MOTIVATING LEARNERS IN SECONDARY SCIENCE CLASSROOMS: ANALYSIS OF A COMPUTER-SUPPORTED, INQUIRY-BASED LEARNING ENVIRONMENT USING SELF-DETERMINATION THEORY

A Dissertation

by

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Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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August 2014

Major Subject: Curriculum and Instruction

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ABSTRACT

In spite of generally poor student reports about science instruction in K-12 classrooms and decreasing interest in STEM careers, some curricular programs have successfully motivated and engaged students. One such program is *PlantingScience*, an inquiry-based, computer-supported learning curriculum developed by the Botanical Society of America. *PlantingScience* uniquely utilizes professional scientists who serve as online mentors to K-12 students engaged in classroom inquiry projects.

In an effort to determine why *PlantingScience* is successful, I began this dissertation with an extensive literature review discussing how technology and mentoring affect student motivation. Additionally, I conducted two original research studies using multiple data streams including classroom observations, teacher interviews, a focus group of teachers and scientists, and online dialogues between students and scientists.

In the first study, I used Elliot Eisner's Connoisseurship/Critique model of qualitative analysis to describe, interpret, and evaluate *PlantingScience*. More specifically, I created a grounded theory explaining how *PlantingScience* motivates and engages students. I subsequently compared these findings with self-determination theory to determine how the results could be explained in regard to autonomy, competence, and relatedness.

In the second study, I used mixed methods to create a rubric measuring scientists' online motivational support from the perspective of self-determination theory.

I also measured student inquiry engagement using a preexisting rubric specifically designed for the *PlantingScience* program. Using these two measures, I investigated the associations between scientist-mentors' motivational support and student inquiry engagement.

The findings in this dissertation provided evidence that students are motivated to engage in *PlantingScience* in part because of student empowerment, online mentor interaction, and authentic scientific experiences. In particular, the relationships developed between students and scientists in the online asynchronous environments were critical to the success of the program. As a general rule, students engaged in the inquiry projects more thoroughly as their scientist-mentors' motivational support increased. Perhaps the online mentoring partnership model offered by *PlantingScience* can be used on a wider scale to address the challenges of students' lack of interest in classroom science and STEM career fields.

DEDICATION

This dissertation is dedicated to the memory of my parents.

To my dad, Charles Scogin (1929 – 2013)

To my mom, Gwen Scogin (1934 – 2013)

Married for almost 60 years, their example of loving commitment made a lasting impression. “So now faith, hope, and love abide, these three; but the greatest of these is love” (1 Corinthians 13:13).

ACKNOWLEDGEMENTS

With the motto of Full Armor Christian Academy (where I served for seven years), I acknowledge the God who made it all possible: “In God’s Power, To God’s Glory, For His Pleasure.”

To my incredible wife Holly, I struggle finding adequate words to express my indebtedness. You have given me life like I never dreamt possible, and your support through this process, as well as every other challenge, has been unwavering and inspiring. I love you, and I thank God for you. You have blessed me with the two greatest children in the universe. Peyton and Emily, you both have been incredibly flexible and supportive, always facing the next challenge optimistically and willingly. I love you all, and I am excited about the next chapter in our life.

To my siblings and extended family, I am thankful for your perseverance and sacrifice. The last few years have been difficult for many reasons, but we overcame by faith. I am continually inspired by your hearts, and through you all, mom and dad’s example of loving commitment lives on!

To my “other” family, my in-laws, I am appreciative of your love and support. I am blessed beyond measure to have inherited in-laws who have always treated me like their own. Thank you for the encouragement.

To Drs. Carol Stuessy and Cathleen Loving, you both made me feel at home since my first visit to Texas A&M University. Your hospitality, professionalism, and vision made A&M my overwhelming choice. To Dr. Stuessy, my committee chair, I cannot sufficiently express thanks. Your tireless support of and passion for students is unmatched. Your love of learning is contagious, and I will benefit throughout my career from your mentoring. I would also like to thank my committee members, Dr. Loving, Dr. Jeffrey Liew, Dr. Larry Griffing, and Dr. Claire Hemingway. I appreciate the time, direction, and insight you offered throughout my course of research.

I also extend appreciation to all College of Education faculty and staff for making my time at Texas A&M memorable. To my fellow Ph.D. students, I am proud to call many of you friends. I am particularly thankful to the BSA research team. I cannot imagine working with a better group, and you all made research productive *and* fun!

I also want to extend my gratitude to the Botanical Society of America for developing and providing access to the *PlantingScience* platform. To the teachers, scientists, and students of *PlantingScience*, I say thank you for sharing your experiences. I am also grateful to the National Science Foundation (Grant No. 9733280), Texas A&M University College of Education and Human Development, and the Department of Teaching, Learning and Culture for their support of this research.

To my former coworker and friend, Sherrie, thank you for proofing this manuscript.

NOMENCLATURE

BSA	Botanical Society of America
CoVis	Collaborative Visualization Project
CMC	Computer-Mediated Communication
CSCL	Computer-Supported Collaborative Learning
HE	Highest Engagement
HMS	Highest Motivational Support
LE	Lowest Engagement
LMS	Lowest Motivational Support
OEIC	Online Elements of Inquiry Checklist
OIT	Organismic Integration Theory
NGSS	Next Generation Science Standards
NOS	Nature of Science
NRC	National Research Council
NSF	National Science Foundation
PS	*PlantingScience*
SDT	Self-Determination Theory
SPORE	Science Prize for Online Resources in Education
SSP	Student-Scientist Partnership
SWOT	Strengths/Weaknesses/Opportunities/Threats

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CHAPTER I

INTRODUCTION

Mr. Potts' voice slowly faded. Johnny gazed out the window in the direction of the familiar scraping sound. Biology class had lulled him into a stupor once again, and Johnny turned his attention toward the proud, green stalk just outside the window as it scratched gently against the glass. The sun was especially radiant today, and Johnny, as he had done on many occasions in biology class, stared intently at the sparkling plant. His mind began to ponder questions about the magnificent specimen: Why does the plant curve that way? Why does the plant curve so much more on sunny days? Does anyone know why?

Well, maybe Mr. Potts knows, Johnny reasoned. But who could get a question in edgewise during biology lecture? Almost on cue, Johnny's attention snapped back to the classroom as the sound of his name crashed through the daydream. Johnny's gaze ripped from the window to the front of the class, and his eyes immediately locked on Mr. Potts' stern glance. "Johnny, welcome back to planet earth! What is the definition of phototropism?" Mr. Potts asked impatiently. Well trained in the art of formal schooling, Johnny quickly swept his finger across the track pad on the laptop perched between his elbows, waking it from sleep mode. He quickly scanned the screen of the digital biology textbook. "Uh, the orientation of a plant or other organism in response to light." Even Johnny was surprised by the mechanical sound of his own voice. Mr. Potts' head swung back toward the screen as he simultaneously advanced the PowerPoint presentation to the next slide. In a mechanical voice eerily similar to Johnny's, Mr. Potts confirmed the answer by reading the exact same definition from the slide and blazed ahead to the next slide. As Johnny faded back into his own world, his eyes trickled back to the plant outside the window. He mumbled softly to himself, "I have no idea what I just said… and I really hate science class."

A thousand miles away, Dr. Janice Scott ripped open a new letter from the National Science Foundation (NSF). As she quickly scanned the page of the "Dear Colleague" letter, the phrase "broader impacts" grabbed her attention. Her shoulders sank as the familiar anxious feelings returned. "How in the world am I supposed to have a broader impact out here?" Janice asked aloud as she slumped back into her chair. While she presented at conferences and had more than a few peer-reviewed publications, Janice never had the feeling her influence reached anyone outside of her field. Society was not exactly beating her door down for information about plant phototropism, and her remote location was not really conducive for sharing with others. "My research is not much of a broader impact," she muttered. Snapping out of the doldrums, Janice quickly checked her email and burst out the door to collect new samples before dark.

While this scenario is fictitious, it raises important questions about how we "do school" and involve (or do not involve) scientists in the educative process. Are there better ways to support student engagement in science, increase the impact of scientists on society, and promote science learning? While technology has become an expectation in many educational settings, we often do not utilize it any differently than its predecessors. Is reading a slide on PowerPoint any different than reading words on a chalkboard? From an educational perspective, is a digital textbook an upgrade from a paper copy? Are we really using technology in innovative ways?

Oftentimes, it seems all the ingredients for learning are present, but the way we mix up the recipe does not achieve the desired outcomes. Eager, curious science learners like Johnny sit in classrooms, watching (or not watching) PowerPoint presentations or staring at computer screens and suffering from intense boredom. Professional scientists, like Janice, bang their head against the wall trying to figure out strategies to share their work and passion with the general public. Both have access to technology that could bring them together for learning, but even if it happened, would it make a difference?

Student Motivation and Broader Impacts

Declines in the number of students pursuing science-related degrees has brought new international focus on science education (Toplis, 2011). Ironically, students often see the value of learning science but have poor attitudes about learning it themselves (Toplis, 2011). This revelation says a lot about our teaching methods. We are boring kids in science classes, even though science is incredibly engaging subject matter. The problem is not necessarily limited to science, however, as research indicates students' interests for many subjects, science notwithstanding, decrease with each advancing grade of formal schooling (Ryan & Deci, 2000a). In other words, Johnny's fictitious experience of boredom and disdain for classroom science is not so fictitious.

The National Research Council (NRC; 2012a) recently reported today's typical K-12 science classrooms do not reflect national calls for engaging inquiry experiences and research-based science pedagogy. Instead, students describe their science classes as fragmented, repetitive, and full of unfamiliar terms (Osborne & Collins, 2001). Additional school-wide issues such as classroom overcrowding and multicultural challenges only add to the problem of providing meaningful science learning environments for students (Sinatra & Taasoobshirazi, 2011).

Fostering Motivation in School Science

In their chapter in the *Handbook of Research in Science Education*, Koballa and Glynn (2007) argued for greater emphasis on motivational research in science education. They reasoned that past research on motivation and attitudes in science education has suffered because of a focus on the cognitive domain and prevailing views that cognition and feelings were separate entities. In these researchers' estimations, policy makers now have a better understanding of the relationship between feelings and cognition. As a result, researchers are paying more attention to affective domains in an effort to increase science achievement.

While focusing more on motivation is an important first-step, figuring out ways to foster motivation in students is quite a different challenge. In the foreword to *A Framework for K-12 Science Education*, the presidents of the National Academy of Sciences and the National Academy of Engineering stated, "The percentage of students who are motivated by their school and out-of-school experiences to pursue careers in these fields [science and engineering] is currently too low for the nation's needs" (NRC, 2012b, p. x). These comments suggest we either do not know how to motivate students in science, or we are not implementing strategies that promote motivation.

Researchers have identified some practices that make a positive impact on student motivation in general (see Hidi & Harackiewicz, 2000) and in science education in particular. For example, Sanfeliz and Stalzer (2003) reported students exhibited more enthusiasm toward learning science when they were empowered by teachers to pursue their own interests in the science classroom. Similarly, Patrick and Middleton (2002) noted students had greater learning experiences when curriculum included inherently interesting and meaningful content. Students with low academic expectations showed greater interest and increased performance when science material made real-life connections (Hulleman & Harackiewicz, 2009). As a general trend, student-generated open-ended questions raised the level of independent thinking and increased student motivation (Moos & Honkomp, 2011). These studies support positive relationships between independent thinking and higher student motivation, in contrast to controlling, passive learning environments stressing rote memorization of scientific facts so common in many science classrooms (Koballa & Glynn, 2007).

