to move more quickly (collect data)" (Lexi, Student Journal #8). Off-Campus participants also benefitted from the time engaged in debrief circles; the discussions within these debriefs, including the exchange of ideas and feedback, positively influenced student motivation and progress. The debrief circles provided a key element, that of immediate feedback, for promoting flow. Participants engaged in content related discourse and received immediate feedback from group-mates, peers, and the teacher.

Influence of Location:

Within the On-Campus case, participants conformed to the class schedule; time restrictions were a challenge. However, no modifications to plans were made even after such restrictions had been noted; modifications, such as conducting fifteen-minute observations instead of twenty, could have alleviated the pressures relevant to time. Additionally, the close proximity of this group's project to other groups not only caused interferences to their own experiment, such as from other students walking back and forth within their observation area, but it also caused distractions for the participants, causing them to lose focus.

Within the Off-Campus case, the nature reserve became increasingly representative, and reflective, of a "hot spot" as described by Parker and Hackett (2012). Off-Campus participants experienced extended periods of time in
isolation from outside influences. Participants formed a group identity as well as group-specific expressions, such as "we're off to the lump" and "data, data, data," that forged and signified their solidarity as a group. Participants became engrossed in their work. Experiencing the data collection phase of this project at the nature reserve provided the Off-Campus participant's time and opportunity to approach and experience flow.

Take Away Message:

The conditions for establishing flow, that of having clear goals, immediate feedback, and a balance between challenges and skills, were more pervasive within the Off-Campus case. Participants in both classes established goals for the day. In the On-Campus case, the goals were only briefly discussed before the group split into two and there was only minimal communication about their progress towards those goals. Interactions that did occur were frenzied and brief. As a result, these participants received negligible feedback from their own group. In contrast, participants in the Off-Campus case discussed their goals extensively at the start of each day and discussed their progress towards those goals throughout the day. Off-Campus participants also shared their experiences and observations with other groups and the teacher; this occurred casually during lunch breaks and formally during debrief discussion circles. These participants received extensive feedback from within their group, from the teacher, and from their peers.

The challenges faced by participants in the On-Campus case did not tax or extend their skill level. The challenges they faced, fixing a broken birdfeeder
and the level of static emitted from their speakers, were easily overcome. Their
data collection needs, that of tallying the number of birds that landed on their
feeder, presented a nominal task for which they were abundantly capable. A
balance between skill and challenge was not sustained; these participants fell
below the optimal conditions for flow and boredom arose. Additionally, however,
they faced challenges from time restrictions that caused them to doubt their
ability to successfully collect the data they desired. This imbalance placed them
above the optimal range for flow and anxiety arose.

In contrast, participants in the Off-Campus case were faced with several
challenges that provided them opportunity to learn new skills and to problem
solve. The Off-Campus participants experienced a sustained balance between
skills required and challenges faced. As the project progressed, new challenges
arose. For example, first the students had to learn how to use the equipment,
then how to interpret the data obtained from the equipment. The Off-Campus
participants entered states of flow.

Insights into IBS and Flow Theory:

The On-Campus participant experiences illustrate typical student
experiences with IBS as it is typically implemented. They faced time restrictions
and little opportunity for receiving feedback. As described by Flick (1998), IBS
lessons are often implemented within strict time constraints that pressure
students to rush through much of the experience without being given an
opportunity to process or discuss their experiences, their work, or the meaning of
the data they are collecting (Flick, 1998). During such experiences, students are
often marched through procedural steps of “the scientific method” without much concern for understanding the meaning of the results they obtain, as long as students complete each of the prescribed steps, they are considered to have successfully completed the experience (Flick, 1998). The On-Campus participants progressed through procedural steps of data collection and obtained data; they were considered by themselves and the teacher to be successful. The Off-Campus participants were also considered successful; they gathered necessary data. They also, however, discussed their progress and the potential meaning of data collected, adjusted plans and methods, and learned new skills.

Flow Theory provides a conceptual understanding of these results; participants in the Off-Campus case had more consistently experienced the three conditions for initiating and sustaining flow. Similarly to what had been seen among scientists in the Parker and Hackett study (2012), states of flow influenced the level of content related discourse and fostered positive emotions about experiences. Parker and Hackett documented that when scientists got into a flow with their work, the level of content related discourse increased and more creative ideas, and enthusiasm for their work, emerged (2012). The Off-Campus participants of my research displayed more positive emotion, engaged in more in-depth and content-related discussion, and sustained enthusiasm for their work.

**The Path Divides Even Further: Time Span Summary**

By the end of the data collection phase, the Off-Campus case had received five hours and fifty-five minutes of additional time for this project. Although this IBS unit had been intended, and every effort had been made, to
have the same total project time, including time for data collection, unexpected timing issues arose that prompted the noted differences. First, there was an overestimate of how long it would take to organize and transport students to and from the reserve each day; as a result, students had one hour longer each day at the reserve to work on their projects than had been anticipated. Four hours of the five hour and fifty-five minute time difference was a result of this miscalculation. Second, unanticipated schedule changes arose within the daily school schedule; the remaining one hour and twenty minute time difference between the two cases was a result of these schedule changes.

Differences in student perceptions about time emerged during this time span. On-Campus participants stated that time constraints made it necessary for them to “divide and conquer our tasks” in order to complete project requirements (Margaret, Student Journal #8). They had little opportunity to engage, as an entire group, in discourse about what had been accomplished and how best to proceed. Off-Campus participants stated that: “Having time to talk to my group-mates made collecting data a lot easier because we knew exactly what’s going on, and we’re not confused” (Paige, Student Journal #8). The benefit of having time to talk to each other led students in the Off-Campus case to collect their data efficiently and confidently.

The conditions necessary to experience flow were more prevalent in the Off-Campus case. As seen in Table 10, participants in the Off-Campus case approached or experienced flow with four times the frequency as participants in the On-Campus case. In order to be counted as an instance of flow, participants
had to have sustained focus and active engagement in an activity or discussion for a minimum duration of five minutes; this was assessed and evaluated through the repeated viewing of video recordings. Additionally, Off-Campus participants expressed positive feelings, engaged in content related discourse, acted like scientists, and identified and resolved problems more frequently than participants in the On-Campus case. On-Campus participants expressed negative feelings with nearly three times the frequency as Off-Campus participants. Evidence of these results emerged in multiple data sources as shown in Table 10.
<table>
<thead>
<tr>
<th></th>
<th>Frequency of Occurrence in the On-Campus case</th>
<th>Frequency of Occurrence in the Off-Campus case</th>
<th>Number of Sources in which evidence appeared in the On-Campus case</th>
<th>Number of Sources in which evidence appeared in the Off-Campus case</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flow Experiences</strong></td>
<td>2</td>
<td>9</td>
<td>2 (researcher field notes, video)</td>
<td>8 (researcher field notes, video, 2 post interviews, 4 student journals)</td>
</tr>
<tr>
<td><strong>Positive feelings or actions</strong></td>
<td>6</td>
<td>19</td>
<td>7 (researcher field notes, video, 3 student journals, 2 post interviews)</td>
<td>9 (researcher field notes, video, 4 student journals, 2 post interviews)</td>
</tr>
<tr>
<td><strong>Negative feelings or actions</strong></td>
<td>8</td>
<td>3</td>
<td>3 (researcher field notes, video, post interview)</td>
<td>3 (researcher field notes, video, post interview)</td>
</tr>
<tr>
<td><strong>Content related discourse lasting more than 3 minutes</strong></td>
<td>3</td>
<td>9</td>
<td>2 (researcher field notes, video)</td>
<td>2 (researcher field notes, video)</td>
</tr>
<tr>
<td><strong>Acting like a scientist</strong></td>
<td>7</td>
<td>12</td>
<td>4 (researcher field notes, video, 2 student journals)</td>
<td>4 (researcher field notes, video, 2 student journals)</td>
</tr>
<tr>
<td><strong>Identified and Resolved Problems</strong></td>
<td>3</td>
<td>8</td>
<td>4 (researcher field notes, video, 2 student journals)</td>
<td>4 (researcher field notes, video, 4 student journals)</td>
</tr>
</tbody>
</table>

Table 10: Summary and Comparison of Frequency and Occurrence

Although these results illustrate that states of flow more regularly emerged within the Off-Campus case in which there was extended time available, it must not be forgotten that states of flow can be realized even within forty-five minute time limits. This was seen during early activities within this curriculum in which
the On-Campus and Off-Campus participants briefly entered into states of flow with equal propensity and frequency. The conditions for entering flow states must be present; the manner in which the On-Campus participants experienced the data collection phase of this project prevented these conditions from materializing as extensively as was seen in the Off-Campus case.

Consistent with Csikszentmihalyi’s depiction of flow, as participants in my research identified and worked towards goals, received feedback, and experienced a balance between required skills and challenges faced, they became increasingly likely to approach or enter states of flow. What became increasingly apparent during this time span, however, was that the quality of participant experiences with these conditions for flow was integral to the extent and intensity with which flow states were approached and entered. As increased opportunities to discuss, evaluate, and hypothesize with their peers about research progress and results were provided the propensity for participant experiences with flow increased; this was more prevalent within the Off-Campus case. As can be seen in Figure 9, as peer-peer discussions increasingly included content-related discourse, feedback and evaluations about ideas and progress, confirmation and analysis of struggles faced, and as group solidarity increased, participants became more intrinsically motivated, elicited enhanced perseverance, and more authentically acted like scientists. The uninterrupted time and the characteristics of hot spots experienced within the Off-Campus case facilitated such peer-peer discussion and perseverance; the pathway of student social interactions and experiences leading to flow and motivation is depicted in
During this time span, the Off-Campus participants approached and entered into states of flow more frequently, and for longer duration, than On-Campus participants. The divergence between the On-Campus and Off-Campus
cases continued as the project progressed. A discussion of how this divergence led to different project outcomes from each case is presented in the next section.

**Ultimate Outcomes:** (June 1-June 16: two and a half week time span)

Following the data collection phase of this project, all science classes in both cases were held within the science classroom at CMS during regularly scheduled times. Time was dedicated for students to complete their data analysis, develop their research conclusions, and create their final products and presentations. Students made graphs of their data and were shown how to conduct a chi-square statistics test for their data. Students also engaged in a peer review of their work and then worked to create their final project products. Two student journal reflections and a final quiz were also completed during this time span.

Students in the On-Campus case went about their work with an air of determination to simply get the project completed; students in the Off-Campus case went about their work with an air of not only completing the project, but also understanding and accurately conveying their results. For example, in the On-Campus case, upon completing their computer generated graph, Margaret commented to her group: “it seems to me the rap [music genre] had the most birds. I don’t know why, but it did” (Margaret, 6/1/11). The group laughed about the results, but no discussion about, or efforts to understand, the results ensued, they simply moved on to the next item on their project requirement checklist.
Additionally, upon completion of their statistics test, the following conversation occurred within the On-Campus case:

Margaret: “our graph supports the HA, but the statistics support the HO”

[HA stood for the alternative hypothesis, HO the null hypothesis]...

Audrey: “oh, but the statistics support the other one, the null”

Margaret: “yeah. But wait, where are our hypotheses? [Margaret briefly looked at the paper where they had written their hypotheses] OK, we’re good. Yeah this is right. Ok what else do we have to do? Let’s work on coloring the title.” (6/7/11)

As can be seen from the verbal exchange above, there was no discussion about what their statistics results actually meant, or how their graph could indicate support for one hypothesis yet the result of their statistics test indicated support for the other.

In contrast, participants in the Off-Campus case engaged in in-depth content-related discussions, many of which occurred, and were necessary before they could make their graph. In order to access their data, these participants first had to scroll through spectrograms, assess each of the highest pitches noted to determine whether a bird had made the sound, and then measure the actual pitch from the spectrogram. The following comments illustrate these efforts:

the darker parts [meaning colors within the spectrograms] are definitely birds… the blue parts are us talking, and the red parts are, I’m almost positive are all birds. We should check the red ones… let me see if I change the color [meaning on the
The Off-Campus participants had to complete four additional steps, finding the highest pitch sounds and assessing whether the sound was made by a bird, determining the value of the highest pitch birdcall, and creating a data table that documented the highest pitch from each trial, in their analysis efforts.

The Off-Campus participants pointed out possible explanations for the result of their statistics test. The following excerpt from their discussion upon completing their statistics test illustrates this point:

Lexi: “so we’re accepting the null hypothesis. Pretty cool.”
Leigha: “so like our experiment is like void?”
Lexi: “no, it just means that we accept our null hypothesis.”
Paige: “cause it doesn’t really matter what the habitat is.”
Lexi: “yeah, it could be certain birds living in certain habitats, like maybe woodpeckers are only in one habitat; it could be lots of different reasons. Maybe like all the birds just go all over the place so it doesn’t matter” (6/7/11).

The Off-Campus participants discussed which hypothesis was supported by their statistics test as well as how that support could be explained.

The discussions presented above are representative of the majority of discussions that ensued during this time span. The On-Campus participants engaged in very little content-related discourse; they focused on completing the remaining project requirements. The Off-Campus participants engaged in
frequent content-related discussions; they worked to complete the project, but also to understand the meaning of their work. Another difference between the two cases, however, emerged during the peer review of their final posters.

The Peer Review Process: Description of Activity

Two days before the final products were due to Mike for grading, students participated in a peer review of each other’s work. During this peer review, students visited each other’s posters and generated written feedback for the creators of the poster. Each group was given a checklist to denote whether required items and information had been included in, or were missing from, the reviewed poster. Students were also asked to write three positive statements about the product they reviewed and two comments suggesting improvements that could be made. Participant reactions to the feedback received from their peers differed between the two cases.

The Peer Review Process: On-Campus Participant Reaction to Peer Feedback

When participants from the On-Campus case received their feedback sheets, they read the comments from their peers with very little reaction. They simply said “Ok. They said it’s not organized and we don’t have a sketch of our set up” (Audrey, 6/13/11) and then quickly went about making some adjustments to their poster. It had been suggested that they rearrange the order of their poster so that it would flow more fluidly. Rather than taking the time to rearrange the sections presented on the poster into a more sequential order, they simply took a marker and wrote numbers beside each section to indicate the proper viewing order. They also added clarifying information about their set up, such as how far
away from the tree their speakers had been and how high in the tree their bird feeder had been positioned, by using a marker to add that information onto an existing picture. When finished with these minor modifications, they quickly looked over their final poster, smiled and commented to each other about how good it looked. Although the group was quite proud of their work, they seemed more pleased to simply be finished. When class ended, they quickly folded up their poster and tossed it, quite nonchalantly, into the corner of the room and left.

A very different reaction to peer feedback unfolded in the Off-Campus case.

The Peer Review Process: Off-Campus Participant Reaction to Peer Feedback

Participants in the Off-Campus case had quite a visceral reaction to the feedback received from their peers. The girls were initially angered and upset by the comments and suggestions received; they seemed upset that any fault had been found in their work. For example, Lexi immediately retaliated to a comment claiming that the positioning of items did not flow in a logical order, by exclaiming: “It does too, look, it goes from here to here. It’s totally obvious which way it goes” (Lexi, 6/14/11) and Ally added “that’s so stupid; it’s totally organized” (Ally, 6/14/11). The group then spent over a minute in silence looking over their poster and glancing back at the feedback they had been given. Leigha then commented: “no, look you guys… they’re right…we should switch the data table and results; they are backwards” (Leigha, 6/14/11). The group then feverishly worked to make the suggested corrections. They actually disassembled parts of their poster and reassembled it in an order that would flow more fluidly. When finished, they stepped back and admired their work as a group. Lexi commented:
"I'm proud of us; we had a hard project" (Lexi, 6/14/11). They quite carefully folded their poster and positioned it gently within their classes designated area.

The differences between the two cases described above are representative of student discussions and work efforts from throughout this time span. Next, I describe the major themes that emerged during this time span.

**Ultimate Outcomes Time-span: Relevant Themes That Emerged**

**Student Social Interactions:**

Social interactions common to each case during this time span included those that were verbal and cooperative. Verbal interactions included discussions that were both content-related and non-content-related. Students in both cases cooperated in order to complete their projects; each participant took on, and completed, various tasks and all helped to create the final posters. The On-Campus participants however continued their "divide and conquer" strategy; they primarily worked independently of each other and then pulled individual pieces together in the end in order to "get it over with" (Kaylee, 6/9/11). Interactions within the Off-Campus case revealed a heightened sense of camaraderie. Off-Campus participants worked collaboratively and discussed each component of their project before moving on to the next. In the Off-Campus case, the amount of content-related discourse that emerged was more than double that witnessed within the On-Campus case.

Three minor arguments also broke out in the Off-Campus case; no such arguments were witnessed within the On-Campus case. Off-Campus participants argued about how to best view their spectrograms, such as what color display
made it easiest to interpret the images, and how best to present their material within their final poster. Such argumentation echoed findings from the Parker and Hackett (2012) study in which the researchers investigated influences on the productivity of scientists. In their study, Parker and Hackett found that emotions fueled the interactions of the scientists and that argumentation arose when the dedication and determination of one scientist did not initially align with the thoughts or goals of another scientist (Parker & Hackett, 2012). Such argumentation typically fueled heated and specific content related discourse that eventually led to an amicable resolution of the disputed points. Similar to Parker and Hackett’s findings, Off-Campus participants occasionally engaged in disputes, fueled by their determination to accomplish particular tasks, but eventually reached agreement on the issue. The emotions within the Off-Campus case were more intense than what was seen in the On-Campus case.

*Emotions:*

Student emotions common to each case included enjoyment, determination, investment, frustration, and pride. Students in both cases engaged in enthusiastic discussions about their projects; they enjoyed their time putting their posters and presentations together. They also interjected playful teasing and casual discussions as they worked. Participants in both cases expressed excitement about their participation in their projects. For example, On-Campus participants shared:

Kim: “we were SO excited, like we started shaking over like these little
birds on the tree. Like we were dead silent, just like watching the tree, and we're like 'look, look, look.'

Kaylee: "It's like, it's like 'oh my god, it's a success!"

Kim: "Cause we worked so hard for it"

Kaylee: "it's working, and, well we came up with this and it isn't stupid"

Kim: "like they were talking about it ALL day" (post interview)

Similarly, participants in the Off-Campus case shared:

Lexi: "I think we really applied ourselves and - you know we're actually really trying. We've like put in a lot...so I mean, I think we're excited about it."

Paige: "Yeah it was a great feeling."

Leigha: "It's your real curiosity as opposed to someone elses."

Paige: "Instead of just being like 'Ahh, I HAVE to do this, I don't want to do this,' it's like 'oh well, I have this question and I really want to know'" (post interview).

Such comments reveal that both groups were excited and enthusiastic about their projects. Both groups also, however, exhibited frustration and anxiety about time constraints they experienced during the project. Students in both cases expressed feeling rushed at various times, particularly near the end of the project. For example, when asked during post interviews whether they had felt any frustrations during the project, Kaylee, from the On-Campus case, stated:

Uh, the timing. Cause we had like 20 minute trials and we only had 45 minutes and it'd usually take us like, almost 10 minutes to get
everything set up and stuff, so we'd start one, and then we won't be able to like finish it out (Kaylee, post interview).

Similarly, students in the Off-Campus case felt frustrations with time constraints near the end of the project as evidenced by Paige's comment: "we got so rushed, especially at the end. It would have been nice to have like more time to like get our presentation better, but class was always over" (Paige, post interview). Even though both groups had felt frustrations, primarily due to time constraints, students in the On-Campus case ultimately expressed such frustration with more than twice the frequency of those in the Off-Campus case.

Both groups were proud of their finished posters. Participants in the On-Campus case momentarily stepped back to observe, and celebrate, their completed poster and stated that it "looked cool" (Margaret, 6/14/11). Participants in the Off-Campus case spent twice the time reviewing their final work; they beamed with pride as they admired their poster. Lexi overtly expressed this pride when she said: "I'm proud of us; we had a hard project" (Lexi, 6/14/11).

Acting Like a Scientist:

Differences also emerged in the manner in which students in each case acted like scientists. In both cases, students engaged in at least some content-related discourse as they completed their work, went through the peer review process, and made final presentations of their projects to the class. Both groups gave and received feedback to other groups during the peer review activity.

Participants in the Off-Campus case engaged in content-related discourse with greater frequency and duration than the On-Campus participants. They
discussed, reflected upon, and reacted to comments and suggestions, including those from their peers. Off-Campus participants conducted a more complex investigation as well as more in-depth analyses of their data and research conclusions.

Although participants in both cases enjoyed, and were dedicated to, their projects, differences in motivation and achievements emerged. Some differences in achievement outcomes are revealed within the participant posters.

**Achievement Outcomes: Comparison of Final Posters**

Differences in the rigor and depth of understanding exhibited by the students were revealed in the manner in which the "Discussion and Conclusion" sections of the student-generated posters were created and presented. In the On-Campus case, Margaret wrote the entire Discussion and Conclusion sections for her group without any input from her group-mates. When completed, she simply asked the group to read what she had written and to make any comments or suggestions. Kaylee quickly, within twenty-five seconds, read what Margaret had written and commented: "looks great; want me to print it?" (Kaylee, 6/9/11). Neither of the other girls in the group read, or commented, about either of these sections. Margaret’s work was simply printed and stapled to the poster. The girls displayed an attitude of just wanting to get the project completed. During her final formal interview, Kaylee described the efforts of her group while working on their poster. She explained: "I just took a stapler and went like, 'boom, boom, boom, boom' [motioning with her hand and arm as if slamming staples into the poster]
and Margaret's like, 'no we gotta..' and I'm like 'Margaret let's just do it 'n get it over with’ (Kaylee, final formal interview).

The girls in the Off-Campus case, however, worked together to create both their Discussion and Conclusion. The entire group discussed what information would be included within each section. Comments, and suggestions, made by individuals were considered and discussed in detail. Adjustments were made and revisions were reread and re-discussed. The sections were not printed out, or attached to their final poster, until everyone was satisfied with what had been included. Differences between the discussions and conclusions that were generated within each case are illustrated next; the actual writings from participants are included in Appendix E.

*The Poster from the On-Campus Participants:*

The On-Campus participant's posed research question was: “Does the genre of music played at a bird feeder affect the number of birds that visit the feeder?” Although this was their actual research question, the question they presented on their final poster was: “What genre of music effects bird activity throughout the day?” This presented question reflected a different experiment than the one they had actually conducted, and discussed throughout their poster. Their discussion and conclusion section included mentioned challenges the group faced during their experiment, specified the genres of music they included in their experiment, and mention was made of their discovered discrepancy between the hypothesis visually supported by the graph of their data and the hypothesis supported by their statistics test. Their discussion and conclusion also
stated that they would make changes to their procedure if they were to repeat their experiment, and they stated their final conclusions.

Their discussion and conclusion sections also lacked some information and included errors. For example, they stated in their discussion that they conducted ten trials when in actuality they had conducted only eight. They mentioned conducting a statistics test, but they neglected to identify what type of statistics test. Although they mentioned they would make changes to their procedure if they were to repeat the experiment, they did not specify what changes they would make.

The Poster from the Off-Campus Participants:

The Off-Campus participant’s posed research question was: “Does the environment the bird is in have an affect on the pitch of its chirp?” The students did investigate this question. One flaw in their presented research question, however, is that one could interpret their intent as having been to study the pitch of chirping from the same bird within different environments, when in actuality, they measured the highest pitch of any bird heard in an area.

The details included within this group’s discussion and conclusion sections were more specific than what was seen in the On-Campus case. The Off-Campus participants not only identified that their null hypothesis had been supported by their statistics test, but they also explained what such support meant. They also identified that the statistics test they had performed was a chi-square test. They specifically identified two of the challenges they faced and discussed ways in which they could improve their experiment. Additionally, they
included three follow-up questions that, if investigated, would lead to a greater understanding of their investigated topic. An error within their poster included a statement that the chi-square test "proved we were correct." Even though Mike had, on several occasions in class, discussed differences between having ones hypotheses supported or refuted by the data and being able to claim proof of conclusions, the girls still incorrectly claimed that the results of their statistics test proved their research conclusions. Overall, the work presented by students in the Off-Campus case illustrated greater attention to detail, depth of understanding, and pride in their work than that presented by students in the On-Campus case.

The project grades received in each case, however, revealed only a two-point difference in final scores; the On-Campus participants received 245/250 points (98%) on their final project and the Off-Campus participants received 247/250 points (98.8%) on their final project. It must be noted, however, that the final grading effort from the teacher to establish these final project grades was admittedly rushed. Mike declared that his grading effort had been superficial at best and that as long as the basic requirements had appeared within their posters, the students received full credit; he did not spend time assessing the quality of the content or depth of analysis within each component. He explained this was because he "only had one afternoon to grade all of the student projects before final term grades had to be submitted to the office" (Mike, 6/18/11).

Insights into IBS and Flow Theory:

The activities and subsequent results that are presented throughout this section illustrate differences between the two cases and reveal aspects of IBS
that are commonly experienced by students. Participants created posters in which they presented components that are typically associated with “the scientific method;” each poster included a title, introduction, research question, hypothesis, experimental design, data table, a graph of the data, statistical analysis of the data, a discussion, and a conclusion. Students were considered successful, based on teacher assessments, if they included each of the required components. Little analysis regarding depth of conceptual understanding was conducted; if required components had been presented, students received full credit and were considered successful. Such presentations and considerations of success are typical within current IBS practices (Flick, 1998).

The practice of rushing students through research and analysis processes are well described, and identified as an existing weakness in instructional practices, within Yore et al. (2008). Participants within my research had been rushed through their analysis efforts and the teacher had been rushed through his efforts. Additionally, limitations within what typically counts for success within IBS are well documented. For example, students are typically considered successful if they can navigate through procedural steps of “the scientific method” and/or receive high marks on standardized tests (Yore et al., 2008). Mike’s practice of considering the inclusion of poster requirements as his primary measure of student success is reflective of these findings from Yore et al. (2008).

Aspects of Flow Theory and influences of hot spots inform much of the motivation and achievement outcomes witnessed within this time span. Students within the On-Campus case had not experienced conditions for entering states of
flow to the same extent as the Off-Campus participants, nor did they experience influences from a location that fostered characteristics of a hot spot. Without such experiences, the group had taken on the desire to simply complete the project as was revealed in Kaylee’s comment to “just get it over with” (Kaylee, 6/9/11) and by their lack of reaction to feedback received during the peer review process.

The visceral reaction displayed by the Off-Campus participant’s to the peer review feedback, however, reflected the reactions to feedback that had been seen among scientists in the Parker and Hackett (2012) study. In this study, the researchers noted that scientists who had participated in remote retreats, and had experienced dimensions of flow, developed group solidarity and were quite resistant to outside criticism of their work. The researchers found that the scientists became emotionally attached to, and invested in, their work; they resented outside criticism and intensely argued with other scientists who criticized their work. Parker and Hackett explained the reasoning behind such an argument by claiming that:

the structure of the meetings erected physical and social barriers against outsiders, which facilitated bonding and intense social solidarity. As a result, members experienced a version of the band-of-brothers phenomenon, becoming much more tightly allied with each other than with the broader scientific community. Skepticism, criticism, and conflict were felt more severely than would otherwise be the case.....outside critiques punctured the group’s membrane of emotional solidarity and trust...The strong collective identity formed by repeated interactions and rituals rallied
the group in the face of an outside threat. With lower emotional investment it is unlikely that a fight would have occurred (Parker & Hackett, 2012).

The Off-Campus participants had experienced extended and isolated interactions; the nature reserve had elicited characteristics of a hot spot. Through their experiences, the Off-Campus participants had developed a group identity and rituals; examples of this include their expressions of “we’re off to the lump” and “data, data, data.” Off-Campus participants had become tightly allied with each other; the outside criticism from the peer review had “punctured the groups membrane of solidarity."

The same sociology of emotions that Parker and Hackett (2012) used to explain the behavior among the scientists in their study explains the lack of reaction to peer feedback that was seen in the On-Campus case, and the strong reaction to peer feedback seen from students in the Off-Campus case. Just as Parker and Hackett had found that the scientist’s solidarity had “rallied the group” to deal with outside criticism, the solidarity among the students in the Off-Campus case, and the investment in their project, had rallied these girls to ultimately be able to objectively consider the outside feedback, and criticism, to make improvements to their final poster. By the end of this time span, considerable differences between the two cases had emerged. Participants in the Off-Campus case had outperformed participants in the On-Campus case.

**Ultimate Outcomes: Time Span Summary**

Throughout this time span, participants worked within their groups to complete the IBS project. Participants in the Off-Campus case consistently
engaged in more frequent, with longer duration, content-related discussions than the On-Campus participants. Off-Campus participants discussed the meaning of their project results, worked collaboratively to complete final poster requirements, and included more specific and content-related details within their poster than the On-Campus participants. Although participants from both cases were proud of their final posters, the On-Campus participants had been primarily focused on completion rather than conceptual understanding. The Off-Campus participants demonstrated an enhanced conceptual understanding of the scientific process and the results of their investigation. Participants in both cases had established goals and received feedback. The depth of discussion and quality of received feedback had been more extensive and specific within the Off-Campus case; such intensive experiences acted as stronger catalysts towards flow experiences. Additionally, the challenges faced by the Off-Campus participants had sustained a balance between skill and challenge; the On-Campus participants had fallen outside of optimal ranges for flow. Finally, the tendency of Off-Campus participants to approach, and enter, into states of flow at fostered greater intrinsic motivation which spawned perseverance and determination to complete and conceptually understand the meaning of their work.

This time span concluded the IBS unit. A case comparison of overall participant achievements is presented below.

**Case Comparison of Ultimate Achievement Outcomes**

Differences in motivation and academic achievements emerged between the On-Campus and Off-Campus cases. Mike primarily assessed student
achievement through summative assessments such as performance on quizzes, completion of worksheet assignments, and final student projects; the scoring rubric that was used by the teacher to establish final project grades for the students is included in Appendix F. Individual student scores from the thirteen summative assessments are included in Appendix G and summarized below in Table 11.

<table>
<thead>
<tr>
<th>Number of Assignments</th>
<th>Average scores in the Off-Campus case Higher than those in the On-Campus case</th>
<th>Average scores in the Off-Campus case Equal to those in the On-Campus case</th>
<th>Average scores in the Off-Campus case Lower than those in the On-Campus case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>46%</td>
<td>31%</td>
<td>23%</td>
</tr>
</tbody>
</table>

Table 11: Comparison of achievement scores across cases

From Table 11, one can see that out of the thirteen academic grades received during this project, 46%, (six out of thirteen) were higher in the Off-Campus case than in the On-Campus case, 31% (four out of thirteen) were equal across cases, and 23% (three out of thirteen) were lower in the Off-Campus case than in the On-Campus case; these scores are summarized in Table 11. These results illustrate higher academic achievement scores, on nearly half of the formal assignments, from participants in the Off-Campus case compared to the On-Campus participants.

There was, however, only a two-point difference in the final project grade assigned to each participant; those in the On-Campus case received 245/250
points, those in the Off-Campus case received 247/250 points. The teacher had admittedly only superficially assessed the final projects due to time constraints. Although the final project grade discrepancies had been nominal, the depth of conceptual understanding exhibited by students within their final posters revealed additional differences between the two cases. The information contained within the Off-Campus participant’s poster included more specific detail and analysis than what was seen within the poster created by the On-Campus participants.