In sum, "effective science instruction has the potential to improve attitudes toward science and heighten the motivation to learn science" (Koballa & Glynn, 2007, pp. 75-76). Motivation should be an important consideration for the development and delivery of science instruction for one simple reason – "Motivation is highly valued because of its consequences: Motivation produces" (Ryan & Deci, 2000b, p. 69). Evidence suggests a relationship between student motivation in science classrooms and increased scientific literacy (Bryan, Glynn, & Kittleson, 2011), as well as with students' perseverance in science learning (Patrick & Middleton, 2002). Systematically investigating motivational supports allows researchers to identify ways to enhance the motivational conduciveness of learning environments.

Having a Broader Impact

The “Dear Colleague” letter referenced in the opening paragraphs of this introduction signifies an actual letter sent from the Director of the Division of Mathematical Sciences of the NSF to those interested in applying for NSF grants (March, 2007). The letter explicitly called for proposals stressing intellectual merit and broader impacts. The letter indicated most researchers understood intellectual merit but did not grasp the concept of broader impacts. In an effort to clarify the meaning of broader impacts, the letter specifically mentioned promoting teaching, training, and learning; increasing participation of under-represented groups; enhancing infrastructure for research and education; broadening dissemination to enhance understanding; and benefitting society as ways to have broader impacts.

The NSF’s inclusion of broader impacts criteria into its funding requirements was controversial when it was introduced and remains that way. While broader impacts were “established to get scientists out of their ivory towers and connect them to society” (Lok, 2010, p. 416), scientists are confused by the requirements and often do not know if their ultimate efforts are really having an impact. Additionally, because scientists have been conditioned to value technical and scientific feedback from peer review systems, they often do not know how to assess broader impacts when stepping out of that highly selective system (Lok, 2010).

So, what would happen if the world of the science learner and the world of the scientist came together? If scientists partnered with students in the classroom, what impact, if any, might these unions have on student motivation? Would these partnerships provide scientists more accessible venues for making broader impacts? This dissertation speaks directly to these questions in an effort to increase our knowledge of motivation, scientist-student partnerships, and technology use in science education.

Context of the Study

The research studies included in this dissertation focused on students, teachers, and scientists engaged in *PlantingScience* (PS), an inquiry-based, computer-supported learning curriculum developed in 2005 by the Botanical Society of America (BSA). PS has been used internationally by over 11,000 students since its inception. Science learners, working in small teams in their school classrooms, design and carry out three- to ten-week long inquiry-based experiments related to plant biology. Professional scientists, over 900 to date, volunteer to assist students with their projects through the PS website. Students and scientists communicate asynchronously about the student-generated inquiry projects as they partner together for the duration of the PS project.

The research presented in this dissertation was part of a larger research agenda investigating the PS program since 2007. After joining the research initiative in 2011, I was involved in several precursor studies resulting in reports to the BSA (Scogin & Stuessy, 2013; Stuessy, Scogin, Ozturk, & Peterson, 2012) and the NSF (Stuessy et al., 2013); and conference presentations (Scogin, 2012a; Scogin, 2012b; Scogin, Ozturk, & Stuessy, 2013; Scogin, Stuessy, Ozturk, & Peterson, 2013; Stuessy et al., 2014). The

Scogin, Stuessy, et al. (2013) study, referenced in Chapter III as the first grounded study identifying motivation as a central component of PS, was particularly informative to the design of this dissertation.

Purpose of the Dissertation

Does student motivation contribute to the success of PS? Are science learners excited and engaged when they partner with real scientists to perform practical inquiry experiments? Because I believe a dearth of information exists related to student motivation and online mentoring in science education, the purposes of this dissertation were to: (1) explain the success of PS in regard to factors contributing to student motivation, and (2) investigate and present specific evidence regarding the broader impacts scientists have had on student motivation by serving as online mentors in the PS program. I offer a comprehensive literature review (a) outlining current research on the topic, (b) underscoring how our understanding of mentoring, technology, and student motivation is incomplete, and (c) indicating we are in need of different techniques to investigate innovative learning programs like PS. Using one such qualitative technique, Eisner's (1985) Connoisseurship/Critique model, I unpack the motivational factors of PS and link them to a grounded theory explaining how PS motivates and engages students in science. Finally, using self-determination theory as a framework, I associate the motivational contributions of scientist-mentors with student engagement. I provide specific examples of how online mentors can contribute to the motivational resources (i.e., autonomy, competence, and relatedness) of protégées in an asynchronous, text-based environment.

Format of the Dissertation

This dissertation contains five chapters, two of which explain independent research studies. The current chapter, Chapter I, provides relevant introductory information including outlining of the problem space, research questions, relevant definitions, and study delimitations/limitations. Chapter II offers an extensive literature review focusing on the intersections of mentoring, motivation, and technology. Chapter III, the first of two research-based studies, qualitatively describes, interprets, and evaluates PS implementation using the lens of student motivation. Chapter IV reports results of the second research study, which is a mixed methods investigation of the associations between scientist-mentor motivational support and student-team inquiry engagement. Chapter V summarizes results, considers implications of the research findings, and calls for new research initiatives related to practice and theory.

Research Questions

The following research questions framed the two independent studies included in this dissertation. Specifically, Chapter III, "Why Does It Work? A Qualitative Investigation of the Motivational Factors Associated With a Successful, Innovative Science Curriculum," investigated the following research questions:

1. What characteristics of motivated behavior are observed when students engage in PS in the classroom? What evidence exists that students' motivation is affected by interacting with scientists in the online asynchronous forum?

2. What are the conditions, contexts, and strategies in PS that lead to student motivation/engagement?
3. What are the strengths, weaknesses, opportunities, and threats associated with the PS program from a self-determination theory perspective?
4. How does evidence from students' classroom and online experiences and the stakeholders' focus group (from inductive grounded theory) compare with an analytic framework developed from the SWOT (Strengths/Weaknesses/ Opportunities/Threats) analysis (from deductive analysis) of the *PlantingScience* project?
5. What are the main factors contributing to the success of *PlantingScience*? What is the role of motivation in evaluating the overall effectiveness of the program?

Chapter IV, “Associations Between Student Engagement in Scientific Inquiry and Motivational Support: Do Online Scientist-Mentors Make a Difference?” considered these research questions:

1. How did autonomy, competence, and relatedness support differ between scientist-mentors in the 10 cases? What specific methods did scientist-mentors use to support motivation in student-teams?
2. What specific ways (based on social presence theory) did scientist-mentors establish relatedness with the 10 student-teams?
3. Did an association exist between the motivational support student-teams received from scientist-mentors and subsequent inquiry engagement in

student-teams among the 10 cases?

4. Using extreme group comparisons, what similarities and differences existed between highly engaged cases and less engaged cases? What similarities and differences existed between cases receiving high motivational support and cases receiving less motivational support?

Definitions of Terms

Terms in need of clarification are divided into four categories: (1) Eisner's (1985) Connoisseurship/Critique qualitative model, (2) Self-determination theory (SDT), (3) SWOT analysis (Helms & Nixon, 2010), and (4) Rigor and validity in qualitative and mixed methods research.

Connoisseurship/Critique Model (Eisner, 1985)

Description. A part of criticism intending to "characterize or render the pervasive and sheerly descriptive aspects of the phenomena one attends to" (Eisner, 1985, p. 94).

Educational connoisseurship. Possessing an appreciation of educational phenomena through awareness and understanding of what one has experienced in the world of education (Eisner, 1985).

Educational criticism. Comments providing disclosure of an educational phenomenon so that others can "experience the qualities and relationships" within the phenomenon (Eisner, 1985, p. 105).

Evaluation. A part of educational criticism intending "to make some value judgments about [a phenomenon] with respect to its educational significance" (Eisner, 1985, p. 98).

Interpretation. A part of educational criticism intending to bring "understanding of the significance that various forms of action" have on education (Eisner, 1985, p. 97).

Self-Determination Theory (Deci & Ryan, 1985)

Autonomy. The desire to regulate and control one's own behavior (Deci & Ryan, 2000).

Competence. The desire to engage in challenging tasks and experience some effectance (Deci & Ryan, 2000).

Internalization. The process in which individuals begin to personally endorse (i.e., internalize) behaviors or activities that were once extrinsically motivated (Deci & Ryan, 2000).

Relatedness. The desire to seek attachments and experience feelings of belonging and connection (Deci & Ryan, 2000).

SWOT Analysis (Helms & Nixon, 2010)

External factors. Factors outside of the PS program's control (e.g., scientist-mentor interaction).

Internal factors. Factors inherent in the structure of the PS program (e.g., curricular modules).

Opportunities. External factors that could be improved to strengthen PS's motivational support of autonomy, competence, and/or relatedness.

Strengths. Internal characteristics of PS perceived to be strengths when related to principles of self-determination theory (i.e., autonomy, competence, and/or relatedness).

Threats. External factors threatening to weaken PS's motivational support of autonomy, competence, and/or relatedness.

Weaknesses. Internal characteristics of PS perceived to be shortcomings when related to principles of self-determination theory (i.e., autonomy, competence, and/or relatedness).

Rigor and Validity

I recognize the debate regarding the use of terms such as rigor, validity, legitimization, and trustworthiness to describe the lengths to which researchers go to provide credibility for their work, particularly in qualitative studies. However, in most cases in this dissertation, I used the same terms as the sources I cited. For example, Yin (2009) often used the term validity when discussing case study research. Therefore, when I cited Yin, I also used the term validity. On the other hand, Wolcott (1994) preferred to not use that particular term in qualitative research, so I refrained from doing so when citing his sources. For general discussions in this dissertation, I chose the term "rigor" to describe the meticulous steps I employed to insure the soundness of the research.

Delimitations and Limitations

This dissertation used data collected over a three-year period as I participated in various PS research projects. The data include in-person and videoed observations of PS implementation in classrooms; teacher interviews; conversations between teachers, scientists, and PS program developers at a focus group meeting; asynchronous text discussions of students and scientists; and field notes created by the research team during these events. The sample is small but presents a manageable amount of data in consideration of the time investment required for rigorous qualitative research (Miles, Huberman, & Saldaña, 2014) and mixed methods research involving intensive qualitative strands (Creswell & Plano Clark, 2011).

The data selected for inclusion in this study represents the “best” of PS. The teachers whose classrooms were included in this study had professional development experience in PS and extended years of teaching experience. Members of the focus group, including both teachers and scientists, were chosen by BSA because of their experience in the program and understanding of the complexities involved in PS. In sum, all of the data used in this study was collected from those who had the necessary experience to understand the complexities of PS and could therefore shed light on the role of PS as a motivator of students. While these findings are not generalizable to a larger population, they are context-specific to the PS program and help us understand how the program motivates/engages students.

Significance of the Research

The worlds of the scientist and the science learner can and do intersect on a regular basis, thanks in part to technological advances nullifying geographical and logistical barriers. Partnerships between scientists and students represent a new era in science education promoting broader impacts for scientists and increased motivation for science learners. This dissertation speaks to both of these areas.

Chapter II divulges research supporting the design of partnerships involving online mentoring to meet the motivational needs of classroom science learners. Chapters III and IV go a step further, taking up the challenge of Sadler, Burgin, McKinney, and Ponjuan (2010) to provide "finer grain" analyses investigating *why* these types of partnerships work. "There is an increasing need for practitioners and researchers to study [online mentoring]…, and ultimately provide suggestions for ongoing improvement" (Ensher, Heun, & Blanchard, 2003, p. 283). In a systematic yet ecologically valid manner, these two chapters develop a grounded theory explaining how PS motivates students, corroborate the grounded theory with principles of SDT, and ultimately identify specific factors contributing to the success of this innovative, computer-supported program from a motivational perspective.

The results from this dissertation apprise researchers, curriculum developers, teachers, scientists, and policy makers of specific curricular factors associated with student motivation. In addition, the unique analytical frameworks combining inductive/deductive methodologies and qualitative/quantitative approaches equip educational researchers with additional tools to study complex learning environments like PS.