One final outcome from this project in which differences between the two cases were noted relates to student perceptions of the term "acting like a scientist." By the end of this IBS experience, participants in the Off-Campus case had expanded their interpretation of the term, and had acted in greater accordance with scientist’s perspectives of the term, to a greater extent than those in the On-Campus case.

Pre and Post Student Perceptions of the Term: Acting Like a Scientist

Participant perceptions of what it means to “act like a scientist” expanded to some extent in both cases during this project. Interpretations of the term expanded farther, however, for participants in the Off-Campus case. At the start of the project, each of the participants perceived the term to mean following procedural steps in order to conduct an experiment. For example, Kaylee initially described the term "acting like a scientist" as: “It means performing [performing] and developing experiments" (Kaylee, Student Journal #1). Her post project description of the term was: “going out and trying to like, um, figure out like, ... actually doing stuff to figure out, um, a problem you might have or something that
you’re curious about” (Kaylee, post interview). Kaylee’s post interpretation had expanded slightly to include awareness that scientists have curiosity.

Similarly, in her post interview, Margaret described the term as “questioning things around you and then you get hands-on trying to figure it out” (Margaret, post interview). Kim described the term in her post interview as “recording it [data] in the right way and like showing other people it and stuff” (Kim, post interview). Finally, Audrey described the term during her post interview as “to be like detailed with your work and stuff. Just like explain it more like not just like few words, but more words” (Audrey, post interview). The On-Campus participant’s original perceptions of the term largely prevailed in their post-project descriptions; acting like a scientist was still viewed as primarily procedural.

The post-project perceptions of the term from participants in the Off-Campus case, however, revealed some additional student insights. For example, in Lexi’s post interview, she described the term as meaning:

you’re literally like in the dirt doing everything. It’s just kind of like you’re IN [her emphasis] it, you’re in the middle of everything. Like really like applying your curiosity, not just thinking ‘gee, I wonder how that works’…. we actually go and like try or like do it. Like I began noticing a lot more details, like the longer I was there, I guess I started noticing like the type of birds, and like, sitting in the silence, like you know sometimes it was boring, but other times it’s like wow, you know you can really like hear everything. You know the difference between like doing your experiment
and like being in [hand gestures motioned downward] your experiment, like, it really helped us like get into the groove (Lexi, Post interview).

When I asked Lexi to explain what the difference was between "doing your experiment and being in your experiment", she went on to say: "I feel like doing it is like this is a school assignment" to which Jessica interjected "just trying to get it done." Lexi continued:

but being in it is really being like involved in it. You - you know want to get the 'A' but you want to yeah, you want to get the data, you want to see, you're actually like interested in your topic - and you're just like really involved (Lexi, Post Interview).

Jessica's description of "just trying to get it done" reflected what had been observed in the work efforts of the On-Campus case as well as in Kaylee's sentiment to "get it over with" (Kaylee, 6/9/11). Lexi's description of "being in it" expanded her interpretation of acting like a scientist to include interest, determination, and investment in the work.

Similarly, during Leigha's post interview, she stated the term meant: “you have to be enthusiastic about it, it's like - well I really want to do this ... so I want to figure this out" (Leigha, post interview). Paige, in her post interview claimed the term meant: “you actually want to find out the results and you're like you keep going, keep like working through everything...if you're not passionate about science, then you're not acting like a scientist” (Paige, Post interview). Finally, Jessica initially stated the term meant: “testing your hypothesis maybe like you having questions and trying to figure them out” (Jessica, Student Journal #1); at
the end of the project she claimed it meant: "Getting into a groove. I am a scientist" (Jessica, Post interview). Of all the participants in both cases, Jessica had appeared the least confident about her abilities in science at the start of the project. Her declaration of "I am a scientist" revealed a substantial leap from original perceptions and confidence.

As can be seen from the Off-Campus participant responses, the term 'acting like a scientist' expanded beyond procedural steps to include aspects of interest, dedication, and determination. In their expanded perceptions of the term acting like a scientist, participants stated an awareness of curiosity and passion for scientific discovery.

**Overall Project Summary**

Throughout this IBS project, as illustrated in Table 12, participants in the Off-Campus case had a greater number of positive interactions, expressed positive feelings, and more frequently engaged in content related discourse. These experiences had been infused with more numerous incidences of dimensions of flow, such as focused attention and concentration on the task at hand. The experiences led to increased academic achievements among Off-Campus participants and more in-depth analysis of research results. These characteristics were apparent within multiple data sources. A direct comparison between the two cases of these categories is summarized in Table 12.
<table>
<thead>
<tr>
<th></th>
<th>Frequency of Occurrence in the On-Campus case</th>
<th>Frequency of Occurrence in the Off-Campus case</th>
<th>Number of Sources in which evidence appeared in the On-Campus case</th>
<th>Number of Sources in which evidence appeared in the Off-Campus case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions of flow evident</td>
<td>3</td>
<td>7</td>
<td>2 (researcher field notes, video)</td>
<td>2 (researcher field notes, video)</td>
</tr>
<tr>
<td>Positive feelings or interactions</td>
<td>8</td>
<td>17</td>
<td>7 (researcher field notes, video, 3 student journals, 2 post interview)</td>
<td>9 (researcher field notes, video, 5 student journals, 2 post interview)</td>
</tr>
<tr>
<td>Negative feelings or interactions</td>
<td>10</td>
<td>4</td>
<td>6 (researcher field notes, video, 2 student journals, 2 post interview)</td>
<td>5 (researcher field notes, video, 2 student journals, 1 post interview)</td>
</tr>
<tr>
<td>Content related discourse lasting more than three minutes</td>
<td>4</td>
<td>12</td>
<td>2 (researcher field notes, video)</td>
<td>2 (researcher field notes, video)</td>
</tr>
<tr>
<td>Acting like a scientist</td>
<td>5</td>
<td>9</td>
<td>4 (researcher field notes, video, 2 student journals)</td>
<td>5 (researcher field notes, video, 3 student journals)</td>
</tr>
<tr>
<td>Episodes of arguing</td>
<td>0</td>
<td>3</td>
<td>2 (researcher field notes, video)</td>
<td>4 (researcher field notes, video, 1 student journal, 1 post interview)</td>
</tr>
<tr>
<td>Reaction to Peer Review Feedback</td>
<td>Minimal to none</td>
<td>Strong reaction; Offense taken</td>
<td>2 (researcher field notes, video)</td>
<td>2 (researcher field notes, video)</td>
</tr>
</tbody>
</table>

Table 12: Summary of comparisons between the On-Campus and Off-Campus cases

By the end of the Classroom Birdsleuth curriculum unit, students in the Off-Campus case had more authentically acted like scientists and had expanded...
their interpretations of what the term “acting like a scientist” meant beyond what was witnessed within the On-Campus case. Students in the Off-Campus case demonstrated increased dedication and motivation towards their research project and engaged in more frequent, with longer duration, instances of content related discourse. A summary of these categories, inclusive of a tally from all time spans, is presented in Table 13.

<table>
<thead>
<tr>
<th>Frequency of Occurrence in the On-Campus case</th>
<th>Frequency of Occurrence in the Off-Campus case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days when dimensions of Flow were evident</td>
<td>8</td>
</tr>
<tr>
<td>Positive feelings/actions</td>
<td>42</td>
</tr>
<tr>
<td>Negative feelings/actions</td>
<td>8</td>
</tr>
<tr>
<td>Episodes of content related discourse</td>
<td>27</td>
</tr>
<tr>
<td>Acting like a Scientist</td>
<td>29</td>
</tr>
<tr>
<td>Sophistication of Student Research Questions</td>
<td>Low</td>
</tr>
<tr>
<td>Achievement Outcomes</td>
<td>Typical of IBS</td>
</tr>
<tr>
<td>Skill to Challenge level comparison</td>
<td>Unbalanced</td>
</tr>
</tbody>
</table>

Table 13: Summary comparison between the On-Campus and Off-Campus cases

As can be seen in Table 13, students in the Off-Campus case experienced dimensions of flow with twice the frequency as students in the On-Campus case. Students in the Off-Campus case also had substantially more positive feelings, engaged in content related discourse to a greater extent, and displayed characteristics of acting like a scientist more frequently than those in the On-Campus case.
Student experiences as they navigated through this IBS curriculum have been tracked, described, and analyzed. Overall conclusions can now be drawn.

**Synthesis of Research Results:**

Upon thorough and rigorous evaluation of the multiple data sources that I examined throughout my research, I have reached two primary research conclusions. First, student social interactions can be directly and positively related to student motivation and achievement outcomes within IBS experiences. Second, Flow Theory can be used to inform IBS practices and to promote enhanced IBS experiences and outcomes. Two substantial implications from these findings are that Flow Theory can be used to promote motivation and achievement outcomes within IBS further than currently realized and that in order for IBS to reach such a higher potential, we must shift our current focus within IBS from a continuum that solely tracks the progression of student experiences from teacher-directed to open inquiry experiences to one that focuses on a continuum that also tracks the conditions necessary for establishing flow. In order to support these research claims, I now present specific characterizations of my two research cases within explicit answers to my initial research questions.

**Explicit Answers to Research Questions:**

My primary research question was: Within two approaches to inquiry-based science, how do student social interactions relate to student motivation and achievement? I designed my research efforts around five topical questions, each having between four and seven sub-topical questions. These topical and
sub-topical questions were designed specifically to promote access to the information required to comprehensively answer the primary research question.

*Topical Question 1: How can the student social interactions within each case be characterized?*

Participant social interactions within both cases can be characterized as cooperative and pleasant. Participants supported and assisted each other throughout the process and engaged with their research topics. Interactions within both cases were primarily verbal, but some playful physical interactions also emerged within each. Verbal interactions included, in both cases, both content-related discussions as well as random, non-content related comments.

Verbal interactions within the On-Campus case were often hurried and inexplicit. For example, during role exchanges, participants would quickly pass each other and call out what had been accomplished and what still needed to be accomplished; often the expressed needs were vague and non-specific, leaving participants unsure where to begin with their work efforts. Verbal interactions in the Off-Campus case were typically calm with longer duration and details and were clearly specified. Off-Campus participants were able to thoroughly discuss their intentions and make clear plans to meet those intentions.

Four main factors influenced the types of interactions that prevailed within each case and ultimately spawned differences between the cases. These four factors were: approaching and entering states of flow, participant emotion, time, and location. First, participant interactions were influenced by experiences with flow. When students approached or entered into states of flow, their interactions
became more focused, content-specific, and enjoyable; participants tended to lose track of time, became engrossed in activities, and increased their productivity. Participants in both cases experienced, at least briefly, states of flow during various activities and lessons, such as the "Equipment Exploration" lesson, near the start of this project. Participants in the Off-Campus case, however, experienced more frequent, with longer duration, episodes of approaching and entering into flow states throughout the project. During states of flow, participants had clear goals, received immediate feedback, and sustained a balance between skills required and challenges faced. However, participants in the Off-Campus case, who engaged in more thorough discussions and evaluations of their work and goals, approached states of flow with greater incidence than the On-Campus participants. Conditions for flow that included more in-depth discussion became influential on the types of research goals established by each group; both in terms of overall research questions and daily goals and accomplishments. The Off-Campus participants, who experienced flow more frequently, ultimately designed a more complex research question, were able to establish clear daily goals, and interacted more collaboratively. Being able to approach and enter into flow ultimately led to enhanced motivation and achievement within the Off-Campus case.

Second, participant emotions emerged as influential on student interactions. Overall, participants from both cases enjoyed their experiences and were proud of their final accomplishments. When participants felt happy, or enjoyed the activity in which they were engaged, they interacted enthusiastically.
When they felt stressed, participant interactions became frantic and intentions less clear. Participants in the On-Campus case expressed more frequent emotions of anxiety and stress. Participants in the Off-Campus case were primarily excited and joyful throughout their experience.

Third, aspects of time were quite influential on participant emotion and behavior. When participants, in both cases, felt pressures from time, they became anxious and their work efforts became more superficial with a primary goal of simply completing a task. Within the On-Campus case, a sense of time pressure prevailed for the majority of the project. Participants in the On-Campus case split into two groups in order to divide and conquer the requirements for the project. Verbal interactions were fleeting. In the Off-Campus case, extended time during the data collection phase of the project fostered an ability to share and discuss responsibilities and to establish clear goals each day; time was also afforded for Off-Campus participants to discuss their progress towards their goals and to share and receive feedback with their peers and the teacher.

Fourth, location was a factor that influenced participant interactions. Experiences at the nature reserve provided extended time for participants in the Off-Campus case to discuss, develop, and implement their research project. In this sense, the location had an influence on productivity because of the time allotted to work while in that location. Second, the nature reserve became characteristic of a hot spot; participants in the Off-Campus case formed a group identity and sense of solidarity that fostered motivation and determination to persist in their research efforts.
Topical Question 2: How does student discourse within each case relate to student interactions and activity?

Participant discourse within both cases included content-specific and random, non-content related, discussion. Whenever students became distracted, their conversations became more random and irrelevant to their project efforts. Participants in the On-Campus case became distracted more frequently and easily than participants in the Off-Campus case. During distractions, participant interactions became inhibitive to their research efforts.

Content-related discourse that emerged within the On-Campus case tended to include telling each other what to do or simply providing content-specific answers to questions that had been posed. Content-specific discourse involved more telling each other information rather than an engagement in any detailed discussion. Content-related discussions that did arise tended to be brief and superficial. Interactions and activities remained largely separate; students maintained their divide and conquer strategy.

Content-related discourse that emerged within the Off-Campus case tended to include in-depth discussions about specific information, questions, or problem solving. Content-related discussions arose with greater frequency and duration than what was seen within the On-Campus case. Content-specific discussions triggered, and were triggered by, states of flow. Interactions and activities that arose were collaborative and productive.
Research Question 3: How is student motivation characterized within each case?

Participants in both cases elicited motivation and sustained engagement during this project. Participants in both cases felt confident of their ability to be successful at the start of the project and described being pleased with their accomplishments at the conclusion of the project. Participants in both cases expressed that they had been very invested in their projects and were excited about their results; they had enjoyed their experiences.

Noticeable differences in motivation, however, did emerge between the two cases. Motivation to engage was high in both cases at the start of the project, however, motivation dissipated within the On-Campus case as the project progressed. By the final day of data collection, they had lost interest in gathering data required for their project. Self-handicapping behaviors, such as packing up materials for the day with time still remaining in class, interfered with progress within the group. Based on my observations as well as sentiments expressed by students, the On-Campus participants shifted to a goal of simply getting the project completed.

Motivation among participants in the Off-Campus case persisted for the duration of the project. These participants maintained a focus on their project and were less easily distracted. Sentiments expressed by Off-Campus participants included enthusiastic determination and investment towards their project. Goal directed activities were initiated and sustained with more than twice the frequency within the Off-Campus case. Off-Campus participants displayed enhanced motivation compared to participants in the On-Campus case.
Research Question 4: How are academic achievements within each case characterized?

Participants in both cases received high marks on summative assessments, including their final project grades, throughout this IBS experience. Although both groups received high marks throughout the project, the Off-Campus participants outperformed the On-Campus participants on forty-six percent of the summative assessments. Additionally, although there was only a two-point difference in the final project grade received by each group, the Off-Campus participants demonstrated greater conceptual understanding of their research results and information presented in their final poster. Participants in both cases reported their research results and stated conclusions; the Off-Campus participants also included explanations, reasoning, and potential alternative explanations for their results.