CHAPTER II

THE INTERSECTION OF MENTORING, MOTIVATION, AND TECHNOLOGY: USING SCIENTISTS TO PROMOTE PRODUCTIVE PARTICIPATION IN SCIENCE CLASSROOMS

Introduction

While ostensibly novel, focusing on student motivation and interest is actually a return to the past. Pioneers of modern educational reform, like John Dewey, stressed the important role of interest in learning and inspired research in student attitude and motivation (Koballa & Glynn, 2007; Zimmerman & Schunk, 2008). In the modern day, many teachers believe one of their most important jobs is to motivate students and help them become responsible for their own learning (Bryan et al., 2011). When students are motivated, they "behave with the intentions of achieving some outcome" (Deci, Ryan, & Williams, 1996, p. 166). Because of declining enrollments in secondary and post-secondary science classes and programs (Koballa & Glynn, 2007), science educators, researchers, and policymakers hope renewed interest in motivational research will ultimately lead to higher achievement in science and greater pursuit of STEM careers.

In spite of desires to increase student motivation, many science teachers "take control" of their classrooms, perhaps thinking their assertiveness provides stability and creates the best climate for learning. However, research shows controlling actions are counterproductive to fostering motivation. For example, teachers trying to meet standardized testing requirements often exert greater control in the classroom, simultaneously alienating their students in the process (Urdan & Turner, 2005). When students lose autonomy in their learning, they become less confident in their abilities to do science (Schunk & Pajares, 2005). Eventually, these conditions contribute to highly controlled school environments no longer resembling positive, motivating learning environments (Deci, Vallerand, Pelletier, & Ryan, 1991). Highly controlled, dry, passive lectures are not the way to promote engaged learning (Garrison, 2011).

Self-Determined Motivation

In a section of the *Annual Review of Psychology*, Eccles and Wigfield (2002) provided a comprehensive review of research focused on motivation, beliefs, values, and goals. In a more recent literature review of motivational theories, Kusurkar, Croiset, Mann, Custers, and Ten Cate (2012) documented many of the motivational theories related to education proposed since the start of the 20th century. Table 2.1 contains a sample but not exhaustive compilation of the motivational theories discussed in these two works. While each theory provides relevant insight into motivation in its own right, Pintrich and Schunk (2002) proclaimed self-determination theory (SDT; Deci & Ryan, 1985) as “one of the most comprehensive and empirically supported theories of motivation available” (p. 257). In addition to its comprehensiveness, SDT provides a systematic way to evaluate both an individual’s motivational needs and an environment’s provision of those needs (Chen & Jang, 2010).

History of SDT

Self-determination theory was developed over a long period of time with many refinements and additions through the years. Early motivational theorists often proposed

Table 2.1

Motivational Theories With Applications To Education

Theory	Author, Year	Reference
Need to achieve theory	Murray, 1938	Franken (1988)
Drive theory	Hull, 1943	Weiner (1992)
Hierarchy of needs theory	Maslow, 1943	Maslow (1970)
Expectancy-value theory	Atkinson, 1966	Atkinson (1966)
Motive to avoid success theory	Horner, 1968	Horner (1973)
Attribution theory	Weiner, 1974	Weiner (1974)
Social cognitive theory or Self-efficacy theory	Bandura, 1977	Bandura (1986)
Self-determination theory	Deci & Ryan, 1985	Deci & Ryan (1985)
Flow theory	Csikszentmihalyi, 1988	Csikszentmihalyi (1988)
Self-worth theory	Covington, 1992	Covington (1992, 1998)
Goal theory	Pintrich, 2000	Pintrich (2000)

Note. Compiled from Eccles and Wigfield (2002) and Kusurkar et al. (2012).

theories focusing on singular aspects of motivation, leaving other researchers to "flesh out" the vague areas. For example, citing deficiencies in Clark Hull's physiological drive theory (Hull, 1943), many psychologists searched for causes of behaviors that did not seem to fit Hull's model (Deci & Ryan, 2000). Hull proposed animals pursued physiological needs such as food, water, and sex, but his drive theory did not account for commonly observed activities such as curiosity and play. Early on, psychologists such as

Robert White noted, “Something important is left out when we make drives the operating forces in animal and human behavior” (White, 1959, p. 297).

In response to this shortcoming in Hull’s model, White (1959) proposed a psychological theory of motivation based on needs of the central nervous system. In addition to his theory being psychologically as opposed to physiologically based, White’s theory was novel because it focused on fulfillment instead of deficiency (Deci & Moller, 2005). In other words, humans, in particular, do not wait for a deficiency to be present before they act; instead, they proactively pursue basic psychological needs to avoid deficiency (Deci & Ryan, 2000). This concept of needs-based motivation was accepted in motivational research until a few years later in the 1960s when a shift to cognitive-based theory took place (Deci & Ryan, 2000). Cognitive studies emphasized choice, and motivational theorists began to embrace more goal-oriented approaches to explain motivation. In the face of growing opposition, proponents of needs-based motivation continued to advocate a position that goals provided little psychological benefit outside of how they helped fulfill the basic psychological needs (Deci & Ryan, 2000).

One of the leading needs-based motivational psychologists, Edward Deci, proposed in 1975 that autonomy and competence were the two primary needs necessary for self-determined motivation. Deci’s proclamation combined Robert White’s (1959) concept of effectance motivation (i.e., competence) and Richard De Charm’s (1968) work on personal causation (i.e., autonomy) into a comprehensive theory that served as the genesis of self-determination theory. After the introduction of the original concept in the 1970s, further research led to the inclusion of relatedness as a third basic psychological need (Ryan & Deci, 2002). Many of the ideas about relatedness were drawn from the work of Harlow (1958). In 1985, Deci and fellow psychologist Richard Ryan published *Intrinsic Motivation and Self-Determination in Human Behavior* (Deci & Ryan, 1985), and SDT was officially born. Since that time, SDT has been empirically verified in well over 700 school-related studies (Rienties, Tempelaar, Van den Bossche, Gijselaers, & Segers, 2009).

Self-Determination Theory Defined

SDT is an organismic-dialectic theory proposing humans are active, growth-oriented organisms who seek out supportive environments to fulfill their basic psychological needs (Ryan & Deci, 2002). The basic needs are autonomy, competence, and relatedness (Deci & Ryan, 2000). SDT proposes people will not need to be coerced into action in situations fulfilling these basic needs; they will act willingly out of a desire to fulfill their needs. According to Deci and Ryan (2000), the three basic needs are defined as follows: (1) autonomy is a desire to "self-organize and regulate one's own behavior (and avoid heteronomous control)"; (2) competence is the desire to "engage optimal challenges and experience mastery or effectance in the physical and social worlds;" and (3) relatedness is the desire to "seek attachments and experience feelings of security, belongingness, and intimacy with others" (p. 252).

According to SDT, motivation is not a simple either/or construct as advocated by some researchers such as Bandura (1977). Conversely, motivation varies in intensity and must be measured on a continuum scale (Deci & Ryan, 2000; Guay, Ratelle, & Chanal, 2008). Some motivations are intrinsic, meaning people engage in the behavior strictly for the satisfaction or pleasure of the activity itself (Deci et al., 1991; Ratelle, Guay, Vallerand, Larose, & Senecal, 2007; Ryan & Deci, 2000a). Other motivations, however, are extrinsic in nature, indicating a participatory cause existing outside of the self (Ratelle et al., 2007). However, SDT also suggests extrinsic motivation occurs on a continuum and can change based on how or if a person identifies with or internalizes the value of the activity.

In order to illustrate intrinsic and extrinsic motivations, consider the context of education. Intrinsically motivated students like school because they enjoy going to class, doing the work, and generally being at school. Their love for school comes from a love of school activities. Conversely, extrinsically motivated students wanting to get accepted to prestigious colleges may try hard even though they do not like school. These students push hard in school for external reasons, not because they enjoy school activities. Research indicates formal schooling does not intrinsically motivate most students (Ratelle et al., 2007). In other words, few students find pleasure and enjoyment in the routine of going to school, doing homework, or listening to lectures. Most students remaining in school do so because they are extrinsically motivated when it comes to school-related activities. If extrinsically motivated, SDT posits students will be either externally or internally regulated (Figure 2.1; Ryan & Deci, 2002). Internally regulated students, for example, are motivated to do school work because they value the opportunity to go to college and know grades are important for that purpose. On the other hand, extrinsically regulated students work hard in school to avoid punishment for poor grades or to gain praise from others. In both cases, students do the work and appear motivated, but the reasons why they complete the work are distinctly different.

The process of internalization. How individuals regulate their motivation is related to the continuum model of motivation, which is part of Organismic Integration Theory (OIT), one of the four mini-theories of SDT. OIT proposes that a person's values of an activity or behavior can change, thereby altering the reason why a person engages in an activity or behavior. As an example, let's assume I do not find inherent pleasure in recreational jogging. However, I decide to impress my friends by losing a few pounds, so I begin a rigorous jogging routine. According to SDT, my motivation is currently extrinsic and externally regulated. If over time, however, I begin to personally endorse the value of being in good shape and relate the benefits of exercise to my overall health, my motivation has moved on the continuum toward a higher level of regulation, shown in Figure 2.1 to be either identified or integrated regulation. I still jog using the same regime as always, but my motivation and regulation for doing so have changed significantly. Based on SDT, I have undergone internalization.

SDT defines internalization as a natural process of taking a value or action that is not intrinsically motivating and personally endorsing it over time (Deci & Ryan, 2000; Ryan & Deci, 2000a). Therefore, OIT suggests internalization, just like motivation as a whole, works on a continuum (Ryan & Deci, 2002). Internalization varies from externally controlled (i.e., introjected) to fully endorsed (i.e., integrated; see Figure 2.1; Ryan & Deci, 2002; Vallerand & Ratelle, 2002; Zimmerman, 2011). However, OIT does not imply or "require" people to move on the continuum in a linear fashion. At any given

Type of Motivation	Amotivation	Extrinsic Motivation				Intrinsic Motivation
Quality of Behavior	Lacking Intention	Controlled	→	→	→	Autonomous
Source of Motivation	None	INTERNALIZATION →	→	→	→	Intrinsic
Type of Regulation	Non-regulation	External Regulation	Introjected Regulation	Identified Regulation	Integrated Regulation	Intrinsic Regulation
Reason for Action	Apathy	Avoid punishment; Obtain rewards	Avoid guilt; Enhance ego	Conscious Valuing	Personal endorsement	Interest and enjoyment

Figure 2.1. Motivation continuum proposed by self-determination theory. Adapted from Ryan and Deci (2002).

time, a person may begin to regulate a certain activity or behavior in a different way, either consciously or subconsciously (Ryan & Deci, 2000a; Vallerand & Ratelle, 2002).

While internalization can occur for a variety of reasons, SDT proposes internalization typically occurs because people want to conform to socially acceptable practices (Deci & Moller, 2005). Even if a particular activity or behavior is uninteresting, people will internalize its value in an effort to function in and/or fit into society (Deci et al., 1991; Reeve, Deci, & Ryan, 2004). Because society plays such an important role in internalization, a person's social context has a huge impact on internalization (Deci & Ryan, 2000). Herein lies an important link between OIT and basic needs theory. While all three basic needs (i.e., autonomy, competence, relatedness) are important for motivation in general and internalization specifically, relatedness seems especially integral to the internalization process (Deci & Moller, 2005; Ryan & Deci, 2002).