An evaluation of the student-generated research questions revealed that the Off-Campus participants developed a cognitively more complex, higher-level question. The research question developed by the Off-Campus participants required more advanced skills and the use of more sophisticated equipment and technology to answer their research question. The research efforts of the Off-Campus case participants fostered a more in-depth investigation. Participants in both cases had enjoyed their experiences and had been successful throughout the project, but the Off-Campus participants outperformed the On-Campus participants both in individual performance and overall group performance. The
Off-Campus participants produced a final product that demonstrated a greater breadth of understanding than the On-Campus participants.

Research Question 5: How are the established case profiles characterized and what conclusions can be drawn?

Participants in both cases primarily enjoyed their experiences and felt pleased with, and proud of, their final products. Participants in both cases engaged in cooperative and collaborative social interactions and successfully participated in and completed an inquiry-based science project. Participants in both cases experienced approaching and entering states of flow providing the three conditions for creating flow, having clear goals, receiving feedback, and maintaining a balance between skills required and challenges faced, were present. Approaching and entering states of flow was more prevalent as depth of discussion and feedback increased.

In the On-Campus case, student interactions were hurried and fleeting. The research question designed by participants in this case reflected a low cognitive level. Although ultimately successful, based on teacher assessments, participant discussions and written products lacked depth and breadth of conceptual understanding. Although highly motivated at the start of the project, student motivation dissipated by the end of the project. Participants in the On-Campus case only briefly and sporadically entered into states of flow.

In the Off-Campus case, student interactions were extensive and frequent. The research question designed by participants in this case reflected a high cognitive level. Participant motivation remained high throughout the duration of
the project. Participants in the Off-Campus case frequently, and for longer duration than witnessed in the On-Campus case, entered into or approached states of flow. Participants in this case expressed greater depth and breadth of conceptual understanding in their discussions throughout the project as well as within their final poster; participants in the Off-Campus case outperformed participants in the On-Campus case.

The Influence of Student Social Interactions on Dimensions of Flow:

Student social interactions were integral to the establishment of flow. Interactions that led to positive emotions fostered increased enthusiasm and determination; interactions that communicated information and feedback triggered content related discourse. Increased content-specific discourse triggered interest, curiosity, and determination towards their research; the combination of these factors enhanced student motivation and achievement outcomes. A cyclical feedback loop emerged within each case. More positive emotions led to more determination to engage in activities and content-related discourse. The more content-related discourse, the more invested students became in their projects; more investment led to further interaction and the process continued. This feedback loop, which is typically experienced in current implementation practices in IBS, is depicted in the blue pathway shown in Figure 9. The red pathway in Figure 9, however, traces the pathway to the enhanced motivation and achievement outcomes that can result from increased experiences with states of flow. When clear goals are communicated, immediate feedback is received, and a balance between challenges faced and skills
required to successfully address such challenges is sustained, states of flow can be entered. Enhanced states of flow, which can be brought about by greater depth and quality of discussion and interaction, lead to focused concentration, increased enjoyment in the activity, and increased motivation. Within IBS experiences, this fosters increased content-related discourse ultimately leading to enhanced achievement outcomes.
Figure 10: Model depicting the influence of flow on IBS outcomes (Blue/dark arrows = the On-Campus case; Red/light arrows = the Off-Campus case).
Table 14 traces the analysis pathway that pointed to flow as a conceptual framework for understanding the results. Reviewing Table 14 reveals that the categories used from Gee's discourse analysis can be traced through the ISTREAM categories of my observation sheets and through the emergent themes which led to, and can be explained by, Flow Theory.
<table>
<thead>
<tr>
<th>Gee's Categories:</th>
<th>ISTREAM Categories:</th>
<th>Five Emergent Themes:</th>
<th>Conditions for Flow:</th>
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<tbody>
<tr>
<td>Relationships</td>
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<td>Social Interactions</td>
<td>Clear Goals</td>
</tr>
<tr>
<td>Interactions</td>
<td>Interactions</td>
<td>- discussion-based</td>
<td>- identified</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- collaborative</td>
<td>- discussed</td>
</tr>
<tr>
<td>(Emotions &amp; Motivation)</td>
<td></td>
<td>- content-based</td>
<td>- evaluated</td>
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<tr>
<td></td>
<td></td>
<td>- specific feedback</td>
<td>Feedback</td>
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<tr>
<td></td>
<td></td>
<td>- goal directed</td>
<td>- collaborative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- peer driven</td>
<td>- discussed</td>
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<td>- frequent and</td>
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<td>interaction and</td>
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<td>motivation</td>
<td>Skill/Challenge</td>
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<td></td>
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<td>Collaborations</td>
<td>- depth of</td>
</tr>
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<td></td>
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<td>Time</td>
<td>challenges</td>
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<tr>
<td></td>
<td></td>
<td>- perception of</td>
<td>- duration of</td>
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<td></td>
<td>time led to depth</td>
<td>challenge</td>
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<td>discussion</td>
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<td></td>
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<td>Location</td>
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<td></td>
<td>- Hot Spot</td>
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<td>- privilege</td>
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<tr>
<td></td>
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<td>- motivation</td>
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Table 14: Analysis pathway leading to Flow Theory
Based on a detailed and thorough analysis of all the data compiled from my research, it became evident that student interactions which included conditions necessary for creating flow, such as having clear goals, being provided with immediate feedback, and having a balance between challenges and skills, promoted enhanced student achievement and motivation outcomes. Of particular importance, and furthering the conditions for flow set by Csikszentmihalyi, were social interactions that fostered collaborative discussions and interactions.

Research Conclusions:

My research exposes influences beyond the currently accepted aspects of opportunities to “act like scientists” and engage in “hands-on” experiences that can account for achievement and motivation outcomes in IBS. Specifically, my research implies that by setting conditions that foster factors necessary for establishing flow within IBS experiences, students will not only more authentically act like scientists, but will also experience enhanced motivation and achievement outcomes in IBS. Required conditions to be set include those described by Csikszentmihalyi: establishing clear goals, providing immediate feedback, and sustaining a balance between challenges and skills. Furthering Csikszentmihalyi’s conditions to include particular qualities of in-depth discussions and evaluations enhances flow experiences. Social interactions are integral to the setting of such conditions.
Current efforts within IBS do not specifically attend to student social interactions. The current continuum within inquiry-based science is focused on a progression of student experiences from those that are teacher-directed, those that are teacher-guided, and finally to open inquiry experiences; as students move along the progression, they assume greater responsibility for the design of their experiences. This continuum is worthy of continuing because it accentuates opportunities for students to make decisions, be in control of their own learning, and increases the likelihood that students will sustain interest in and motivation to engage in their experiences. As lessons and opportunities progress along the continuum, student’s intrinsic motivation is likely to increase because students increasingly have responsibility for the process. Current claims among educational practitioners state that if IBS lessons are properly scaffolded, then students will be increasingly successful, and thus experience enhanced motivation and achievement as they progress along the continuum (Flick, 1998). Inconsistent results from IBS, however, indicate that the currently accepted reasoning for successes seen provides insufficient explanation; other factors must also influence IBS processes and its success.

Based on the results of my research, I argue that the social interactions that emerge within IBS experiences are integral and influential on the motivation and achievement outcomes within IBS. I further argue that the future success of IBS would be enhanced by shifting the current focus in IBS from a continuum that focuses primarily on a progression from teacher-directed, teacher-guided, to open inquiry, which focuses on the degree to which students are responsible for
the topic of investigation, to a continuum that also includes a focus on eliciting conditions for establishing flow. The integration of Flow Theory into IBS practices sets conditions that lead to enhanced student motivation and achievement outcomes in inquiry-based science.

Best Objections to Research Conclusions:

Potential objections to this argument arise from possible alternative explanations as to why this inquiry-based science unit led to enhanced outcomes within the Off-Campus case. First, one might claim that the students in the Off-Campus case simply had more fun while at the off campus, nature reserve, location and thus were more engaged during the experience. One could argue that the nature reserve location, and its status as a hot spot, stimulated more fun and the increased positive gains that were observed within the Off-Campus case. As described by Schunk et al. (2008), when students are more engaged, they tend to be more focused and thus reach higher academic achievement and motivation outcomes. The Off-Campus participants were more engaged.

Second, one might claim that the extended time, during the data collection phase, that was experienced by the Off-Campus students was potentially more influential to the noted academic achievement and motivation gains than the influence of student social interactions. Proponents of this argument may claim that simply giving students more time to complete a particular challenge allows them to more thoroughly investigate options and solutions to tasks and challenges and thus become more involved and invested; motivation and achievement gains would result from such increased efforts.
Third, one might claim that the results of my research may be gender specific because of the widely held view that girls are more sociable than boys. One might argue that my research results may not hold true for boys and thus should not be credited beyond this one experience.

Response to Best Objections to Research Conclusions:

The objections noted above raise challenging points and are worthy of careful consideration. Two of the objections, the aspects of time and fun, can be related to the aspect of location. I do not deny that the location in which the Off-Campus participants experienced this IBS unit influenced the results. I do not dispute that the “fun factor” and aspects of the nature reserve that reflected characteristics of a hot spot location were influences on the increased enthusiasm and success seen in the Off-Campus case. Experiences at the nature reserve did have a positive influence on student experiences and outcomes; students enjoyed being at the reserve, they were given special privileges, and they were removed from the traditional school situation. The level of fun resulting from such experience, however, does not trump the importance of experiencing flow. The aspect of fun can be traced back to the social interactions that emerged. Interactions that led to positive emotions promoted engagement and a sense of fun among the participants. The results of my research suggest that the more one enters into a state of flow, the more one enjoys the experience. Experiencing flow leads to fun. Location was an influence on the fun factor, but the social interactions that emerged, and experiences with flow, were a stronger influence. However, the fact that location did positively influence fun, which in
turn positively influenced student motivation and achievement outcomes, provides justification for educational practitioners to seek out and include such opportunities and experiences in their lessons when possible.

The location of the nature reserve also introduced the element of increased time during the four days that participants implemented their investigations. Time to engage did positively influence student outcomes. Students in the Off-Campus case had more time to investigate their research question; they had more time to engage and interact. Simply having time, however, does not guarantee positive results. Having time does not assure that students will take advantage of the available time.

For example, students in the On-Campus case often squandered time they had; there were five instances when class time remained, as much as fifteen minutes, in which participants could continue working, but students opted to pack up their materials or just sit and listen to music. When students were not in states of flow, they tended to be acutely aware of time remaining in class and often packed up their materials in preparation to leave. When in states of flow, however, students engaged and worked intently right up until the end of class. Flow state emerged as a stronger influence than time.

Although more time was available within the Off-Campus case during the four days of data collection, the way in which the time was used more was potentially more influential than the time itself. For example, participants used available time to discuss and establish clear goals and to provide and evaluate feedback. At times, such as during debrief circles, such feedback was structured
by the teacher, at other times it was structured by the students. Additionally, simply having time does not guarantee that students will develop research projects that are well balanced between the skills possessed by students and the challenges they will face. Time is an important, and influential, factor for the success of IBS, but it is the ability to maximize opportunities for flow within the time that is available that is most important. Practitioners of IBS lessons could increase student motivation and achievement outcomes by maximizing student flow experiences within the time they have available.

Some simple restructuring in the manner in which lessons were implemented within the On-Campus case could have increased the flow experiences for those students within the time they had available. For example, Mike could have conducted debrief circles within the On-Campus classes that would have provided higher incidences of immediate feedback for those students. He could have either allotted a greater number of data collection days for students in the On-Campus case, which would have provided more time for those students to discuss their goals and progress towards those goals, or he could have had intermittent discussion days in which students did not collect data, but rather discussed the data they had already gathered. Additionally, Mike could have encouraged students to design research investigations that provided more of a balance between skill and challenge level for students. This may have required restructuring the time allotted for data collection efforts during the project so that students could implement more complex projects, yet still feel confident of success. The participants from the On-Campus case had originally
brainstormed more complex project ideas, but had abandoned those ideas due to fear of time constraints. A simple restructuring of the time available could have addressed this issue.

Finally, in response to potential arguments that the results of my research may be relevant to only the female gender, I must admit that possibility. One limitation of qualitative studies, particularly those with such a small sample size, is that research results are not generalizable to the general population. My research results are only representative of my research participants within this time and space and the Classroom Birdsleuth IBS curriculum. Further research will be needed to test whether my research claims hold true for boys. Two factors raise my confidence that these results would hold true. First, when I compared differences in complexity of the student-generated research questions, the patterns I found were consistent across cases regardless of gender. Second, research has shown that "optimal experiences are described in the same way by men and women, by young people and old, regardless of cultural differences" (Csikszentmihalyi, 1999). I fully acknowledge, however, that more research is warranted. However, even if my research results only hold true for females, this information is valuable and worthy of attention. Current goals in science education include attracting more girls to continue their participation in science, technology, engineering, and mathematical (STEM) courses and careers (Lawrence & Mancuso, 2012). As such, improving educational experiences for girls that encourage their enjoyment and interest in science, increase the
probability that girls will enroll in further science classes and science related careers.

**Concluding Statements:**

Csikszentmihalyi warns that when “you drop out of your potential, you become or remain average” (Csikszentmihalyi, 1996, p. 6). IBS may currently be dropping out of its potential through our seemingly unquestioned acceptance of successes seen within IBS being due to the “hands-on” experiences and opportunities to “act like scientists” that these experiences typically present. Such experiences are important and integral to IBS experiences and should be continued. We must also, however, remove barriers that currently block us from seeking a more comprehensive understanding of possible influences on IBS.

My research shows that student social interactions that emerge during IBS lessons can be influential and positively related to student motivation and achievement outcomes in IBS. Within my research, student social interactions, particularly interactions that communicated goals and feedback, were integral to the development of flow experiences. Participants from the Off-Campus case were able to maintain clear goals throughout the process, received frequent and immediate feedback, and maintained a balance between skills and challenges faced. Participants from the Off-Campus case elicited more focused attention, a stronger investment in their project, more enjoyment in the process, and ultimately demonstrated enhanced motivation and achievement outcomes compared to participants in the On-Campus case.
Positive outcomes emerge when student interactions promote enjoyment, challenge, and interest. Such positive aspects are likely to evolve when students feel confident of success and are able to find a balance between the skills required to complete a task and the challenges faced within the task. Intertwining Flow Theory with IBS by creating and implementing lessons that attend to conditions required for establishing flow promotes enhanced student motivation and achievement outcomes in IBS.

The results of my research have numerous implications for the future of inquiry-base science. Future implications for teachers and researchers in education are discussed in Chapter Six.
CHAPTER 6

FUTURE IMPLICATIONS

The results of my research suggest that student social interactions, particularly those that include communications within conditions that foster states of flow, can be influential on, and positively related to, student motivation and achievement outcomes in inquiry-based science. Although my research conclusions, which arose from a qualitative case study with a small sample size, are limited to this particular group of girls within this IBS unit instructed by this teacher at CMS and thus are not generalizable to larger populations, several implications for future educational practices and research in IBS can be drawn.

The results of my research suggest that attending to Flow Theory and incorporating opportunities for flow to develop within IBS instruction is warranted. According to Csikszentmihalyi (1996), the three conditions necessary for creating flow include: having clear goals, receiving immediate feedback, and maintaining a balance between one's skill level and the level of challenge presented in the activities one faces. Ensuring that each of these conditions is prevalent within instructional practices promotes the likelihood that students will approach and/or enter into states of flow, sustain their motivation and engagement during lessons, and experience elevated achievement outcomes. The conditions identified by
Csiksentmihalyi reflect sound educational practices. Establishing contextual situations that set such conditions in particular ways, such as ensuring and dedicating time for student discussions that foster in depth evaluation of content related concepts and student ideas, extends the reach of Csiksentmihalyi's Flow Theory and further enhances student motivation and achievement outcomes.

Attending to conditions for flow within the design and implementation of IBS lessons has several implications for educators.

Implications for Educators:

Educators who adeptly establish the three conditions necessary for creating flow within their instructional practices will see enhanced motivation and achievement outcomes from their students in inquiry-based science. It is therefore important that teachers understand and are sufficiently trained to establish strategies and conditions that foster, and enhance, flow within their lessons. The benefits from students approaching and entering into flow experiences during implemented lessons, that include enhanced motivation and achievement outcomes, requires educators to attend to establishing clear goals, providing immediate feedback, and balancing presented challenges with student skills. The beneficial outcomes of setting these conditions can be leveraged even further by establishing contextual situations that promote characteristics of hot spots and provide time for students to engage in detailed, content-specific discussions that include the evaluation of ideas and information.
Clear Goals:

It is imperative for teachers to have identified clear educational goals for their lessons in order to be able to convey clear goals to their students. Communicating clear assignment goals, requirements, and expectations for activities establishes benchmarks against which teachers and students can assess their progress throughout the experience. Providing opportunities for students to reflect upon and discuss not only their progress towards the teachers stated goals, but also towards their own student-generated goals and progress, fosters a more in-depth understanding of the intended goals as well as student abilities to attain those goals successfully. Such opportunities can be accommodated through numerous means such as allotting time for students to engage in small or large group open-forum discussions or by providing specific question prompts designed to initiate focused conversation. Other strategies include student self-reflection and journaling exercises, and/or the facilitation of debrief discussion circles throughout an experience. Establishing clear goals requires not just time to talk, but time to converse in a particular way, including opportunities to evaluate content, progress towards goals, and to communicate thoughts, ideas, and reflections with others.

Student social interactions that include the communication of specific details, content-related material, accomplishments, questions, ideas, challenges faced, and possible resolutions to those challenges assist students in clarifying their progress towards, and conceptual understanding of, the intended goals. For example, in a 2007 study conducted by Anderson et al., the researchers found
that providing students with more detailed information prompted more in-depth discussions amongst the students and the development of greater conceptual understanding of the content material. This promoted the student's ability to craft detailed and accurate responses to questions posed and to meet the goal of conceptual understanding of content material. The results of my study support this finding; students in the Off-Campus case, who engaged in more frequent discussions, developed a more complex research question, overcame greater challenges, and developed a more in-depth understanding of their results than participants in the On-Campus case, who engaged in fewer discussions. The results of my research also advance the findings from the Anderson study in that my research participants were able to develop content specific discussions without the frontloading of specific information from the teacher. My research participants were stimulated into detailed discussions through intrinsic motivation that had been spawned by approaching states of flow. Having, and being able to discuss, clear goals was one aspect that facilitated their approaching flow.

Inquiry-based science experiences, as they are currently and typically implemented, march students through procedural steps of "the scientific method" with relatively little time for discussion (Flick, 1998). During such experiences, students are often more focused on successfully completing each step of the procedure and/or on the physical manipulation of materials than on developing a conceptual understanding of what they are studying (Cuevas et al., 2005). The research results from Cuevas et al. (2005) also suggest that students who experience hands-on inquiry-based lessons outperform those with fewer hands-
on experiences. Results such as this support the currently accepted notion that IBS lessons are often successful due to their hands-on nature.

My research results support the findings of Cuevas et al. (2005) and provide additional insights and implications for further research. Participants in both my research cases participated in hands-on experiences. Participants in the Off-Campus case, however, participated in hands-on work that required higher cognitive skills and more complex manipulations of materials. The discussions within this group were more in-depth and led to greater conceptual understanding than those in the On-Campus case. This suggests that it is not merely the physical manipulation of materials, but the cognitive challenge that arises from particular hands-on experiences that may be of more influence on student outcomes. Additionally, the Cuevas et al. study focused more on the student's physical interaction and manipulation of materials and less on specific verbal interactions such as the sharing of ideas and discussion of results; the study did not assess whether such verbal interactions could have influenced student achievement outcomes. My research adds to this study in that it illustrates how student verbal interactions, particularly those that are content-specific, can be positively related to student achievement outcomes.

My research illustrates the benefits of students not only having clear goals but also the opportunity to assess and discuss their progress towards such goals. Opportunities for students to reflect, discuss, and communicate not only assists in establishing and conveying clear goals and progress, but also provides valuable, and immediate, feedback to students.
Immediate Feedback:

Opportunities for discussion and communication provide invaluable sources of feedback for both teachers and students. In addition to ascertaining an understanding of intended goals and assessing progress towards goals, communications that provide specific, and timely, feedback forge connections between the content material being learned, its application within activities undertaken, and conceptual understanding of content material (Berg et al., 2003). Feedback, which may include verbal, physical, and/or written forms, inherently involves interaction with others.

Receiving timely feedback has been positively related to student motivation and achievement outcomes in IBS. For example, in a study conducted by Berg et al. (2003), researchers investigated how student attitudes towards science influenced their experiences with open inquiry at the college level. Their research revealed substantial gains in conceptual understanding and a student's ability to apply content material learned to their experiences. The researchers found that students who had participated in an open inquiry experience that had included timely feedback from their instructor at times throughout their IBS experience were more capable of describing the details of the experiment they had conducted, could more rigorously evaluate the results of their data and possible sources of error and/or bias, and were able to suggest improvements for future investigations (Berg et al., 2003). The researchers interpreted these results to indicate a deeper conceptual understanding of both process and
content material (Berg et al., 2003). Having immediate feedback from the instructor positively influenced achievement outcomes.

My research results support the findings from Berg et al. (2003). Participants in the Off-Campus case, who had engaged in daily debrief circles while collecting data, had daily small group discussions about specific goals and progress towards their goals, shared ideas openly, and gave and received thoughts about the challenges they faced and their research conclusions, demonstrated enhanced motivation and achievement outcomes compared to their peers from the On-Campus case; the On-Campus case had not experienced such regular and immediate feedback. The implications for teachers and IBS instructional efforts are to ensure that students not only experience inquiry, but that they have time to reflect and discuss their experiences, data, results, the meaning of their results, and to consider sources of error or potential bias' in their methods or conclusions. Such immediate and regular feedback is one condition necessary for establishing flow.

Teachers can ensure such feedback through many avenues including, but not limited to, summative assessments, formative assessments, verbal discussions with students, sharing observations with students, allotting the necessary time for students to engage in peer discussions and debrief circles, providing specific questions to guide or prompt discussions, and/or by facilitating student peer review sessions. Such opportunities throughout the IBS process would provide frequent and timely feedback. In typical IBS practices, many teachers limit peer review opportunities to the end of the project at which time
students review each other's work to assess whether project requirements have been completed. My research supports that students benefit from engaging in receiving peer, and teacher, feedback throughout the inquiry process. Participants in the Off-Campus case, who experienced more frequent opportunities and experiences with giving and receiving feedback, outperformed their peers in the On-Campus case who had fewer experiences with such feedback.

Feedback, such as that described above, provides information and insight that can lead to a more in-depth conceptual understanding of the experience and/or content material. Providing appropriate challenges, or opportunities for students to develop their own cognitively appropriate challenges, that are well balanced between student skills and the challenges presented by the project is another requirement for initiating states of flow.

**Maintain a Balance Between Skill and Challenge Level:**

Providing challenges in which individuals feel confident and capable of being successful motivates students to engage (Wigfield & Eccles, 2000). Part of sensing the ability to be successful is related to facing challenges that are cognitively appropriate for the individuals experiencing the challenge. In terms of IBS experiences, this is typically easier to accomplish, or at least to plan, at the teacher-directed level because teachers have control of the activities and challenges presented within any given lesson. It becomes more challenging for teachers to ensure appropriate challenges as one progresses along the IBS continuum because students take on increasing responsibility for the challenges.
they face based on the activities selected and required within student-generated investigations; teachers increasingly relinquish control of such activities to students. At any level, however, whether tasks be provided by teachers or developed by students, those that are too simple or below student skill levels are likely to trigger student boredom and disengagement (Berndt & Miller, 1990). In contrast, if tasks are too difficult and/or stimulate a sense of having an inability to be successful, students are likely to become anxious and disengaged (Berndt & Miller, 1990). For example, the 1990 study in which Berndt and Miller examined the influences of a student's expectancy to be successful and the value they placed on an activity on academic achievements in junior high students, found that although both factors influenced student performance, a student's expectancy to be successful was more strongly correlated to their achievement outcomes (Berndt & Miller, 1990).

My research results support the results found by Berndt and Miller. Although participants in both cases in my study felt capable of successfully performing their chosen tasks, only the Off-Campus case maintained that attitude throughout the entire process even while pursuing a more challenging research question. The On-Campus case became anxious and at times doubted their ability to be successful even though they implemented a less complex investigation. Participants in the Off-Campus case repeatedly commented that they felt confident of success and were able to get into a flow with their work; comments from participants in the On-Campus case revealed feelings of stress and expressed doubts about their ability to be successful. This was particularly
true during the data collection phase of the project; students in the On-Campus case expressed concern that they would be unable to gather all the necessary data for their experiment.

The differences between the two cases can be explained by flow theory and the optimal conditions for flow as described by Csikszentmihalyi (1996). When challenges faced are balanced with skills required, and individuals have clear goals, and receive feedback, individuals will approach and/or enter into states of flow. When they fall either above or below the optimal balance of challenge and skill, they may become either bored and/or anxious. At such times, individuals disengage from the activity (Csikszentmihalyi, 1996). This was witnessed within my research. Participants in the On-Campus case simultaneously fell above and below the optimal range for flow; their research question did not challenge their cognitive abilities and they became bored, and time constraints and interruptions to their work caused them to doubt their ability to be successful and they became anxious. Within my research, student social interactions, such as clearly communicating goals, progress towards goals, sharing ideas, collaborating on resolving challenges, and evaluating methods and research results was integral to maintaining a balance between challenges faced and student skills to handle the challenges. Experiences with flow were integrally connected to the enhanced motivation and achievement outcomes within the Off-Campus case.
Flow Theory and IBS:

Although variations in number exist, it is generally accepted that there are three basic levels of inquiry-based science. The levels are placed along a continuum spanning from teacher-directed inquiry, in which the teacher provides the directions and materials for the experience, to teacher-guided, in which the students begin to take control of and responsibility for at least some of the procedures or decisions and materials, to open-inquiry, in which students have full responsibility for procedures, decisions, and materials to be used (NRC, 2000). As students progressively take on more responsibility, they gain a sense of control for their learning and begin to be responsible for decisions, such as what topics to study or how to conduct an investigation. Such decisions are often based on personal interests and curiosities; the sense of control and incorporation of personal interest stimulates student motivation to engage (NRC, 2000). Properly scaffolding student experiences along the continuum helps to ensure student success (Flick, 1998).

Proper scaffolding alone, however, does not guarantee success in IBS. Many teachers, including myself, have properly scaffolded IBS lessons, provided hands-on experiences, and opportunities for students to act like scientists, yet the lessons have yielded less than successful outcomes (Flick, 1998). For example, in his 1998 study, Flick investigated the characteristics present within successful IBS lessons implemented by different teachers. Based on his findings, he developed a list of twelve qualities that can make IBS successful. Included among his list are two qualities that coincide with Flow Theory: evaluating the
challenges that will be presented to the learner to determine their cognitive appropriateness and providing the learner with feedback (Flick, 1998). The remaining features in Flick’s list include organizational tasks and assessment strategies, such as making tasks accessible to students and designing assessments that are calibrated with the tasks (Flick, 1998). Although Flick includes sustaining student interest in his list, there is no mention about how best to do this other than progressing students along the IBS continuum in order to provide students with more personal choice and control of their learning. Such student choice is expected to foster student interest because they place greater value on the tasks (NRC, 2000). Flick’s list is still wanting, however, for if his list provided sufficient criteria for consistently successful IBS outcomes, one could expect increasing instances of IBS success since the development of this list. This is not the case.

Although Motivation Theory has long been intertwined with IBS, Flow Theory has not. Flow Theory provides a catalyst that brings student motivation and IBS together and fosters elevated student achievement outcomes in IBS. Providing age and cognitively appropriate challenges that are well balanced with student skill sets, or encouraging students to develop such challenges themselves, in combination with providing clear goals and immediate feedback, provides a means to reach more consistent and reliable IBS success. The results of my research suggest that shifting our attention from an IBS continuum that progresses from teacher-directed to open-inquiry experiences based on the level of student responsibility within the lesson, to one that also focuses on providing
the conditions necessary for flow to emerge, will foster enhanced motivation and achievement outcomes in IBS. Flow theory leverages and enhances IBS.

Based on my research, I propose that the current progression of IBS continue to be used, but primarily as a means to assess the level of student choice and responsibility that will be present within any IBS lesson. The primary focus for lesson design and implementation practices, however, should shift to ensuring that the conditions necessary for creating flow within lessons are present and leveraged. One would progress along this new IBS continuum based on whether the three conditions necessary for creating flow were present and to what extent. As currently implemented, IBS experiences typically include at least two of the three conditions for flow. Usually there are clear goals at some point during the experience; students are typically aware of end product goals as described by the teacher. Students also typically receive feedback at some point during the process. This commonly occurs during peer reviews near the end of the process and final teacher assessments. Within both of these first two conditions, however, students are rarely given the opportunity to thoroughly discuss the goals or their progress towards the goals, or to collaboratively evaluate and discuss feedback that is received. Additionally, the third condition, a balance between skill and challenge may or may not be present depending on the ability of teachers to create such a balance or to encourage students to take on challenges that match their skill levels. It's not that the three conditions for flow do not exist within current IBS practices; it's that they are minimally present, tend to exist in isolation of each other, and are rarely discussed or evaluated by
students. An inclusion of all three conditions for establishing flow, simultaneously, throughout IBS experiences will more readily lead to consistent and successful outcomes in IBS.

Although incorporating flow theory into IBS lessons may increase the consistency and reliability of successful IBS outcomes, one potential obstacle remains to be addressed; time.

**Time:**

IBS lessons typically take longer to implement than traditional, lecture based, science lessons (Holliday, 2006). All of the discussions, peer reviews, and feedback sessions described above are integral to leveraging the overall success of IBS, but require time to accommodate. Although having more time may offer certain advantages, having more time is not a requirement for the successful implementation of IBS lessons; the key is to utilize the time that is available effectively. Time need not be the nemesis of IBS; attending to flow theory may assuage this misnomer.

Assessing how much time is reasonably available to implement a particular lesson or unit, and determining whether inquiry-based lessons are appropriate for the time that is available is important to the ultimate success of IBS. IBS lessons that are rushed often struggle to meet the desired outcomes (Holliday, 2006).

Attending to flow within IBS experiences does not mandate additional time than what is already spent implementing IBS lessons. My research results
suggest that attending to flow theory can yield improved student outcomes within the time that is already dedicated to IBS. Participants within the Off-Campus case, who were afforded the time necessary to allow the conditions for flow to emerge, outperformed their peers in the On-Campus case who had half the experience with states of flow. At least two aspects of time come into play with IBS: actual clock time and the teacher's ability to effectively use the time that is available.

Clock time includes the actual minutes that are available for instruction. Rather than focusing on clock time as a limiting factor, focusing on how to create conditions for flow within the available time would be beneficial. Daily activities that capitalize on time available may be more beneficial than actually having more time; using the time that is available in a particular way is more important than actually having more time. For example, opportunities for students to engage in conversations about ideas, plans, problems, and possible conclusions are important to the success of IBS lessons. Accommodating such discussions when there is less chance for interruption and a greater chance for the conversation to be brought to a close is more effective than providing more clock time. It may not be prudent to designate the last five minutes of class for such discussions; it may be difficult for students to become completely engaged with discussions when their mindset may have already shifted to their next class. It may be more prudent to begin class with a discussion and allow topics to be thoroughly discussed before moving onto other activities. For example, allowing one class period twenty minutes of concentrated discussion time may be more
productive and beneficial to overall outcomes than providing ten minutes at the end of three or more classes.