In several SDT studies, three primary conditions are reported to increase internalization toward a given activity. These conditions include: (1) providing a rationale for the activity, (2) establishing interpersonal relationships that emphasize choice over control, and (3) acknowledging negative affect (Deci, Eghrari, Patrick, & Leone, 1994; Deci & Moller, 2005; Reeve, 2002). As all three conditions require a third party, we now understand why relatedness (i.e., feelings of connection and belonging) is so important. Highly respected relationships are likely to provide the conditions necessary for internalization, thus causing a previously unmotivated person to identify with or integrate an activity or behavior on a personally autonomous level.

In summary, SDT suggests people are motivated because a task is intrinsically motivating, external pressures or rewards prompt the activity or behavior, or the person has internalized the value of the task at some level (Koestner & Losier, 2002). If the task is pleasurable in and of itself, the motivation is intrinsic. If rewards or punishments promote participation, the motivation is extrinsic and externally regulated (Ryan & Deci, 2002; Vallerand & Ratelle, 2002; Zimmerman, 2011). If the task is seen as beneficial and/or is accepted internally on some level, the motivation is extrinsic in nature but is regulated more autonomously (see Figure 2.1).

Internalization in an education context. In a classroom, the motivation continuum explains why some students perform school tasks with resentment (i.e., externally regulated extrinsic motivation) or with an attitude of willingness and acceptance (i.e., internalization or intrinsic motivation; Ryan & Deci, 2000a). As a practical example of the motivation continuum at work in an educational context, consider the contrast of motivations in the following scenario shared by Deci et al. (1996). Biology student #1 loves studying animals and finds them interesting. Student #1 is intrinsically motivated by the subject matter and works hard in biology class every day, gaining pleasure from studying animals. Biology student #2 hopes to become a veterinarian and also works hard in biology class, but this student does not find the class itself particularly enjoyable. Student #2 is highly autonomous and internalized, exhibiting either identified or maybe even integrated regulation. Student #3 also works diligently in biology class. However, student #3 is motivated by parental threats to take away driving privileges if grades are not maintained at a certain level. Student #3 is controlled and, therefore, is extrinsically motivated and externally regulated (see Figure 2.1).

When uninformed observers, including educators, see students 1, 2, and 3 working diligently in biology class, they may be tempted to think all three students are equally “motivated,” not realizing different types of motivation can lead to different outcomes. SDT researchers caution against this conclusion and cite the ill-effects of controlled motivation. For example, Deci and Ryan (2000) indicated autonomously motivated students (i.e., those who exhibited internalization) were characterized by joy and proactive coping strategies when challenged. In contrast, students who exhibited controlled motivation were characterized by anxiety and maladaptive coping strategies. Additional research shared by Ryan and Deci (2000a, 2000b) indicated autonomous motivation was associated with better engagement, higher performance, lower dropout rates, and deeper learning when compared to controlled forms of motivation.

When considering the motivation continuum and how differing forms of motivation affect students, it becomes evident that promoting internalization should be an important consideration for educators. If we aim to motivate students in science to have long-lasting interests and positive attitudes about science and perhaps pursue science-related careers, we must develop strategies for internalization. As previously mentioned, most students have extrinsic motivations for school as opposed to intrinsic motivation. Consequently, we must help students develop the necessary autonomous forms of motivation that come about as the result of internalization. “For students to be actively engaged in the educational endeavor, they must value learning, achievement, and accomplishment even with respect to topics and activities they do not find interesting” (Deci et al., 1991, p. 338). In other words, as Niemiec and Ryan (2009) declared, “understanding how to facilitate internalization becomes a critical educational agenda” (p. 139).

Promoting internalization in schools. While most SDT researchers agree autonomy and competence are the most crucial needs for supporting intrinsic motivation, relatedness has been shown to play a more critical role in internalization (Ryan & Deci, 2002). Consider again the example of recreational jogging, but this time from a different perspective. If I am not intrinsically interested in jogging, I am probably not going to jog unless someone initially influences me to do so. If someone whom I respect talks me into jogging for the first time, I may begin to see the value of the activity after losing a few pounds. Over time, if I begin to identify with and internalize the activity, I have experienced internalization. When considering school-aged students, adults are typically the agents who first influence children to participate in tasks that are not particularly interesting from the child's perspective.

> There are, however, many things that adults consider important for children to learn and do, but that the children might not find interesting. Thus, adults must initially prompt such activities extrinsically while at the same time promoting the internalization and integration of these extrinsic regulations. (Deci et al., 1996, p. 174)

While parents are often thought of as the adults in this scenario, teachers also influence children's behavior.

Ryan, Stiller, and Lynch (1994) reported teachers, in addition to parents, promoted high levels of internalization in school-related behavior by students. This finding is critically important, as many school tasks are not intrinsically motivating for students. In these cases, it often falls upon the teacher to draw students into participatory roles. In these cases, as conveyed by Urdan and Turner (2005), "It may be the teacher's interest in the task that helps students to see its value and relevance, rather than characteristics of the task itself" (p. 311). While teachers represent the most common internalizing agents in the schools, additional research has identified "significant others" such as coaches as important to internalization (Koestner & Losier, 2002). Furthermore, Ryan and Deci (2000a) found people are usually prompted to engage in externally prompted behaviors when the other person who initiates the behavior is valued as a significant other with whom the original people would like to be connected.

Supporting the basic needs. Central to SDT is the proposal that under the right social contexts supporting autonomy, competence, and relatedness, motivation can flourish (Deci et al., 1991). Motivation, as discussed previously, is not a static construct. Instead, motivation is fluid and can be positively influenced by needs-supporting environmental conditions (Jarvela, 2001). Environments supporting the three psychological needs promote expression of intrinsic motivation and/or foster developing internalized motivation. Environments thwarting the basic needs promote amotivation (Deci et al., 1996; Ryan & Deci, 2000b).

While it may be tempting to adopt a behavioral view of motivation, providing the necessary conditions does not guarantee motivated behavior. People are not mindless robots who must obey environmental commands. Educators, for instance, cannot guarantee motivated behavior simply by environmental manipulation. They can, however, provide an environment promoting self-determined behavior by offering students purposeful choice and realistic options. Students typically respond to these environments. For example, Bryan et al. (2011) revealed high school students wanted conditions where they could make choices, be challenged, and collaborate with others. Even though the Bryan et al. study was conducted from a social cognitive perspective and not a self-determination theory perspective, the fact these areas match well with the three basic needs of SDT (i.e., autonomy, competence, and relatedness) is not surprising.

As students mature, they naturally desire more autonomy, competence, and relatedness. Maybe teachers' refusal to grant more autonomy in the classroom is a primary reason why students disconnect more from the school environment as they progress through grades. Students want purposeful choice, and teachers are faced with a decision to grant more autonomy or take more control. Pajares (2008) suggested teachers respond with positive support for autonomy. Deci et al. (1991) carried it a step further, postulating that positive support for autonomy would provide fertile ground for internalization and integration of extrinsically motivated tasks typical of the school environment.

As students grow in independence, they also grow in their desire for competence. In response to the need for competence, Bandura (1997) noted students seek out role models who are more competent and whose interests match their own. Described from an SDT perspective, one could say that students autonomously seek additional competence through relatedness. Ironically, and counterproductive to what SDT predicts about motivation, the formal school system oftentimes discourages group work and demands independent study (NRC, 2012a). When forced into a school situation depriving them of basic psychological need satisfaction, students react with apathy and disinterest toward learning. In opposition to this trend, we should provide students with collaborative opportunities within the learning environment involving people whom students respect. Under these conditions, SDT predicts students would feel more connected and respond with increased motivation (Roca & Gagne, 2008).

Mentoring

The term “mentor” has existed since Homer’s poem the *Odyssey* gave account of Mentor, the advisor to Odysseus’ son Telemachus. Since that time, mentoring has been used to describe almost every kind of relationship between an expert and a protégé

(O'Neill, Wagner, & Gomez, 1996). Mentoring strategies have been used in business, industry, and practically every level of education (Bierema & Merriam, 2002). Mentoring is defined as “an educational or professional relationship that supports developmental and mastery learning and fosters self-efficacy and self-actualization” (Mullen, 2011, p. 137).

While students most often turn to teachers for help in traditional school contexts (Zimmerman & Schunk, 2008), students will also pursue help and enrichment opportunities from other sources (Newman, 2008). As Guay et al. (2008) noted, help from adults outside of school sometimes can make significant contributions to students’ motivational resources. Science educators can leverage this research by forming mentorships between scientists and classroom learners.

Scientists as Mentors

While many curricula offer hands-on science, few provide an authentic scientific experience in the classroom (Hickey & Granade, 2004). In addition, teachers are often ill-equipped to add authenticity to science lessons because most do not have the practical experiences in laboratory settings needed to duplicate a relevant context. Using professional scientists as mentors makes intuitive sense because they are experts. They can raise the level of expertise, increase the authenticity of the experience for students, and fulfill national calls for productive participation in science (NRC, 2007) and community-centered approaches to learning (Bransford, Brown, & Cocking, 2000). Mentors providing support within their area of expertise give a real-world context to learning. For protégés, receiving mentoring from someone who “has been there and done that” raises the level of authenticity.

Furthermore, mentors who share genuine science experiences can provide an authentic context and a motivational resource otherwise lacking in traditional classrooms. Learning contexts providing real-world applications tend to increase positive attitudes towards science (Koballa & Glynn, 2007). In their study of high school students, Bryan et al. (2011) found students’ motivation was most affected by instructional practices that made science relevant to students’ lives and showed them how science provided opportunities in life. Furthermore, Wijnia, Loyens, and Derous (2011) reported increased student motivation when tutors shared their own experiences with protégés during the mentoring experience.

Professional mentors add authenticity and contribute to students’ self-efficacy (Mullen, 2011) by promoting active learning guided by experience (Pajares, 2008). As tasks get more difficult, mentors are able to glean from their own previous experiences and provide expertise to scaffold learners and offer support to keep students’ confidence high. These contributions are directly supportive of student competence. Reeve (2002) discovered that competence support, specifically providing structure and “clear expectations, optimal challenges, and timely and informative feedback” (p. 193), was an effective way to motivate students. If trained properly, mentors are especially qualified to accomplish this feat.

Some researchers have called for additional mentoring interventions to promote classroom learning in science education. In particular, Bryan et al. (2011) suggested the recruitment of "women and men who are in science-related careers in the community to participate in school science activities and serve as science role models" (p. 1062). According to these authors, mentors could share experiences, discuss responsibilities, relay challenges, and generally build relationships with students. As a product of these relationships, students would respond with increased autonomy, self-efficacy, and motivation.

Programs joining students and scientists together in project-related work have been around for many years. Many students have attended summer camps, weekend research events, and after-school science mentoring programs at local colleges and universities (e.g., Yale Science Outreach, Mentoring for Science at Harvard). Specifically, programs uniting students with scientists in research apprenticeships have become increasingly popular, and some programs have produced positive student outcomes (Sadler et al., 2010).

Programs uniting students and scientists in partnerships are advantageous because they break down some of the stereotypical beliefs students have about scientists. Many students have misconceptions about who scientists are, what they do, and how science is practiced in authentic contexts. In a classic study of 35,000 high school students conducted by Mead and Meatraux (1957), students supposed scientists to be older males wearing white lab coats who worked long hours doing good work while neglecting their families. A more modern discussion of student misconceptions pertaining to scientists indicated perceptions have not changed much over the years (Welch & Huffman, 2011). Interestingly, teachers promote many misperceptions about scientists (Welch & Huffman, 2011). However, Welch and Huffman (2011) revealed that misconceptions disappeared as students worked directly with scientists over time. In these cases, students also developed more accurate and positive impressions of scientists. For instance, in one particular robotics study, students who initially thought scientists were “geeks” and “nerds” saw them as “cool” and “hip” after working with them on extended projects.