Within my own research, Mike often allowed students to set their own daily schedules, yet students had minimal prior experience with either such flexibility or investigative processes within IBS. In the Off-Campus case, time was available for focused discussion, daily planning, and debrief circles; such opportunities were rare within the On-Campus case. Providing some structure, or guided discussions within the On-Campus case, such as dedicating part of a class period for debrief circles and such discussions may have led to different experiences and outcomes for the On-Campus participants. Time dedicated for student discussions, peer reviews, and for activities, such as data collection, does not necessitate more time, but rather a restructuring of available time.

It is important to note that successful IBS lessons can be implemented even within traditional 45-60 minute class periods. Much of the research conducted in IBS, such as that of Basaga et al. (1994), Berg et al. (2003), Cuevas et al. (2005) and Taraban et al. (2007), has investigated IBS experiences within regularly scheduled class times. The results from this research supports claims that IBS lessons can foster increased motivation and achievement outcomes compared to traditionally based lessons, that the more students experience IBS the more enhanced the outcomes become, and that teacher-guided inquiry can lead to promote motivation and achievement gains in students. For example, results from the Taraban et al. study (2007), which investigated the impact that a teacher-guided approach to inquiry would have on
student achievement outcomes compared to a teacher-directed approach, found that students who experienced the teacher-guided approach expressed more positive attitudes about science and outperformed their peers from the teacher-directed approach in content recall, critical thinking skills, and their understanding of process skills (Taraban et al., 2007). Both approaches were implemented during regularly scheduled class time. Although each of the studies mentioned above demonstrated positive gains from IBS, our ability to comprehensively explain why these gains emerged remains unrealized. These studies did not investigate whether potential influences student social interactions, such as verbal comments or discussions about research methods, results, or the meaning of experimental results, may have had on the outcomes of the studies.

Considering these studies from the perspective of flow theory, one is left wondering whether verbal comments or discussions may have clarified goals, provided valuable feedback, or whether challenges presented within the IBS lessons were well matched with student skills. One is left wondering whether the positive results that were noted by the researchers may have led to even more positive results had conditions and states of flow been experienced by students.

In another study, conducted by Gibson and Chase (2002), the researchers investigated the long-term effects of student participation in a two-week summer IBS program. The results indicated that students who participated in this camp maintained a more positive attitude towards science and interest in science related careers for a longer period of time than their peers who had not experienced the camp (Gibson & Chase, 2002). The researchers speculated that
the positive gains were due to the hands-on experiences and opportunities to act like scientists during this camp experience. There had been no investigation of aspects of Flow Theory such as whether clear goals had been communicated, whether participants had received immediate feedback, or whether challenges presented were balanced with student skills. There was no speculation by the researchers about whether the witnessed gains could have been due to specific social interactions that occurred during the camp experience.

Another aspect of interest, however, that emerges from Gibson and Chases' research is the potential influence that location may have had on the outcomes. My research suggests that the location in which an experience occurs may have considerable implications for outcomes. It has been well documented that opportunities to engage with community locations often sparks intrinsic interest and motivation in students (Sobel, 2005).

Location:

The results of my research align with results from place-based research, such as that of Lattimer (2011), in which researchers have found that student participation in place-based experiences leads to positive gains in content understanding as well as student abilities to conceptually explain student-generated research results. The location in which lessons occur can be influential on student motivation and the overall success of the lesson (Lattimer, 2011). Place-based research has largely focused on community-based activities and lessons in which students become increasingly aware of and connected with
areas in their communities as well as the resources available to them within their communities (Sobel, 2005). Establishing connections with community resources, such as nature reserves, conservation committees, and parks departments, may assist teachers in extending their lessons, and students inquiry-based investigations, into areas beyond the school walls; such efforts may lead to even more enhanced student interest and motivation to participate in IBS lessons.

My research results suggest such influences from location and align with the research results of Parker and Hackett (2012) in which the researchers found that "hot spots," or extended periods of isolated research, were integral to the productivity of scientists. In my research, the nature reserve effectively became a "hot spot" for the participants in the Off-Campus class. These participants produced more detailed and in-depth analysis of their research results than participants in the On-Campus case. Striving to create such "hot spots" through connections with community resources, such as local nature centers, may foster increased student productivity in IBS. Additional research is needed to determine whether, and if so how, it is possible to create characteristics of "hot spots" within classrooms and school grounds.

All of the aspects discussed above, setting conditions for promoting flow and aspects of time and location, have implications for how science teachers implement lessons. They also have ramifications for those responsible for teaching teachers and thus have implications for teacher training and certification programs.
Teaching Teachers of Science:

Science teacher certification programs typically require prospective teachers to take some sort of science methods course. Within such courses, prospective teachers are taught differentiated strategies for teaching science in order to meet the differentiated needs and multiple intelligences of students. IBS is typically introduced as an instructional method that can be used to teach scientific processes. As such, prospective teachers review steps to the scientific method and discuss ways in which students can conduct a variety of investigations. Little is discussed about the meaning of the term inquiry-based science or how to effectively implement IBS lessons within typical time constraints of school schedules (Flick, 2006).

Perhaps the first aspect of teaching prospective science teachers about how to successfully implement IBS lessons is to establish a clear understanding within such prospective teachers of what the term inquiry-based science actually means and how the stipulated goals of IBS can be accomplished. In order to successfully implement IBS, prospective teachers must understand its meaning and intentions; IBS is intended to foster student’s understanding of how to do scientific investigations, to understand about scientific inquiry, and to develop understanding of content-based concepts through inquiry approaches (NRC, 1996). Many prospective, and practicing, science teachers are unclear about the definition and goals of IBS (Crawford, 2007). Discussions about IBS goals, current practices, limitations, successes, and pitfalls within IBS would facilitate such an understanding. Opportunities for prospective teachers to directly
observe, and/or experience first-hand, successful IBS lessons would further leverage their understanding.

Prospective science teachers should also develop a thorough understanding of Flow Theory and the conditions required to foster states of flow. Evidence of how Flow Theory conceptually understands the results of my research has been extensively discussed throughout this dissertation. Flow Theory can also offer insights into the results of other IBS research. For example, in research conducted by Barbara Crawford (2000), six key instructional characteristics for the successful implementation of IBS, as measured by student motivation and achievement, were identified: situating instruction within authentic problems, student grappling with making sense of data, collaborations between students and with the teacher, making connections with the community, students having ownership in the experience, and authentic modeling of behaviors of scientists. These six characteristics are reflected in the results of my research and illustrate the importance of bridging IBS and Flow Theory. Student ownership in the experience can be achieved through the progression along the IBS continuum into teacher-guided and open inquiry experiences. Positive benefits of making community connections can be fostered through developing characteristics of hot-spots and place-based education. Each of the other characteristics identified by Crawford (2000) are fostered through setting conditions for flow.

As evidenced through my research, as students are given opportunities to engage in collaborative and content-specific discussions in which students share
and evaluate ideas, goals, and progress, student understanding and motivation is enhanced. Such understanding and motivation leads to the development of more cognitively challenging, and thus potentially more balanced between skills required and challenges that will be faced, student-generated investigations. As students engage in more challenging investigations, further discussion is fostered, and students take on authentic behaviors of scientists such as evaluating data, wrestling with the meaning of data, and the potential meaning of research results. Developing an understanding of Flow Theory, and how setting conditions that foster flow can foster student achievement and motivation in science, will better equip prospective science teachers to implement IBS.

Teaching teachers of science should also include an awareness of how to notice and assess student understanding of concepts and processes. Research has shown that students are often considered successful within IBS if they can simply complete the steps of the scientific method (Flick, 1998). Prospective teachers must be taught to develop and utilize assessment techniques that more authentically and comprehensively measure student skill and conceptual understanding of scientific concepts and processes. Recent research has illustrated that prospective, and practicing, science teachers are more likely to notice, and cite as evidence of student success, process skills associated with the steps of the scientific method than student analysis of data or the generation of conclusions that consider and evaluate the meaning of the data obtained (Talanquer, Tomanik, and Novodvorsky, 2013). For example, research demonstrated that teacher assessments focused on procedural steps and correct
formulation of hypotheses more than reasoning and potential explanations that were discussed by students (Tang, Coffey, Elby, and Levin, 2010). It is important that teacher training and certification programs teach prospective teachers how to become accurate assessors of IBS experiences and outcomes.

Teaching prospective teachers of science about IBS, current practices and limitations within IBS, motivation theory, and flow theory will better prepare them for the successful implementation of IBS within their classes. Including assessments that include and attend to student discussions, collaborations, and process skills will foster a more comprehensive assessment of student understanding. Training prospective teachers to dedicate opportunity within their lessons for students to discuss and evaluate goals, plans, results, and scientific processes will foster students more authentically acting like scientists as well as student motivation and achievement outcomes in IBS.

Attending to the influences that Flow Theory has on student motivation and achievement outcomes in IBS, as well as aspects of time and influences of location, has numerous implications for future research. Additional research is needed to develop a comprehensive understanding of the extent to which Flow Theory has influence on IBS.

Implications for IBS Research:

My research results indicate that motivation and achievement outcomes from IBS experiences can be influenced, and improved, by attending to student social interactions, particularly communicative interactions, and how they relate
to Flow Theory. My research, however, was limited to a small group of high achieving 8th grade girls. Additional research that studies influences of Flow Theory on boys, both boys and girls, different ability levels, and different age levels would assist in determining whether my research results would hold true across gender, cognitive ability, and grade levels. Although I set out to understand the influences of student social interactions on IBS outcomes, the results of my research have implications for educational practices across disciplines.

Since Mihaly Csikszentmihalyi’s introduction of Flow Theory in the 1960’s, much attention to Flow Theory has emerged in fields such as sociology and psychology (Engeser, 2012). Flow Theory, and individual experiences with flow, has been used to explain the accomplishments of artists, musicians, and athletes. Researchers, such as Csikszentmihalyi (1999), Jackson & Marsh (1996) and Fave et al. (2010), have conducted extensive studies on how dimensions of flow influence performance in activities such as rock climbing and playing chess.

Flow Theory has also been investigated in relation to outcomes in education. For example, researchers, such as Carli, Fave, and Massimini (1988) and Nakamura (1988), found that increased incidences of flow led to increased student achievement (Hanson, 1999). Hektner & Asakawa found that the level to which students experienced flow within a course was a better predictor of student success within that course than student aptitude (2000). There has been more extensive research conducted, such as that by Csikszentmihalyi and Rathunde
(1993), Csikszentmihalyi & Schneider (2000), and Shernoff, D.J., Shernoff, E.S., Csikszentmihalyi, and Schneider (2003), on the influences of flow experiences on high school students than on younger students. More recently, elements of Flow Theory have been explicitly investigated within the area of mathematics (Engeser, 2012). Flow Theory has not yet, however, been extensively investigated in specific relation to science experiences, nor specifically to inquiry-based science. The most prominent mention of flow within IBS research appeared in an article by Lawrence Flick (1998) in which he discussed flow in terms of the progression of properly scaffolded activities from teacher-directed through open inquiry experiences.

The actual measurement of flow, however, presents challenges to researchers. In the majority of research investigations to date, dimensions of flow have been assessed using Experience Sampling Forms (ESF’s) in which participants are randomly prompted to fill out questionnaires regarding their experiences at each particular moment (Engeser, 2012). Using such forms within educational settings can be quite interruptive to classroom progress and aspects of flow itself. It is ironic that the most prevalent research on flow utilizes a research technique that interrupts the very process it is investigating. Another disadvantage to the use of ESF forms is that they require participants to be able to read and accurately interpret the questionnaire, making elementary school use of such forms, as well as studies of individuals who’s native language is other than that used on the ESF, problematic. Carefully designed qualitative research studies, which include direct researcher observations for the duration of the
investigation, would expose nuances of flow and flow experiences in a less disruptive, and more naturally occurring, manner. Future research efforts are needed that thoroughly investigate the influences of flow experiences in all educational contexts, including inquiry-based science experiences.

Future Research: Flow Theory and Inquiry-Based Science:

My research has left me with many questions. For example, I wonder whether if Mike making relatively minor adjustments to his instructional practices within the On-Campus case could have had led to enhanced student experiences and outcomes. Had participants within the On-Campus case had more frequent, and longer duration, experiences with conditions for flow, they may have experienced elevated motivation and achievement outcomes. Had Mike held occasional debrief circles within this class, or included two more data collection days, so that students would not have to double their observations on any one day, or required students to create research questions that balanced their research challenges with their skills, perhaps enhanced motivation and achievement outcomes may have emerged within the On-Campus case. Additional research is needed to determine whether such results would actually have come to fruition.

Additional research questions that have risen include: How would my research results have differed if participants had been all boys or mixed gender groups? Would groups of boys have reacted to, and participated in, the IBS experience in the same manner given the same circumstances as the girls? If a group of students from the On-Campus case had an identical research question
to the group of students from the Off-Campus case, how would the results have been similar or different? How are influences of flow similar and different across classes, or individuals, exhibiting different goal structures? Do experiences with flow lead to different IBS outcomes depending on student goal orientations? How would research results compare to my results if participants included low-level learners rather than high-level learners? What influences on motivation and achievement outcomes do flow experiences in IBS have on special needs students? Do flow experiences lead to enhanced motivation and achievement in all content areas? How do experiences with flow influence student motivation and achievement outcomes from IBS experiences when implemented in classrooms with achievement goal structures compared to performance goal structures? Would students who had been placed in research groups by the teacher have similar experiences and outcomes as groups that self-selected to work together?

A more comprehensive understanding of IBS would be advanced through quantitative and qualitative investigations. Three additional research questions are of particular interest to me.

Three additional research questions:

1) How do groups consisting of all boys and mixed gender groups experience flow during IBS lessons? In what ways are these experiences similar and different to groups consisting of all girls?

2) How would my research results have been different had all students participated on school grounds and how would they have been different if all had participated at the nature reserve?
3) Can characteristics of hot spots be established within school settings and if so, how?

Understanding the answers to these research questions could substantially improve our understanding of IBS as well as how Flow Theory can be related to enhanced positive outcomes within IBS.

Concluding Statements:

Student experiences with inquiry-based science have been shown, by researchers such as Basaga et al. (1994), Berg et al. (2003), and Taraban et al. (2007), to lead to increased student achievement and motivation in science. Research, such as that conducted by Marx et al. (2004), has also shown that an increased exposure to IBS opportunities can lead to further gains in student achievement and motivation outcomes in science. Additionally, Gibson and Chase (2002) found that students who have had successful experiences with IBS are more likely to continue to enroll in science courses throughout high school and college and are more likely to pursue science related careers. Consistently successful results from IBS, however, remain elusive.

A necessary ingredient needed to promote consistently reliable success from IBS lessons, as measured by enhanced student achievement and motivation outcomes, has been missing. My research, which investigated whether student social interactions could be related to student achievement and motivation outcomes in science, has exposed one such ingredient. Based on the results of my research, I suggest that Flow Theory, and setting conditions that
lead to enhanced experiences with approaching and entering states of flow, can provide necessary elements to improve the reliability and consistency of student achievement and motivation outcomes in IBS and education. Flow Theory bridges the current gap between typical IBS outcomes and the possibility of more consistent and enhanced achievement and motivation outcomes.

My research has shown that student social interactions can be positively related to motivation and achievement outcomes in inquiry-based science. Social interactions include physical, verbal, and emotional aspects of the manner in which students relate to each other, and the teacher, within a given contextual situation. Of particular importance are interactions that relate to the conditions necessary for initiating and sustaining flow; these could include discourse in which goals are established and discussed, peer reviews in which plans, progress, and problem solving strategies are discussed or shared, as well as discussions about the challenges that particular tasks present to individuals and groups. Allowing time, which may require a restructuring of available time, for the fostering of such interactions within IBS experiences will foster positive motivation and achievement gains.

I have argued throughout this dissertation that IBS fails to meet its intended goals and potential because of our current tendency to attribute the successes seen in IBS to the hands-on nature of the experiences and the tendency for students to have opportunities to act like scientists. Specifically, I have argued that our currently narrow interpretation of what it means to act like a scientist, which includes following procedural steps of a prescribed "scientific
method," eclipses other potential influences, such as student social interactions, on IBS outcomes. My research has demonstrated that student social interactions that develop within IBS experiences can be positively related to achievement and motivation outcomes in science. In particular, social interactions that promote conditions necessary for approaching and initiating flow experiences, which include establishing clear goals, receiving regular feedback, and maintaining a balance between presented challenges and skills, lead to enhanced achievement and motivation outcomes in inquiry-based science.

Characteristics of Flow Theory are not foreign to education; the three conditions represent already recognized and sound educational practices. Flow Theory has not, however, been explicitly connected to IBS education. The conditions necessary for creating flow can currently be found within IBS practices, however, such conditions tend to appear only sporadically and often in isolation from each other. My research suggests that attending to the conditions for flow simultaneously and with frequent regularity advances positive and more consistent outcomes seen in IBS.

IBS has the potential to be a far more successful and reliable teaching strategy than is currently realized and practiced. Attending to Flow Theory and the conditions that promote states of flow among students will assist IBS in reaching enhanced outcomes. John Dewey claimed that it is imperative for the educational community to continue its search for what is sound educational experience. According to Dewey, "the intensity of the desire measures the strength of the efforts that will be put forth" (Dewey, p. 70). Continued research
investigating the relation of Flow Theory to IBS outcomes would demonstrate a continued effort to search for sound educational practices. Instructional practices within IBS that promote conditions necessary for creating flow would demonstrate enhanced educational experiences for students. According to Csikszentmihalyi, "When you drop out of your potential, you become or remain average" (Csikszentmihalyi, 1996, p. 12). IBS instructional practices are currently dropping out of their potential; implementation and outcomes continue to be inconsistent.

Attending to Flow Theory in IBS will assist educational practices being implemented that promote optimal conditions for flow and for realizing the educational potential of IBS. Shifting the focus of our instructional efforts from the current IBS continuum which presents a progression from teacher-directed to open-inquiry experiences to a continuum which also integrates and attends to the characteristics of Flow Theory will bolster our ability to create and implement IBS lessons that more consistently, and predictably, enhance student achievement and motivation in science.
Appendix A1: Pre-project Formal Interview Guide;
(The corresponding research question(s) to which student answers may be relevant are listed in parenthesis).

1) What does a typical science class/day look like for you? (general perceptions)
   o What kinds of things do you do? (general perceptions)
     - Activities, responsibilities, opportunities (3c, 3d)
   o Do you have to make decisions during class, or does the teacher typically tell you what to do? (1d, 2a, 2d, 2e, 3c, 3e) – if yes, ask:
     - What decisions do you have to make? (1d, 2d, 2e, 3c, 3e)
     - What factors enter into those decisions? Why? (general perceptions, 1a, 1b, 1f, 2a, 2b, 2c)

2) Do you typically get a chance to talk with your classmates during science class? (1a, 1b, 1c, 2a, 2b, 2d, 2e, 3c, 3e) – ask follow up questions below:
   o Do your conversations tend to be quick, taking place whenever the teacher stops talking for a few moments, or do you sometimes get a chance to chat for a few minutes with your classmates? (1a, 1b, 1c, 2a, 2b, 3c)
   o If you do have a chance to chat with your classmates, do you chat about science or something going on in class, or do you take the time to chat about other things? Can you give an example? (1a, 1b, 1c, 2a, 2b, 2c, 2d, 2e, 3c, 3d, 3e)
   o Are there certain times when you know you’re supposed to be talking about science or something going on in class? How do you know that’s the expectation? (1a, 1b, 1c, 2a, 2b, 2c, 2f, 3a, 3b, 3c, 3e)
   o When you’re doing a science activity, do you find it helpful to talk with your classmates about what you’re doing? Why/why not? (2c, 2d, 2e, 3b, 3c)
   o Can you describe a time when it was helpful for you to have the time to talk to a classmate about what was going on in class (or in an activity)? (2c, 2d, 2e, 3b, 3c)
     o What do you think would have been different if you had NOT had the chance to talk with your classmate(s)? (2c, 2d, 2e, 3b, 3c)
   o Can you describe a time when you wish you had been able to chat with your classmates about science? (2c, 2d, 2e, 3b, 3c)
     o Why would it have been helpful to be able to chat about it? (2c, 2d, 2e, 3b, 3c)
3) During class, when you are working with your classmates, are you able to stay focused on science or do you get distracted? Why/why not? (1a, 1b, 1c, 1d, 1f, 2a, 2b, 2c, 2d, 2e, 3b, 3c, 3e)

- What types of things help you to stay “on task”? Why? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b)
  - Can you give an example of when it was easy for you to stay on task? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b)
    - What was happening to make it easier to stay on task? (1a, 1b, 1c, 2a, 2b, 2c, 2d, 2e, 3b)
- What types of things make it easy for you to get “off task”? Why?
  - Can you give an example of when you got off task? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b)
  - What was happening to make you get off task? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b)
- When you are working in a small group, are you ever supportive of the other people in your group?
  - Can you give an example of when you were supportive to someone in your group? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b, 3c, 3d, 3e)
- When you are working in a small group, are you ever critical of the other people in your group? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b, 3c, 3d, 3e)
  - Can you give an example of when you were critical of someone in your group? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b, 3c, 3d, 3e)
- When working in a small group, do your group conversations tend to be quick, designed to simply get an answer or get the assignment done, or do you tend to try and understand what you are working on? Why? (2c, 2d, 2e, 3b)
  - Can you give an example?
- When working in a small group, do you ask the other people in your group to share their ideas with you? Why/why not?
- Do you share your ideas with the other people in the group? Why/why not? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e)
  - Do your group-mates ask you for your ideas? Why/why not? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e)
  - During whole class discussions, do you feel everyone openly shares their ideas? Why or why not? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e)
Do people tend to be supportive of each other or critical of each other? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e,)
How do you know?
Can you describe a time when something was said or done in class that made you change how you participated or how you acted? (1e, 1f, 2d, 2e)

4) How do you typically feel during science class? (are you comfortable, nervous, interested, bored)(1e, 1f)
   Can you explain what makes you feel that way? (1e, 1f)
   Has there been a time during science when you had fun, felt excited, relaxed? Can you describe what was going on at that time? (1e, 1f)
   Has there been a time during science when you have felt stressed or anxious? Can you describe what was going on at that time? (1e, 1f)
   Has there been a time during science when you have felt frustrated or annoyed? Can you describe what was going on at that time? (1e, 1f)
   Has there been a time during science when you have felt that everything was going well? Can you describe what was going on at that time? (1e, 1f)
   Has there been a time when the way you were feeling changed the way you participated or acted in class? Can you describe what was going on at that time? (1e, 1f)

5) What does the term "Hands-on" mean to you? (general perceptions, 3b, 3c, 3d, 3e)
   Can you give some specific examples of when you participated in something "Hands-on"? (general perceptions, 3c, 3d, 3e)
   Can you describe how those "hands-on" experiences made you feel about science? (general perceptions, 3d, 3e)

6) What does the expression "Acting Like a Scientist" mean to you? (general perceptions, 3b, 3c)
   Can you give some examples of when you have "acted like a scientist"? (general perceptions, 3d, 3e)
   Can you describe how those "acting like a scientist" experiences made you feel about science? (general perceptions, 1e, 1f)
   Does being able to talk with your classmates about science material and/or activities make you feel more like a scientist? Why/why not? (general perceptions, 1e, 1f)

7) Do you feel like you are able to do well in science? Why or Why not? (3a, 4a,)
   Do you feel you understand the concepts you learn in science? (4b)
What do you think would help you learn, and understand science concepts better?

What do you feel is required from you in order to do well in science? (3a)

What do you feel is your level of involvement/engagement in science class? Why? (3e)

8) How often do you work outside, in the environment, during science class? (general perceptions, 3c, 3d)
   - Do you ever spend time outside when you’re not in school? (general perceptions)
     - If so, what sorts of things are you doing outside? (general perceptions)

9) Do you feel science is important to everyday life? Why or why not? (3b)
   - Can you think of a time when you learned something in science that you felt was important for you to learn and understand? If so, can you describe what you learned and why you felt it was important? (3b)
   - Do you feel you will use anything you learn in science in your everyday life? Why or Why not? (3b)

10) Do you like science? Why or why not? (general perceptions)
    - What do you like best about science / science class? Why? (general perceptions)
    - What do you like least about science / science class? Why? (general perceptions)

Research Questions 1-3 are covered in this interview guide; questions 4 (a-d) and 5 (a-g) were answered through the analysis of collected data.
Appendix A2: Post-project Formal Interview Guide;
(The corresponding research question(s) to which student answers may be relevant are listed in parenthesis).

All Questions will be specified as related to THE IBS UNIT.

1) What did a typical science class/day during this unit look like for you? (general perceptions)
   - What kinds of things did you do? (general perceptions)
     - Activities, responsibilities, opportunities (3c, 3d)
   - Did you have to make decisions during class, or did the teacher typically tell you what to do? (1d, 2a, 2d, 2e, 3c, 3e) – if yes:
     - What decisions did you have to make? (1d, 2d, 3c, 3e)
     - What factors entered into those decisions? Why? (general perceptions, 1a, 1b, 1f, 2a, 2b, 2c)

6) Did you typically get a chance to talk with your classmates during this unit? (1a, 1b, 1c, 2a, 2b, 2d, 2e, 3c, 3e) – ask follow up questions below:
   - Did your conversations tend to be quick, taking place whenever the teacher stopped talking for a few moments, or did you ever get a chance to chat for a few minutes with your classmates? (1a, 1b, 1c, 2a, 2b, 3c)
   - If you did have a chance to chat with your classmates, did you chat about science or something going on in class, or did you take the time to chat about other things? Can you give an example? (1a, 1b, 1c, 2a, 2b, 2c, 2d, 2e, 3c, 3d, 3e)
   - Were there certain times when you knew you were supposed to be talking about science or something going on in class? How did you know that was the expectation? (1a, 1b, 1c, 2a, 2b, 2c, 2f, 3a, 3b, 3c, 3e)
   - When you were doing a science activity during this unit, did you find it helpful to talk with your classmates about what you were doing? Why/why not? (2c, 2d, 2e, 3b, 3c)
   - Can you describe a time when it was helpful for you to have the time to talk to a classmate about what was going on in class, or during an activity? (2c, 2d, 2e, 3b, 3c)
     - What do you think would have been different if you had NOT had the chance to talk with your classmate(s)? (2c, 2d, 2e, 3b, 3c)
   - Can you describe a time when you wish you had been able to chat more with your classmates during this unit? (2c, 2d, 2e, 3b, 3c)
o Why would it have been helpful to be able to chat about it? (2c, 2d, 2e, 3b, 3c)

o During this unit, if the teacher did not specifically tell you to discuss the science material with your classmates, did you? Why or why not? (1b, 1c, 1f, 2a, 2b, 2c, 2d, 2e, 3b, 3c, 3e)

o Did it help you to understand science to be able to talk things over with your classmates? Why/why not? (2c, 2d, 2e, 3b, 3c, 3e)

o Did the type of assignment you were given (lab activity, worksheet, illustrating, etc.) affect the types of conversations you had with your classmates? Why or why not? Can you give an example? (2a, 2b, 2c)

7) During this unit, when you were working with your classmates, were you able to stay focused on science or did you get distracted? Why/why not? (1a, 1b, 1c, 1d, 1f, 2a, 2b, 2c, 2d, 2e, 3b, 3e)

o What types of things helped you to stay "on task"? Why? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b)

o Can you give an example of when it was easy for you to stay on task? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b)
  o What was happening to make it easier to stay on task? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b)

o What types of things make it easy for you to get "off task"? Why?
  o Can you give an example of when you got off task? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b)
  o What was happening to make you get off task? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b)

o When you were working in a small group, were you ever supportive of the other people in your group?
  o Can you give an example of when you were supportive to someone in your group? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b, 3c, 3d, 3e)

o When you were working in a small group, were you ever critical of the other people in your group? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b, 3c, 3d, 3e)
  o Can you give an example of when you were critical of someone in your group? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e, 3b, 3c, 3d, 3e)

o When working in a small group, did your group conversations tend to be quick, designed to simply get an answer or get the assignment done, or did you try to understand what you are working on? Why? (2c, 2d, 2e, 3b)
  o Can you give an example?

o When working in a small group, did you ask the other people in your group to share their ideas with you? Why/why not?

o Did you share your ideas with the other people in the group? Why/why not? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e,)
Did your group-mates ask you for your ideas? Why/why not? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e.)

During whole class discussions, did you feel everyone openly shared their ideas? Why or why not? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e.)

Did people tend to be supportive of each other or critical of each other? (1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 2e.)

How did you know?

Can you describe a time when something was said or done in class that made you change how you participated or how you acted? (1e, 1f, 2d, 2e)

8) During this unit, how did you typically feel during science class? (were you comfortable, nervous, interested, bored) (1e, 1f)

Can you explain what made you feel that way? (1e, 1f)

Was there a time during this unit when you had fun, felt exciting, relaxed? Can you describe what was going on at that time? (1e, 1f)

Was there a time during this unit when you felt stressed or anxious? Can you describe what was going on at that time? (1e, 1f)

Was there a time during this unit when you felt frustrated or annoyed? Can you describe what was going on at that time? (1e, 1f)

Was there a time during this unit when you felt that everything was going well? Can you describe what was going on at that time? (1e, 1f)

Was there a time during this unit when the way you were feeling changed the way you participated or acted? Can you describe what was going on at that time? (1e, 1f)

9) After completing this unit, what does the term “Hands-on” mean to you? (general perceptions, 3b, 3c, 3d, 3e)

Can you give some specific examples of when you participated in something “Hands-on” during this unit? (general perceptions, 3c, 3d, 3e)

Can you describe how those “hands-on” experiences made you feel about science? (general perceptions, 3d, 3e)

At the beginning of the unit, you described “hands-on” as meaning ___________ (refer to student’s original answer). Do you have anything to add to, or change, what you said previously?

10) After completing this unit, what does the expression “Acting Like a Scientist” mean to you? (general perceptions, 3b, 3c)

Can you give some examples of when you “acted like a scientist” during this unit? (general perceptions, 3d, 3e)

Can you describe how those “acting like a scientist” experiences made you feel about science? (general perceptions, 1e, 1f)
Did being able to talk with your classmates about science material and/or activities make you feel more like a scientist during this unit? Why/why not? (general perceptions, 1e, 1f)

At the beginning of the unit, you described "acting like a scientist" as meaning __________ (refer to students original answer). Do you have anything to, or change, add to what you said previously?

11) Do you feel like you were able to do well in science during this unit? Why or Why not? (3a, 4a,)
   - Do you feel you understand the concepts you learned during this unit? (4b)
   - What do you think would help you learn, and understand those science concepts better?
   - Can you describe one or two science concepts that you learned?
   - What did you feel was required from you in order to do well during this unit? (3a)
   - What did you feel was your level of involvement/engagement during this unit? Why? (3e)

12) How often did you work outside, in the environment, during this unit? (general perceptions, 3c, 3d)
   - How did you feel about your time outside?
   - What did you enjoy, if anything, about your time outside?
   - What did you dislike, if anything, about your time outside?