Mentoring Challenges

Bringing scientists and students into mentoring relationships obviously has a promising upside, but lack of availability of qualified mentors and geographical barriers are prohibitive factors (Ensher et al., 2003). Many communities do not have access to non-parent adults who could mentor others in an effective manner (Rhodes, Spencer, Saito, & Sipe, 2006), much less qualified scientists. The NSF (2013) recently reported scientists are predominately clustered in a small number of states and selected major metropolitan areas. This report reiterates the challenge of uniting scientists with classroom learners in face-to-face mentoring arrangements. However, the discovery that authenticity of classroom experiences increases when students are able to share with others, even when the sharing is done through technology-based outlets, is encouraging (Blair, 2012).

Bridging the Gap: Motivation, Mentoring, and Technology

As a byproduct of recent STEM program initiatives, educators are finding new ways to unite technology and science (Kubasko, Jones, Tretter, & Andre, 2008). While these unions increase opportunities for science learning, they also promote some misconceptions. Technology is not the magic bullet for solving education's problems. Creating meaningful and effective learning environments requires more than "buying a set of computers, interactive whiteboards, and tablet computing devices. Technological devices provide tremendous benefits to students, but they are not the backbone of 21st century learning" (Wells, 2012, p. 12). According to Wells (2012), technology is best suited for enhancing "research, organization, analysis, and communication" (p. 12), but it is not the savior of education. Bachman and Stewart (2011) concurred, stating psychological and pedagogical strategies should garner more attention than the technology when considering online course development.

Online Mentoring

Educators and curriculum developers can, however, use technology to bring parties together that may otherwise be barred from interchange. While physically bringing scientists into classrooms for face-to-face interactions is logistically challenging, Internet connectivity can break the logistical and geographical barriers and foster new relationships between students and scientists in classrooms across the world. In other applications, such as at-risk youth counseling programs, online mentoring partnerships have become tangible ways to unite mentors with protégés (Rhodes et al., 2006).

Online mentoring has also been used in science education. O'Neill et al. (1996) discussed an online mentoring project linking a geology graduate student with students studying earthquakes in an Earth Science class. The students communicated with their mentor via e-mail over a seven-week period. The researchers reported the project was successful because the online mentor helped students narrow down their ideas through focused intervention while raising student confidence during a difficult project. An additional discovery was the increased autonomy the teacher gave the students in the classroom due to the comfort level provided by the expertise of the scientist-mentor. The teacher also had more time to focus on other aspects of classroom orchestration because the mentor helped students with content and process questions.

The Earth Science class mentoring experience was part of the Collaborative Visualization (CoVis) project at Northwestern University in Chicago, Illinois. Developers designed the project to "understand how science education could take broad advantage of [technological] capabilities, providing motivating experiences for students and teachers with contemporary science tools and topics" (Pea, 1993, p. 61). Discontinued in 1998, the CoVis project explored remote collaborations between high school students involved in inquiry-based activities and atmospheric and environmental scientists and graduate students. The CoVis project did not provide fixed curricular materials or standardized activities, only resources and technology (Edelson, 1998). While e-mail, an asynchronous mode of communication, was used in many of the mentorships, synchronous modes of communication were also used in CoVis (Edelson, 1998).

Overall, research indicated the CoVis project was successful. For example, students engaged in a global warming module showed significant gains from pre- to post-tests and self-reported greater learning as a result of the innovative mentorship (Gomez & Gordin, 1995). Additionally, Edelson (1998) reported CoVis projects provided increased scientific authenticity for classroom learners as a result of connecting scientists and students with technology.

The BSA's *PlantingScience* program provides a more recent example of using scientists as online mentors (Hemingway, Dahl, Haufler, & Stuessy, 2011). Launched in 2005, PS was awarded the American Association for the Advancement of Science SPORE (acronym for Science Prize for Online Resources in Education) award for its innovation and use of online scientists to mentor students involved in plant-related inquiry projects. Similar to CoVis, PS partners practicing scientists or graduate students with classroom science learners. While similar in principle, the two programs differ on many traits. PS, unlike CoVis, provides curricular materials and activities for its participants. Additionally, PS allows only asynchronous communication between scientist-mentors and classroom learners, whereas CoVis used both synchronous and asynchronous methods. Nevertheless, Hemingway et al. (2011) reported, "Talking online with a scientist is exciting and motivating to students. Teachers commonly relate that their students develop a new level of confidence and responsibility toward their experiments" (p. 1536). PS has experienced tremendous growth since its launch in 2005, with over 11,000 students and over 900 scientist-mentors participating in the program since its inception (Hemingway & Adams, 2013).

Advantages of online mentoring. The CoVis and PS projects illustrate the potential for increasing productive participation between professional scientists and classroom learners through online mentoring. By rendering geographical barriers inconsequential, online mentoring provides additional opportunities for scientists and students to work together (Ensher et al., 2003). Additionally, for many students, the opportunity to communicate online removes the awkwardness of face-to-face meetings (Rhodes et al., 2006). For those students, seeking help from others can be a daunting task (Zimmerman & Schunk, 2008), and the “safer” online environment lowers the anxiety threshold and eases tension, thereby promoting greater interaction.

Not only does online mentoring provide advantages for mentors and students, it also can be beneficial for researchers. Researchers are rewarded with an abundance of archived data when the online mentorship is text-based. Without need for transcription, these dialogues provide excellent opportunities for researchers to study the relationships between scientists and students through content analysis (Ensher et al., 2003; Rhodes et al., 2006).

Disadvantages of online mentoring. Online mentoring has many advantages, but it also has its challenges. For many schools, the cost of purchasing the needed equipment for conferencing and other forms of synchronous communication is prohibitive. Additionally, if synchronous communication is desired, scheduling becomes an issue, particularly with the inflexibility of most school schedules and the logistics of communicating across different time zones. Asynchronous methods may hold some advantages for schools in general, but they too have disadvantages.

Ensher et al. (2003) reported many potential problems with asynchronous communication including: (1) likelihood of miscommunication due to absence of non-verbal cues and lack of tone, (2) slower development of relationships, (3) potential lack of typing and written communication skills, (4) computer malfunctions, (5) nonresponse, and, (6) issues of privacy and confidentiality. Lin, Hsieh, and Chuang (2009) singled out the potential for long lag times between posts as particularly problematic for developing relationships online. When the pace of communication slows down, frustration builds, and the mentoring relationship suffers (Ensher et al., 2003).

Supporting Student Motivation Through Online Mentoring

In order to efficiently and productively develop and evaluate online learning environments and mentoring programs, we need established frameworks and models (Akyol, Garrison, & Ozden, 2009). While online mentoring interventions such as CoVis and PS have experienced some success, we do not know why. Much of the research in this area is atheoretical (Akyol & Garrison, 2008; Garrison, 2011), which makes it difficult to identify the underlying reasons behind many online programs' success. SDT provides a useful theory-based framework through which we can gauge the need-supporting capabilities of these online environments. Perhaps the lens of SDT can shed light on why these interventions are experiencing success and how we can continue to modify these programs to engage students and scientists in productive science.

State of the research. While novel technological applications are introduced to education on a regular basis, many researchers point to a general lack of scholarly literature in some key areas. For example, Mayer (2011) lamented the neglect of research dealing with motivation in technology-supported environments. Ensher et al. (2003) noted a lack of scholarly articles published on online mentoring. More specifically, Xie, Debacker, and Ferguson (2006) commented, “There is little research that directly addresses students’ motivation related to their participation in online discussion" (p. 68). Although general articles about educational technology are well represented in the literature, many are program descriptions as opposed to research-based studies (Rhodes et al., 2006).

While motivational research related to online contexts is lacking, research articles applying SDT in general are becoming more common. In 2012, over 350 articles using SDT applications were published, and over 7,000 references to SDT studies were cited in the literature at large (Ryan & Deci, 2013). SDT studies are gaining in popularity because the theory provides a well-researched framework for evaluating and answering the *why* questions associated with motivation. Highly popular in psychology, business, and health care applications, SDT provides a framework that can be easily applied to educational contexts such as online mentoring interventions.

As mentioned previously, SDT has been regularly applied in educational contexts (see Deci et al., 1991; Guay et al., 2008; Niemiec & Ryan, 2009; Ratelle et al., 2007; Reeve, 2002; Reeve et al., 2004). Studies specific to online learning have historically been sporadic, although the volume has increased noticeably in recent years (see Bachman & Stewart, 2011; Chen & Jang, 2010; Hartnett, St. George, & Dron, 2011; Moos & Honkomp, 2011; Xie et al., 2006). SDT studies specific to science education are even more rare (Lavigne, Vallerand, & Miquelon, 2007).

Positive indicators. In a SDT study of pre-service teachers involved in distance learning, Hartnett et al. (2011) discovered ultimate success of the online learning environment depended on learner characteristics, facilitator characteristics, and the online environmental conditions. Contrary to popular belief that online learners were primarily intrinsically motivated, Hartnett et al. (2011) revealed learner motivation, even in online environments, was highly contingent upon situational conditions. Facilitators of the online environment, not just the learners, were extremely important actors in promoting learner motivation.

This study's findings are significant because they substantiate the claim that if online environments contribute to student autonomy, competence, and relatedness, students are more likely to respond with increased motivation. Based on the research linking relatedness to internalization shared earlier, mentors can add value to the student experience by fostering internalization and contributing to increased learning. The link between motivation and learning is unmistakable, as reiterated by the NRC (2012a) document *Education for Life and Work*: "Deep learning occurs when students are motivated to exert the effort to learn, so another way to promote deep learning is to prime student motivation" (p. 164).

Providing online motivational support. However, we cannot assume student-scientist online mentorships automatically produce motivated students and broader impacts for scientists. To the contrary, Chen and Jang (2010) suggested supports not directly related to students' psychological needs are likely to "lead to adverse – even worse than 'no effects' – outcomes" (p. 750). Similarly, Bachman and Stewart (2011) implored online instructors to carefully consider SDT when constructing web-enhanced courses. Specifically, these authors called for curriculum designers and teachers to move away from false notions that online learning is primarily about content delivery and, instead, embrace the principle that online learning environments need to be motivationally supportive. In Bachman and Stewart's view, online learning environments need to enhance student autonomy, develop greater perceived competence, and create discussions that bring students "into a world in which they can safely share and engage in discussion and reflection" (p. 185).

Autonomy support. Online mentors, just like face-to-face mentors, contribute to student autonomy in several different ways. Autonomy supportive actions include encouraging learners to pursue their own interests and providing them with meaningful choice (Reeve, 2002). Limiting controlling language is also autonomy supportive (Deci et al., 1996). Finally, providing rationales for why students should engage in a particular activity provides autonomy support (Deci et al., 1994).

An additional "built-in" autonomy supportive feature of online environments is the increased distance between participants (i.e., transaction distance; Moore, 1993). As perceived transaction distance increases, feelings of autonomy increase. Also, if the online environment features asynchronous communication, autonomy is further supported; learners have the option to respond to mentor comments; and if they do choose to respond, learners control the timing of their feedback (Bachman & Stewart, 2011). Conversely, when students are "forced" to respond to posts, students' perceived autonomy is decreased (Xie et al., 2006).

Competence support. In regard to competence, good online mentors provide feedback and reinforce the self-esteem of their protégés (Ensher et al., 2003). Competence supportive actions also include providing good explanations that do not imply incompetence on the part of the learner (Ryan & Deci, 2000a). Posing challenging questions that stretch learners to think more deeply also promotes greater competence (Bachman & Stewart, 2011; Elliot, McGregor, & Thrash, 2002; NRC, 2012a). Finally, online asynchronous environments inherently provide competence support because students have time to reflect and revise their thinking before posting (Garrison, 2011).