13) After completing this unit, do you feel science is important to everyday life? Why or why not? (3b)
   - Can you think of a time when you learned something during this unit that you felt was important for you to learn and understand? If so, can you describe what you learned and why you felt it was important?
   - Do you feel you will use anything you learned during this unit in your everyday life? Why or Why not? (3b)
     - Can you explain what it was you learned and why it may be important to you?

10) Do you like science? Why or why not? (general perceptions)
   - What do you like best about science / science class? Why? (general perceptions)
   - What do you like least about science / science class? Why? (general perceptions)

Research Questions 1-3 are covered in this interview guide; questions 4 (a-d) and 5 (a-g) will be answered through the analysis of collected data.
Appendix A3: Informal Interview Question Guide

These questions are anticipated to be of relevance to student interactions I may observe during the IBS unit. Other questions will surface while in the field and/or while engaged in interviews with students. My observations in the field will inform additional questions.

1) Can you explain why _____________ (a comment or action) occurred?  
   (I will ask several such questions that are specific to individual students)

2) I noticed that you _____________ (a comment, action, decision made by student); can you explain that to me?  
   (I will ask several such questions that are specific to individual students)

3) You seemed to get _____________ (excited, motivated, frustrated, annoyed, etc.) when ________________ (a particular event, comment, etc.). Is that an accurate observation? Can you explain why you felt that way?  
   (I will ask several such questions that are specific to individual students)

4) Can you explain why you chose to use ________________ (certain equipment).

5) Can you explain how your group came to settle on your particular research question?

6) What impact does this research location seem to have on your decision to pursue your selected research question?

7) Do you think that ________________ (a comment, action, etc.) would have happened if you were doing this project at school? (only asked of GBNERR students) Can you explain your answer?
Appendix B: Sample Signed Consent Form
(All identifying information has been removed for inclusion here)

UNIVERSITY OF NEW HAMPSHIRE

INFORMED CONSENT LETTER FOR CHILD PARTICIPANTS (AGE 12-17)

Dear 8th grade student,

I am conducting a research project to investigate how students experience inquiry-based science lessons. I am writing to invite you to participate in this project. I hope to work with the entire 8th grade class, but will focus my research primarily on approximately ten students.

I will be observing a science unit that your teacher, XXXXXXX will be teaching. If you agree to participate in this study, in addition to the work you will be doing for your science class, you will be asked to complete two surveys and might be asked to participate in two formal interviews and possibly some casual interviews as the project continues. All of the above activities will take place during regularly scheduled science classes; no additional time will be required of you. In addition, you may be asked to participate in one half-day, and four daylong, field trip excursions to the XXXXXXX Reserve; these trips will take place during regularly scheduled school hours and are tentatively scheduled for the third week in May. The XXXXXXX is located at the XXXXXXX.

Throughout this study, I will be video recording, audio recording, and photographing classroom and small group activities and discussions. The purpose of the video/audio recordings and photographs is to help me see, and understand, what takes place during these science lessons. All recordings and images will be kept confidential and viewed only by myself and possibly my advisor at the University of New Hampshire (UNH). If, at any time, I would like to show a video clip or photograph to anyone else, I will first obtain signed permission from you, your parents, and anyone else in the video or photo. You will not receive compensation for participating in this study.

There are no potential risks for participating in this study. Benefits to you include participation in an inquiry-based science project. In addition, the benefits of the knowledge gained from this research are expected to contribute to our overall understanding of inquiry-based science as well as inform future instructional practices within the XXXXXXX schools.
Participation is strictly voluntary; refusal to participate will involve no prejudice, penalty, or loss of benefits to which you would otherwise be entitled. If you agree to participate and then change your mind, you may withdraw at any time during the study without penalty. If you choose not to participate, you will still be expected to complete the regularly scheduled science class activities and requirements; you will, however, not participate in any surveys or interviews and will not be included in any video/audio recordings or photographs.

I seek to maintain the confidentiality of all data and records associated with your participation in this research. You should understand, however, there are rare instances when I am required to share personally-identifiable information (e.g., according to policy, contract, regulation). For example, in response to a complaint about the research, officials at the University of New Hampshire, designees of the sponsor(s), and/or regulatory and oversight government agencies may access research data. You also should understand that I am required by law to report certain information to government and/or law enforcement officials (e.g., child abuse, threatened violence against self or others, communicable diseases). All data will be kept in a locked file cabinet in my office at the University of New Hampshire (UNH); only I, and my faculty advisor, will have access to the data. All video/audio recordings and photographs will be kept in the locked file cabinet and destroyed at the completion of the project. If I wish to show video clips or photographs to any additional people, or include clips or photos in any future presentations, signed written consent will first be obtained from you, all involved individuals, and your parents.

I will conduct all the research work for this project. I am a doctoral candidate in the Education Department at the University of New Hampshire. In order to establish reliability of my data analysis, another graduate student in the Education department at UNH will be asked to code some sections of data for comparison purposes. All data viewed by this graduate student will have been transcribed and all student identities will have been masked by pseudonyms; there will be no identifiable information that links you to the data.

If you have questions about this research project or would like more information before, during, or after the study, you may contact my faculty advisor, Dr. Eleanor Abrams at eleanor.abrams@unh.edu. If you have questions about your rights as a research subject, you may contact Julie Simpson from UNH Integrity Services at 603-862-2003 or Julie.simpson@unh.edu to discuss them.
I have enclosed two copies of this letter. Please sign one indicating your choice and return in the enclosed envelope. The other copy is for your records. Thank you for your consideration.

Sincerely,

Robin Ellwood

Robin Ellwood
Doctoral Candidate; UNH Education Department

Yes, I, ____________________________ (please print name) consent/agree to participate in this research project.
No, I, ______________________________(please print name) do not consent/agree to participate in this research project.

______________________________ (Student Signature)  ________________ (Date)

________________________________ (Parent signature)  ____________ (Date)
Appendix C: ISTREAM Observation Sheet

I = Identities
   Leader
   Follower
   Time manager/progress tracker
   Procrastinator/inhibiter to progress

Disposition of Scientist:
   Peer review
   Data analysis
   Critical discourse (content related discussions, debate, argument)
   Arguing for expressed points/beliefs
   Asking questions
   Searching for evidence
   Assessing bias
   Creativity

S = Significant/Surprising
   Anything unexpected – either not on list, or unanticipated that seems of Interest and/or possible influence

T = Triggers
   Anything that abruptly changes the course of events
   Subtle aspects that influence the course of events
   Glances
   Comments
   Actions
   Postures

R = Relationships
   Collaboration
   Competition
   Community
   Physical
   Verbal
   Adversarial/belittling
   Playful
   Glances
   Posturing
   Discourse: tone/type
      Casual, content based, productive, counterproductive, insights into student perceptions of task value
E = Emotions
   - Excitement/enjoyment
   - Frustration/anger
   - Contentment
   - Feelings

A = Activities & Accomplishments
   - Tasks attempted/completed
   - Perseverance
   - Giving-up
   - Self-regulatory behaviors
   - Self-handicapping behaviors
   - Student contributions to events/artifacts
   - Perceptions of opportunity
   - Conceptual Understanding

M = Motivation: towards participants, location, artifacts, activities, contributions
   - Expectancy for success
   - Ability
   - Task Value
   - Intrinsic
   - Attainment
   - Utility
   - Cost
   - Engagement
Appendix D: Description of ISTREAM Categories

1) **Identities:** This category refers to the various roles, such as student and/or scientist, taken on by individuals and/or groups. The identity category includes “the identities that the people involved in the situation are enacting and recognizing as consequential” (Gee, 2005; p. 111).

2) **Significance/Surprising:** This category provides a space for noting any event, action, comment, or artifact that reveals unexpected insights and/or reveals possible areas of interest needing closer examination. This category includes “how and what different things mean—the sorts of meaning and significance they are given” (Gee, 2005; p. 110).

3) **Triggers:** This category refers to any action, comment, or gesture that may lead to a change in student activity, progress, and/or disposition. This may include isolated incidents and/or patterns that seem to develop.

4) **Relationships:** This category refers to the student-student interactions as well as student-teacher interactions. It includes physical and verbal interactions. The relationship category includes “relationships that people involved enact and contract with each other and recognize as operative and consequential” (Gee, 2005; p. 111).

5) **Emotions:** This category refers to the various feelings and sentiments expressed by students. Emotional expression may take the form of overt declarations and/or subtle comments and gestures.

6) **Activities & Accomplishments:** This category refers to the various types of activities in which students engage. It includes academic tasks as well as general student activities. This category also includes accomplishments – real and perceived – of students. It includes accomplishments as they are expressed verbally by students as well as scores on course assignments. This category includes “the specific social activity or activities in which the participants are engaging: activities are, in turn, made up of a sequence of actions” (Gee, 2005; p. 111).

7) **Motivation:** Processes that initiate and/or sustain an individual’s activity.
   a. **Task Value:** the personal value an individual places on a task.
   b. **Intrinsic:** the level of personal interest, or the sense of joy and excitement that arises from engaging in a particular activity.
   c. **Attainment:** the importance an individual places on doing well on a particular task.
   d. **Utility:** the personal benefit, and usefulness, an individual assigns to a task.
   e. **Cost:** how much effort will need to be expended in order to complete a task and the degree to which this effort might limit engagement in other, more desirable, activities.
"Discussion:
Throughout this experiment, many things went according to our planned procedure, but some occurrences surprised us. For example, while we were designing this experiment, we were expecting that our trial days would be beautiful sunny days. In the end though, most of our trial days were gloomy and rainy. We expected that the speakers would be loud, but it turned out that they were static and quiet. Other than those minor disturbances, our overall project worked out well. Some days we had a great number of birds, while on others there were no birds at all, but the different amounts of birds got balanced out over our 10 trial process. If we were to do this experiment again we would keep the basic idea the same, but make some minor changes that would allow all parts of our experiment to work according to plan.

Conclusion:
Throughout this experiment we were trying to find out which genre of music birds prefer, out of: smooth jazz, rock, yodel, pop, and rap. We played different genres of music near a bird feeder, and tallied the number of birds that came for each genre. After conducting our experiment, we analyzed our data. After observing our graphs it appeared like rap music was the preferred genre of music. Next, we conducted the stats test with our data. According to the stats test, our null hypothesis is supported. After ending our project we found that birds do not prefer one genre of music over another."
APPENDIX E2: Off-Campus Case: Student Poster “Discussion and Conclusion” Section

“Discussion:

As a result of our experiment, the null hypothesis was supported by our Chi-Square Test. This means that the habitat of the bird has no affect on how high the pitch of its chirp is. During this experiment, we had various challenges and obstacles that we had to overcome. For example, our recording device kept running out of batteries! We used up almost three packs throughout the week! Another challenge that we faced was having to be silent for fifteen minutes straight. We were not allowed to talk and we had to walk really quietly without hitting any branches.

If we were doing this experiment professionally, we would want to “tighten up” the variables. In order to do this, we would have to be completely silent throughout the whole recording. It was really hard to stay silent during the whole fifteen minute recording period, and eventually we started talking. If we hadn’t talked, the information would have been more accurate. Another thing that we could do to “tighten up” the experiment would be to extend the time period. If there was some weather interference (like for example a hurricane) the amount of birds and their pitches would be different.

Three questions that we conducted during our experiment that would help us to understand it better are:

What would our experiment be like if we had recorded the same type of bird in all three habitats?

Was our experiment effected because we were in a relatively populated area?

Would our experiments results have the same outcome if we did it here at the school?

Conclusion:

By the end of the experiment we came to the conclusion that our data supported the null hypothesis. The different environments do not affect the pitch of the birds. We found that our graph/our data table showed this, but we still followed the chi-square test. The chi-square test proved that we were correct. I think that the whole process was a really good learning experience and that it really helped our group to connect. Now that the experiment is over we have many more questions and other tests that we want to perform.”
Appendix F: Grading Rubric for Final Poster

Bird Project Rubric

1) Criterion: Group met all project deadlines:
   — Research Question/Hypothesis developed and approved
   — Experimental design approved, including data table
   — All data collected
   — Graph of data
   — Statistical significance calculated
   — Poster for Peer Review
   — Final Poster
   
   7 = score 5  4 = score 2
   6 = score 4  3 = score 1
   5 = score 3  <3 = score 0

   0 --------1--------2--------3--------4--------5
   Smattering Round of Standing
   of applause applause ovation

2) Criterion: First Impressions of poster (or comparable project):
   — Significant color
   — Readable from about 3 feet (title from about 10 feet)
   — Photographs and/or sketches (EFFORT) of project in process
   — Organization – poster "flows"
   
   4 = score 5  2 - 2.5 = score 2
   3.5 = score 4  1.5 = score 1
   3 = score 3  <1.5 = score 0

   0 --------1--------2--------3--------4--------5
   Smattering Round of Standing
   of applause applause ovation

390
3) Criterion: Statistical Significance calculated (Done in class)
   ___ "chi-square" test conducted (appropriate calculations)
   ___ Degrees of freedom recorded
   ___ x compared to x-critical (comparison shown)
   ___ Null/alternative hypothesis rejected or supported

4 = score 5
3 = score 4
2 = score 2
1.5 = score 1
<1.5 = score 0

0 -------1-------2--------3---------4--------5
Smattering Round of Standing
    of applause    applause         ovation

4) Criterion: All components met in poster
   ___ Title
   ___ Introduction/background
   ___ Objective/ Research question
   ___ Hypothesis (HO & HA)
   ___ Experimental design, incl. blank data table
   ___ Diagram of experimental design
   ___ Results - completed data table
   ___ Graphs/tables/charts
   ___ Discussion
   ___ Conclusion

9.5-10 = score 5
8.5-9 = score 4
7.5-8 = score 3
5.5-7 = score 2
3-5 = score 1
≤ 2.5 = score 0

0 -------1-------2--------3---------4--------5
Smattering Round of Standing
    of applause    applause         ovation
5) Criterion: Presentation
   ___ Active participant in presentation
   ___ Project explained clearly
   ___ Voice projection/eye contact
   ___ Poster/project used in presentation

   4 = score 5
   3.5 = score 4
   3 = score 3
   2 = score 2
   1 = score 1
   <1 = score 0

Final Grade:

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Appendix G: Individual Student scores on Summative Assessments

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Appendix H: Research Integrity Services (IRB) Approval

University of New Hampshire

Research Integrity Services, Service Building
51 College Road, Durham, NH 03824-3585
Fax: 603-862-3564

09-Mar-2011

Ellwood, Robin
Education, Morrill Hall
1 Barberry Coast Road
Newmarket, NH 08857

IRB #: 5084
Study: An Ethnographic Investigation into the Possible Relation Between Student Social Interactions During Inquiry-based Science Experiences and Student Motivation and Achievements in Science
Approval Date: 03-Mar-2011

The Institutional Review Board for the Protection of Human Subjects in Research (IRB) has reviewed and approved the protocol for your study as Expedited as described in Title 45, Code of Federal Regulations (CFR), Part 46, Subsection 110.

Approval is granted to conduct your study as described in your protocol for one year from the approval date above. At the end of the approval period, you will be asked to submit a report with regard to the involvement of human subjects in this study. If your study is still active, you may request an extension of IRB approval.

Researchers who conduct studies involving human subjects have responsibilities as outlined in the attached document, Responsibilities of Directors of Research Studies Involving Human Subjects. (This document is also available at http://www.unh.edu/osr/compliance/irb.html.) Please read this document carefully before commencing your work involving human subjects.

If you have questions or concerns about your study or this approval, please feel free to contact me at 603-862-2003 or Julie.simpson@unh.edu. Please refer to the IRB # above in all correspondence related to this study. The IRB wishes you success with your research.

For the IRB,

Julie F. Simpson
Director

cc: File
Abrams, Eleanor
References:


Abrams, E. S., Sherry A; and Silva, Peggy (2008). Inquiry in the Classroom: Realities and Opportunities, Information Age Publishing, Inc.