Relatedness support. Ensher et al. (2003) stated increased contact time between mentor and protégé, whether face-to-face or through technology, contributed to more positive experiences for protégés. Although increased contact time could correlate to increased relatedness, measuring relatedness support in an online context is somewhat difficult. Autonomy and competence supporting statements can be identified in asynchronous dialogues, for instance, but how do you know if mentors' text-based comments are supportive of students' relatedness? Social presence theory, a concept derived from the Community of Inquiry (CoI) framework (Garrison, 2011), has been used as a tool to measure connectedness in online contexts, and consequently provides a way to evaluate relatedness support in online contexts.

Garrison (2011) defined social presence as "the ability of participants to identify with a group, communicate purposefully in a trusting environment, and develop personal and affective relationships progressively by way of projecting their individual personalities" (p. 23). According to Garrison, social presence is established by interpersonal communication, open communication, and cohesive communication. Interpersonal communication consists of self-disclosure statements, humorous statements, and affective expressions. Open communication is characterized by expressions of agreement and inviting further participation from other parties. Cohesive communication includes referring to other parties by given names, making references to teamwork, and using phatic and social words and/or phrases.

As online conversationalists establish social presence, they develop “a climate that supports and encourages probing questions, skepticism, and the contribution of explanatory ideas” (Garrison, 2011, p. 32). Ultimately, online participants form bonds as they build group identity and experience social adhesion (Akyol & Garrison, 2008). In online mentoring between a scientist and a group of students, perhaps the scientist’s greatest contribution as a mentor is developing an interpersonal relationship with students through online interaction and promoting greater student motivation.

Although not well researched at present, students may perceive online scientist-mentors as less threatening than teachers because scientists are not the primary grading and disciplinary agents. Because grading and disciplinary action are considered controlling by many students and therefore motivationally limiting (Deci et al., 1994), scientists’ participation can more easily promote motivation. As more research on online mentoring is conducted, studies should focus on how scientist-mentors’ motivational support enhances student outcomes.

Research Paradigm

Research on motivation is often based on self-report surveys, with few studies occurring in the natural context of the learning environment (Urdan & Turner, 2005). Self-report data, while useful and responsible for much of our knowledge on motivation, may not provide the information needed to address complex questions about the intersection of technology, motivation, and mentoring in the science classroom. While we know some of these online programs are successful, we struggle to identify why. The ecological validity of a study becomes particularly important when investigating and drawing conclusions about why a certain program or intervention is successful.

Ecological Validity

A study has ecological validity if the conditions in which the research is conducted closely match the conditions in which the results will be applied (Bracht & Glass, 1968). Studies involving psychological concepts are often conducted in laboratory settings where conditions can be carefully monitored and standardized. However, some studies conducted in pure laboratory conditions do not generalize well for applications in genuine classroom contexts (Hacker, Bol, & Bahbahani, 2008; Hacker, Bol, & Keener, 2008; Nietfeld, Cao, & Osborne, 2005). Many factors in the classroom, including student motivation, do not translate well to laboratory conditions (Hacker, Bol, & Bahbahani, 2008). When the research context or methods are divorced from the practical context, any obtained results are of questionable value in answering the *why* questions and therefore are limited in application (Covington, 2004).

Computer-supported collaborative learning (CSCL) environments are unique. Therefore, it stands to reason that researchers should carefully consider the ecological validity of their methodology and analysis techniques when studying these complex systems. Moreover, when studies involving online mentoring in text-based mediums are considered, it is appropriate to consider the actual “conversations” as part of the data as opposed to strictly relying on self-report data. Although most of the research on CSCL environments rely on self-report (Gress, Fior, Hadwin, & Winne, 2010), some computer-mediated communication (CMC) studies have successfully incorporated content analysis as an evaluative method (Enriquez, 2009).

Content Analysis

Krippendorff (2013) referred to content analysis as potentially one of the most important research techniques in the social sciences. In particular, he pointed to its unobtrusive and contextually dependent nature as important qualifications of its value. One benefit of using content analysis in online mentoring studies is the accessibility of the archived dialogues between mentors and protégés (Ensher et al., 2003; Rhodes et al., 2006). However, content analysis requires a huge time investment if done properly (Jyothi, McAvinia, & Keating, 2012). Nevertheless, content analysis of dialogues provides an unobtrusive and constructive way to evaluate mentoring relationships in online contexts. Particularly in mentorships reliant on asynchronous communication, dialogues provide key pieces of information revealing the motivationally supportive strategies employed by mentors. In these relationships, mentors and protégés are not privy to what the others are thinking or doing. Dialogues provide the sole link between the participants. While the analysis may be time consuming, the results from these content-based analyses are more ecologically valid.

Mixed Methods

The complexity of the motivation construct, according to some researchers, demands diverse research methods beyond the quantitative instruments common to motivational studies (Wolters, Benzon, & Arroyo-Giner, 2011). Also, utilizing multiple methods helps uncover more of the complex interactions that are characteristic of educational settings (Butler, 2002). For some researchers, the limitations of a strictly quantitative or qualitative approach prevent sufficient investigation of complex problems. For example, Patrick and Middleton (2002) lauded the usefulness of quantitative methods to define the constructs involved in motivation, but lamented the shortfalls of quantitative methods in considering the context of the motivated behavior. Additionally, these authors recognized qualitative methods as great for addressing context, but subsequently pointed out the failures of qualitative research in identifying the specific constructs at work. As a result, they called for mixed methods approaches. Mixed methods approaches seem particularly useful when trying to understand the complexities involved when technology, mentoring, and motivation meet.

By combining qualitative and quantitative paradigms, mixed methods utilize multiple data collection techniques and analytic measures (Creswell & Plano Clark, 2011; Tashakkori & Teddlie, 2003). As Johnson, Onwuegbuzie, and Turner (2007) mentioned, mixed methods provide "breadth and depth of understanding" (p. 123) to research efforts, particularly efforts in complex educational contexts. Some researchers see the increased complexity of online contexts as further validation for mixed methods approaches (Akyol & Garrison, 2008). In one particular quantitative study involving SDT and student motivation, Liu, Wang, Tan, Koh, and Ee (2009) called for future mixed methods approaches that would "help to triangulate the quantitative data and would offer more insights into students' perceptions, and changes in their perceptions over time" (p. 144). These researchers recognized the shortcomings of a one-sided analytic technique, particularly in the context of studies involving student motivation and online mentoring.

The Next Step

Ironically, even though little is known about the nature of relationships formed during online interactions, programs continue to be developed at an astounding rate (Rhodes et al., 2006). As sociologist Zygmunt Bauman (2007) wrote, society too often “lifts the value of novelty above that of lastingness” (p. 85). Education is too important to have a “flavor of the month” mentality when it comes to implementing new programs and interventions. The time has come to synthesize our understanding of what we know to be effective as opposed to blindly trying innovations for the sake of novelty (Koballa & Glynn, 2007).

Online mentoring shows promise, and the success of programs like PS suggests hope for students like Johnny and scientists like Janice. Now, we need to use ecologically valid research techniques, mixed methods analyses, and strong theoretical foundations (e.g., SDT) to discover *why* online partnerships are effective and how we can make them more effective. If successful, the Johnnys of the world will begin to look forward to classroom science learning, see its relevance, and be motivated to learn more about the awe and wonder of science. At the same time, the Janices of the world will have opportunities to share their passion and make significant contributions through interacting with others, all the while building the inner motivational resources of learners in classrooms all over the world.

CHAPTER III

WHY DOES IT WORK? A QUALITATIVE INVESTIGATION OF THE MOTIVATIONAL FACTORS ASSOCIATED WITH A SUCCESSFUL, INNOVATIVE SCIENCE CURRICULUM

Introduction

With declines in the number of students pursuing science-related degrees (Toplis, 2011), "What's wrong with science education?" is an *in vogue* question among educators and scientists. Students have offered their answer, claiming science class is fragmented, repetitious, and replete with unfamiliar terms (Osborne & Collins, 2001). School science learning is not fun, and students often have poor attitudes about taking science classes (Toplis, 2011). Many continue to speculate on the reasons why school science disconnects students from the field. Organizations such as the NRC (2012a), however, claim today's typical K-12 science classrooms do not reflect national calls for engaging inquiry experiences and research-based science pedagogy.

In spite of these international trends, some classroom practices have a positive impact on student motivation in science education. For example, Sanfeliz and Stalzer (2003) reported students who are empowered in the classroom show more enthusiasm toward learning science. Comparably, students had better learning experiences when lessons included inherently interesting and meaningful content (Patrick & Middleton, 2002). In addition, student-generated questions increase independent thinking and improve student motivation (Moos & Honkomp, 2011). Results from these studies support positive relationships between independent thinking and higher student motivation. Unfortunately, many science teachers still emphasize passive learning through rote memorization of scientific facts (Koballa & Glynn, 2007).

Investigating successful programs, however, presents an imposing challenge. Classroom environments are extremely complex, rarely if ever following a one-size-fits all "Betty Crocker" pattern (Eisner, 1985). "Consequently the evaluative task in this situation is not one of applying a common standard to the products produced but one of reflecting upon what has been produced in order to reveal its uniqueness and significance" (Eisner, 1985, p.55). Therefore, I chose qualitative research methods for this study because they offered more explanatory power for complex classroom dynamics (Meyer & Turner, 2002). During data collection, qualitative methods also provided ecologically valid methods focusing on "naturally occurring, ordinary events in natural settings" (Miles et al., 2014, p. 11). The data's richness and the potential to provide deep, meaningful descriptions, interpretations, and evaluations made my selection of qualitative methods appropriate for this study. A successful, innovative science program, *PlantingScience*, provided the context for the study.

What is *PlantingScience*?

PlantingScience (PS), developed in 2005 by the BSA, is an award-winning program recognized for its complex design engaging classroom teachers, students, and scientist-mentors in an innovative, computer-supported science learning environment (Hemingway et al., 2011). Used internationally by over 11,000 students since its inception, PS provides advanced technology tools to mix scientific inquiry, classroom instruction, and online mentoring by practicing scientists and advanced science graduate students. Science learners, working in small teams of two to four students, design and carry out three- to ten-week long inquiry-based experiments related to plant biology. Students communicate asynchronously about their scientific inquiries with practicing plant scientist-mentors in an online forum open to the public. Scientist-mentors read students' posts and provide their own comments and questions to enhance the quality of the students' inquiry experiences. Specific topics for the inquiry units include seed germination (i.e., *The Wonder of Seeds*), photosynthesis (i.e., *The Power of Sunlight*), and sexual reproduction and alternation of generations in ferns (i.e., *C-Ferns in the Open*), among several others.

Although labeled as highly successful, the specific factors contributing to the success of PS are largely unknown. To date, no publications exist using PS data to identify the factors associated with students' successful engagement in the processes of classroom-based scientific inquiry. The purpose of this study is to describe, interpret, and evaluate PS using multiple data streams and various qualitative research methods to identify specific factors contributing to the program's success in engaging students in scientific inquiry.

Research Questions

More specifically, I used qualitative methods to consider the following research questions:

1. What characteristics of motivated behavior are observed when students engage in PS in the classroom? What evidence exists that students'

motivation is affected by interacting with scientists in the online asynchronous forum?

2. What are the conditions, contexts, and strategies in PS that lead to student motivation/engagement?
3. What are the strengths, weaknesses, opportunities, and threats associated with the PS program from a self-determination theory perspective?
4. How does evidence from students' classroom and online experiences and the stakeholders' focus group (from inductive grounded theory) compare with an analytic framework developed from the SWOT analysis (from deductive analysis) of the *PlantingScience* project?
5. What are the main factors contributing to the success of *PlantingScience*? What is the role of motivation in evaluating the overall effectiveness of the program?

Methodology

Data Sources

Four data sources were consulted in this study (Table 3.1). They included one stakeholders' focus group held in Columbus, OH; two high school classroom observations (one in the western U.S. and one in the midwestern U.S.) and follow-up interviews with the teachers observed; and 17 online scientist-student dialogues associated with "exemplary" projects identified by the BSA.

Focus group. In an effort to formatively assess the PS program, the BSA's PS Support Team spawned the idea of bringing teachers and scientists together in a focus

Table 3.1

Data Sources and Characteristics

Context	Source/Informants	Data
Focus group	Scientists, teachers, and science educators engaged in a 1-1/2 day stakeholders' meeting (*n* = 19)	Audio-recorded discussions, transcripts, field notes
High school classrooms	Student-teams from two different classrooms engaged in PS (*n* = 10)	Video-recorded classrooms; online dialogues of scientists and student-teams
High school teacher interviews	Two teachers observed in two different PS classrooms (*n* = 2)	Audio-recorded discussions, transcripts, field notes
Online dialogues	Asynchronous dialogues between scientist-mentors and student-teams from projects identified as "exemplary" by the BSA (*n* = 17)	Scientists-students coded dialogues

group to discuss the challenges, successes, and future direction of PS. The stakeholders' focus group meeting occurred over a day-and-a-half period and included 19 participants (i.e., scientists, teachers, PS program developers, and education researchers). The PS Support Team selected participant teachers and scientists based on their experience and expertise in the PS learning environment.

Due to the fact PS is an international program, getting teachers and scientist-mentors together in one place for a focus group presented logistical challenges. As a result, the focus group was held in conjunction with a national botany conference. The number of participants in the group was significantly larger than is customary for a focus group (Krueger & Casey, 2009). However, in a manner consistent with a Town Hall Focus Group (Zuckerman-Parker & Shank, 2008), smaller groups were formed during the session to facilitate intimate discussions. At times, scientists met together while teachers met separately. At other times, pairs or trios of teachers and scientists met in mixed small groups. Intermittently, the whole group met for debriefings.

The PS Support Team facilitated discussions and kept proceedings on topic using an outline of semi-structured questions. I played a role in the focus group as a member of the PS research team. I remained, for the most part, a passive listener and note taker. I did ask participants for clarifying statements during the focus group sessions as needed. Also, I had personal conversations with participants during social events. Overall, the discussion environment was open and relaxed, providing everyone with comfort to have passionate yet productive exchanges about the strengths and challenges of the PS program. Throughout the meeting, the research team amassed audio recordings and field notes as participants discussed the successes, challenges, and future of the PS program.

High school classrooms. Two classroom observations yielded field notes and video recordings of four lessons engaging students in inquiry activities associated with *The Wonder of Seeds*. After my classroom observations, I conducted exit interviews with each teacher while taking notes and audio recording the conversations for transcription. While this study was delimited to observations of one particular class section at each school, I was in each school for two full days and observed multiple class sections engaged in the PS program.

Online dialogues. Finally, I analyzed online dialogues between students and scientist-mentors. I chose two sources for dialogues. The first were dialogues from the 10 student-teams associated with the two classroom observations. When completing the grounded theory, I added an additional 17 exemplary online dialogues to reach theoretical saturation (Strauss & Corbin, 1990; see grounded theory method section). In all, 27 student-team/scientist-mentor dialogues were included as data sources in this study.

Analytical Strategies

I framed this study using Eisner's (1985) Connoisseurship/Critique evaluation model. According to Eisner, educational connoisseurs are experienced educators who appreciate education and have developed high levels of discernment and awareness, allowing them to serve as instruments of evaluation. Educational connoisseurship, therefore, is an "art of perception" that does not promote a liking or preference for what is observed, but rather "an awareness of its characteristics and quality" (Eisner, 1985, p. 104). Due to their expertise, connoisseurs are qualified to critique educational programs by communicating and disclosing observed subtleties in a way that enlightens others and paints vivid images of the observations (Eisner, 1985). I became the instrument through which data flowed and was interpreted (Miles et al., 2014).

My Positionality and Qualifications as a Connoisseur

My role was to serve as both connoisseur and critic as defined by Eisner's (1985) Connoisseurship/Critique model. I have 15 years combined experience as a teacher, school administrator, and education researcher. In addition, I participated as a teacher in one of the PS Summer Institute professional development experiences.

For the past three years, I have been a member of the internal PS research team. During this time, I participated in a number of research projects. I personally have observed multiple classrooms implementing PS and joined in various analyses using different lenses to interpret student-scientist dialogues. I was present at the focus group meeting of teachers, scientists, and program developers. I personally video recorded and observed the classrooms for the two observations referenced in this study. My role as the researcher in this study, therefore, was to serve as the evaluative instrument with the knowledge and experience to describe, interpret, and evaluate PS implementation using the included data.

As a new member of the research team, I had a healthy skepticism of how an online program could garner support amongst so many different participants (i.e., teachers, scientists, students). During data collection, analysis, and write up, I attempted to remain neutral about my personal likes and dislikes of the PS program. I tried to remain as unobtrusive as possible, and I strictly adhered to rigorous qualitative standards as specifically outlined in future sections of this chapter. I used methods like SWOT analysis to provide outlets for both positive and negative data. I perceived my position as being neutral throughout the process, but I also fully recognize my extended involvement in the project and my study of SDT have affected my current views. Nevertheless, to my knowledge, none of the instruments or techniques I used during this study biased my observations, analyses, or conclusions.

Eisner’s Framework

The Connoisseurship/Critique model (Eisner, 1985) includes three stages of qualitative investigation including description, interpretation, and evaluation. Description is defined as the part of criticism intending to “characterize or render the pervasive and sheerly descriptive aspects of the phenomena one attends to” (Eisner, 1985, p. 94). Interpretation is the part intending to bring “understanding of the significance that various forms of action” have on education (Eisner, 1985, p. 97). Finally, evaluation seeks “to make some value judgments about [a phenomenon] with respect to its educational significance” (Eisner, 1985, p. 98). In this study, various qualitative techniques were used at each stage to uncover and communicate specific factors of the PS program responsible for its overall success (Table 3.2).

I refer to PS as successful because of its overall popularity and its recognition as a SPORE award winner by AAAS. I chose the PS program as the context for this study because I wanted to focus on “health and resilience” as opposed to “pathology and disease” so common in social science research (Lawrence-Lightfoot & Davis, 1997, p. 8). However, I wanted to avoid the mistake of searching for goodness with intentional blindness toward imperfections and weaknesses. While focusing on what worked and asking the questions, “What is happening here, what is working, and why?” imperfections and weaknesses were judiciously uncovered and illuminated (Lawrence-Lightfoot & Davis, 1997).

Since Eisner’s (1985) model does not require or even recommend separating out description, interpretation, and evaluation, readers will find all three elements in various

Table 3.2

Data Sources, Analytical Methods, and Research Questions Framed by Eisner's (1985) Connoisseurship/Critique Model

	Connoisseurship/Critique Process		
	Description	Interpretation	Evaluation
Research Strategy	Narrative structure	Analytical effort (Wolcott, 1994) SWOT analysis (Helms & Nixon, 2010)	SWOT analysis (Helms & Nixon, 2010)
Qualitative Methods	Story-telling (Wolcott, 1994) Portraiture (Lawrence-Lightfoot & Davis, 1997)	Grounded theory (Strauss & Corbin, 1990) Deductive coding (Miles et al., 2014)	Theoretical comparison (Wolcott, 1994) Deductive coding (Miles et al., 2014)
Data Sources	Classroom observations and teacher interviews; Focus group; Scientist-student online dialogues	Classroom observations and teacher interviews; Focus group; Scientist-student online dialogues	Classroom observations and teacher interviews; Focus group; Scientist-student online dialogues
Research Question(s) Addressed and Expected Outcomes	1 Evidence of motivation in class and online	2 Conditions, contexts, and strategies leading to student motivation 3 Strengths, weaknesses, opportunities, and threats of PS from an SDT perspective	4 Comparison of inductive grounded theory to deductive SWOT 5 Factors contributing to PS success from motivational perspective

concentrations throughout the discussion. However, I employed different qualitative techniques at each stage of analysis to tease out relevant information and create understanding of the complex environment known as PS. While describing PS, I tried to bring the reader into the classrooms and focus group meetings, thereby providing a feel for the inner workings of the program and the stories of the students, teachers, and scientists involved in PS. For interpretation, I systematically examined the qualitative data to determine patterns and relationships. As student motivation emerged as a primary theme in the analysis, I proceeded with evaluation using a motivational lens.

For evaluation, Eisner (1985) recommended comparing analytical results against an established standard. I chose SDT as the standard in an effort to shed more light on how the PS program contributed to student motivation. As part of the evaluation process, I conducted a SWOT analysis to explain how the various components of PS contributed to (or detracted from) student motivation. The following paragraphs further clarify the specific procedures I used while describing, interpreting, and evaluating.

Description. My descriptions of the classroom observations and focus group meeting follow a narrative structure informed by Lawrence-Lightfoot and Davis' (1997) portraiture framework and Wolcott's (1994) story-telling method. I used mixtures of empirical descriptions and aesthetic expression to bring readers into the classrooms and meetings, thereby illuminating the intricacies of PS implementation to a broader audience (Lawrence-Lightfoot & Davis, 1997). Since description, like other forms of analysis, is an iterative process (Wolcott, 1994), I wrote descriptions early in the research process and constantly revisited and revised as the qualitative analysis progressed into interpretation and evaluation.

Interpretation. I began the interpretation process by systematically examining the descriptions, field notes, memos, and transcripts using a scientific and inductive process as per Wolcott (1994). In the early stages of this research, I considered the focus group meeting in isolation from the other data sources. This initial effort had significant, direct effects on the current study. For this reason, I will explain the analytical steps taken in this early stage.

The first grounded theory. After the focus group meeting, the four PS research team members (including me) who collected data began the long process of coding the field notes generated from the discussions. Written field notes included records of participants' comments that may have been (a) transcribed word-for-word as they were being spoken, (b) recorded as heard from audio-recorded conversations, or (c) paraphrased as phrases or sentences drafted by the researcher to describe or recollect a particular event. Researchers independently transcribed and organized their own hand-written field notes into electronic documents. They also copied their transcribed field notes on separate color-coded sheets so each researcher's notes could be identified and crosschecked.

Using a basic grounded theory methodology (Glaser & Strauss, 1967), we inductively determined the major themes of the focus group discussions. Individual researchers segmented their transcribed field notes into smaller units, or "raw data bits" (Lincoln & Guba, 1985), representing discrete events that were apparently related to the same content. Individual researchers used constant comparison to code and cluster their data bits to yield temporary categories (Goetz & LeCompte, 1981). Following Lincoln and Guba's process, research team members met together to discuss groupings and establish rules to describe categories and justify the inclusion of data bits. As researchers determined final placements of data bits, they adjusted and refined properties and dimensions of categories to provide more precision in their definitions and delimitations of categories.

As we considered all the data and conclusions, the topic of motivation was seen as the thematic thread throughout the focus group discussions. Time and time again, teachers and scientists alike made reference to students' interests in science, plants, and/or experimentation skyrocketing after PS engagement. As a research team, we identified student motivation as the core category and related the complementary categories to motivation (Scogin, Stuessy, et al., 2013).

Theoretical sampling. While our initial use of grounded theory methodology revealed a central phenomenon (i.e., student motivation) and several contributing categories, our original interpretation lacked process. Strauss and Corbin (1990) defined process as "the linking of action/interactional sequences" (p. 143). In order to gain additional perspective, I extended the original study by incorporating other data streams as a form of theoretical sampling. As stated by Strauss and Corbin (1990), theoretical sampling is the inclusion of additional data in an effort to increase understanding of the properties and dimensions of categories as well as verify the relationships between categories. By investigating how categories and relationships changed under differing conditions, I developed a more comprehensive and robust theory describing and outlining the reasons why PS successfully motivated students and how the other actors (i.e., teachers and scientist-mentors) facilitated motivation under differing contexts and conditions.

My theoretical sample included data from two classroom observations, interviews with the teachers of those classrooms, the scientist-student dialogues generated from the 10 student-teams in the two classrooms, and the online dialogues of 17 exemplary projects as identified by the BSA. I used open, axial, and selective coding (Strauss & Corbin, 1990) to systematically integrate this new data and reconstruct the grounded theory. Specifically, I expanded the original theory by identifying the factors affecting student engagement in PS.

During this process, open codes were used to fracture the data and identify categories and ascertain their properties and dimensions. Axial coding followed, as I identified the *central phenomenon*, *causal conditions*, *intervening conditions*, *strategies*, *contexts*, and *outcomes* of successful PS implementation. Finally, I used selective coding to systematically relate the categories and conditions together, thereby creating an inductive grounded theory. Specifically, I used the paradigm model established by Strauss and Corbin (1990) to theoretically integrate all emerging categories.

The paradigm model provides a framework to help ascertain relationships between the following categories: causal conditions, phenomenon (core category), actions/strategies, intervening conditions, and consequences. Using all data streams (Table 3.1), I collapsed new emerging categories, verified relationships between categories, and established and validated the properties and dimensions of all categories. Ultimately, a theory emerged from the process to explain why PS is successful. This grounded theory represented the interpretation stage of Eisner's (1985) Connoisseurship/Critique model.

Evaluation. Educational evaluation involves comparisons between what has been observed and an established standard (Eisner, 1985). Theory is often used as a standard of comparison to help connect the study to a bigger picture (Wolcott, 1994). In this study, I applied a comprehensive theory of motivation retrospectively to the initial findings, a practice common in qualitative research (Creswell, 2009).

Self-determination theory. Self-determination theory (SDT) is a comprehensive theory of motivation positing that humans have basic psychological needs of autonomy, competence, and relatedness (Deci & Ryan, 2000). Deci and Ryan (2000) defined *autonomy* as the desire to regulate one's own behavior and act volitionally; *competence* as the desire to experience mastery over certain behaviors and/or affect the surrounding world; and *relatedness* as belongingness, or the desire to experience attachment and connectedness with others. Used often in educational contexts, SDT has been verified in well over 700 school-related studies (Rienties et al., 2009).

According to SDT, fulfilled basic needs contribute to healthy people who have a strong sense of well-being (Deci & Moller, 2005; Deci et al., 1996; Ryan & Deci, 2000b). Unfortunately, research findings indicate most students' basic psychological needs are not met in formal schooling environments (Ratelle et al., 2007). However, students can and do receive differing levels of support for autonomy, competence, and relatedness, even at school. When receiving differing levels of support, SDT suggests people will experience varying levels of motivational energy (Deci & Moller, 2005; Ryan & Deci, 2002). Therefore, motivation is experienced on a continuum and can change based on several factors, including the social conditions surrounding the individual.

In the school setting, SDT can be used to evaluate the motivational conduciveness of a particular learning environment. A look for supports of autonomy, competence, and relatedness can result in inferences about student motivation. In this study, evaluation included deductively coding (Miles et al., 2014) the data (Table 3.1) using predetermined categories of autonomy, competence, and relatedness. I then reported evaluation results using a SWOT (i.e., strengths/weaknesses/opportunities/threats) analysis.

SWOT analysis. SWOT analysis started in the 1950s and is often used in business contexts to identify internal and external factors affecting the present and future health of a company (Helms & Nixon, 2010). In this study, I used SWOT as a framework to compare the factors identified in the inductive grounded theory to principles of SDT. In other words, the emerging factors from the grounded theory were deductively categorized into the SWOT framework based on their relationships to autonomy, competence, and relatedness. The following definitions outline the parameters I used to differentiate between strengths, weaknesses, opportunities, and threats.

SWOT analysis considers both internal and external characteristics affecting an institution or program. In this study, internal factors were defined as those inherent in the structure of the PS program such as curricular modules, online interaction, and inquiry-based learning, to name a few. Specifically, strengths were defined as the internal characteristics of PS contributing to the autonomy, competence, and/or relatedness of students. Weaknesses referred to the internal characteristics of PS perceived to be detrimental to student autonomy, competence, and/or relatedness. In other words, strengths and weaknesses were considered in light of factors that either contributed to or undermined students' motivational resources.

In addition to internal characteristics, a SWOT analysis considers external factors that could impact on a program. In this study, external factors were defined as the variables outside of the PS program's control such as mentor interactions, teacher orchestration, and other characteristics related to actors' participation in PS. More specifically, opportunities were defined as external factors that increased motivational support for students' autonomy, competence, and/or relatedness. Threats were defined as external factors that lessened motivational support of students' autonomy, competence, and/or relatedness.

Limitations and Delimitations

This study was delimited to data relevant to answering the question, "Why is *PlantingScience* successful?" Since qualitative research is labor-intensive, the data selected for inclusion in this study represented the "best" of PS. First, two veteran teachers with professional development experience in PS and extended teaching experience were purposively selected for observation and interviews. Second, the 17 scientist-student dialogues were part of studies recognized by BSA as “exemplary” because of the student-teams’ excellent research questions and methods, posted artifacts on the website, and in-depth dialogues with scientists. Third, focus group participants were chosen by BSA because of their experience in the program and understanding of the complexities involved in PS, either as teachers or scientists.

In sum, the data used in this study was collected from those who had the necessary experience to understand the complexities of PS and could therefore help answer the big question of why PS is successful. These delimitations also fit well with my desire to focus on goodness in the spirit of portraiture (Lawrence-Lightfoot & Davis, 1997). The sample is small but presents a manageable amount of data in consideration of the time investment required for rigorous qualitative research (Miles et al., 2014). While the findings will not generalize to a larger population, they are context-specific to the PS program and help us understand how the program successfully engages students in authentic science activities.

Analytical Rigor

Throughout data collection, description, interpretation, and evaluation, I used several strategies to promote rigorous and trustworthy research. Since Eisner’s (1985) Connoisseurship/Critique model was used as the framework for the study, we will first consider his recommendations.

Eisner (1985) recommended two primary methods to insure trustworthiness when using his model. (1) He advocated structural corroboration, a process that “seeks to validate…one's conclusions about a set of phenomena by demonstrating how a variety of facts or conditions with the phenomena support the conclusions drawn" (Eisner, 1985, p. 100). (2) Eisner demanded researchers using the Connoisseurship/Critique model be able to communicate and describe specific phenomena in such detail that facts could easily be verified by looking at the data. Eisner called this method referential adequacy. Referential adequacy is an important complimentary strategy to structural corroboration, and together these two strategies establish analytical rigor.

In order to provide a chain of evidence with which one can apply structural corroboration and referential adequacy, Eisner (1985) recommended archiving data, such as actual videos. "Disputes about the adequacy of the criticism can be resolved, at least in principle, by re-examining particular segments of the tape" (Eisner, 1985, p. 115). In the current study, archived data including video recordings, audio recordings, and textual discussions are available for reexamination by authorized individuals.

In addition to Eisner's recommendations, other qualitative researchers offered valuable insights on substantiating qualitative research. While Wolcott (1994) did not favor using terms like "validation" or "validity," he conceded his qualitative studies were undergirded by practices serving as validation measures. These strategies included unobtrusive listening, accurate recording, early writing, full reporting, candor, seeking feedback, and accurate writing (Wolcott, 1994).

I adopted many of Wolcott's (1994) strategies in this study. (1) I conducted classroom observations in an inconspicuous fashion. I unobtrusively video recorded, took field notes of observations, and analyzed online communications. (2) The research team archived all collected data including video and audio recordings, transcribed information, and field notes. (3) The research team prepared reports to the BSA and the NSF and authored conference presentations at all stages of the research process, thereby establishing a chain of evidence representative of Wolcott's "early writing." (4) All members of the research team, including me, made significant efforts to report results candidly, accurately, and with feedback from other researchers involved in various capacities with the project.

In addition to the considerations offered by Wolcott (1994), Johnson (1997) provided additional strategies for rigorous qualitative analysis. Johnson suggested extended fieldwork, low inference descriptors, triangulation (including data, methods, and investigator), and peer review. (1) I collected the data used in this study from extended fieldwork including PS classroom observations, teacher interviews, focus group discussions, and scientist-student asynchronous dialogues. (2) I collected data in various ways, including direct observations, personal interviews, focus group conversations, and textual dialogues. (3) Methods triangulation occurred by my use of multiple qualitative methods, including narrative analysis, portraiture, story-telling, grounded theory, inductive and deductive coding, and SWOT analysis. (4) Other PS team members reviewed the work as a form of peer review. (5) In addition to the aforementioned strategies, I used a theoretical framework during evaluation, a technique recommended by Miles et al. (2014). While the use of theory is less common in qualitative research, the theory provided a diagnostic tool to evaluate PS and connect practice with theory (Eisner, 1985).

A Day in the Life: Describing PS Implementation

Dan's Classroom

I first met Dan at the 2011 Summer PS Institute. Dan graduated from a large university and completed postgraduate work at a smaller regional university. Dan had taught life science, physical science, general science, and social studies over the course of his 10-year career. As a veteran teacher using PS, Dan was chosen to be a teacher/leader in the 10-day Institute workshop bringing teachers and scientists together to conduct inquiry experiments and discuss ways to implement them in the classroom.

Dan seemed rather laid back, yet he often spoke about holding students to a higher standard. I was impressed with Dan's vision for science education and knew immediately I wanted to visit his classroom when the opportunity arose. I got the opportunity during the ensuing fall semester and flew out to observe Dan's freshman biology class as they began a new PS project.

First impressions. Arriving at the school, I snaked my way through the well-lit hallways to the freshman wing in the back of the building. Dan's classroom was not small, yet it was not overwhelmingly large either. Lab tables with slick, black tops formed tetrads across the tile floor of the room. On the front wall, a Smartboard hung grandly just in front of an old-fashioned green chalkboard, serving as a stark reminder of the contrast between what used to be and what had come in the world of technology. Science posters covered the walls, ranging from the traditional periodic chart of the elements to vividly illustrated posters heralding the advantages of inquiry learning. Cow skulls hanging from hooks flanked the green chalkboard at the head of the room, proudly claiming the space for biology. Terrariums lined the periphery, adding to the biology flavor of the room. In the back left-hand corner perched on a table, the “light garden” shone brightly. This homemade contraption, constructed of portable 110-volt fluorescent shop lights, stood ready to bathe newly assembled PS projects in artificial light. In the opposite corner, bags of potting soil and Perlite sat adjacent to water bottles that were cut in half. I eventually figured out these supplies were for constructing “potting chambers.” The traditional amenities (e.g., chalkboards, posters), hands-on biology supplies (e.g., terrariums, light garden, potting supplies), and technology (e.g., Smartboard, laptops, Wifi hotspots) reminded me that the PS program was truly a unique mixture requiring diverse ingredients.

Signs of life. Well before the starting 7:30 am tone sounded, four students quietly entered the classroom and purposefully headed to the terrariums. Dan entered the room a few moments later and casually conversed with the four, hardly seeming to recognize the huge snakes wrapped around the forearms of two students. In fact, Dan seemed amused with the conversation as he plugged up the computer cart and booted up his personal computer and Smartboard for the day’s activities. As the time for first period drew closer, the students gently deposited the snakes back into the terrariums and bid Dan goodbye. I got the distinct feeling that Dan’s classroom was going to be a comfortable place where students had the freedom to explore.

As the tone for first period sounded, students barreled into the room and took their seats at the lab stations. They were dressed casually in shorts and jeans, and the group was proportionally split between males and females. As students took their seats, some pulled out earbuds while others fished in their pockets to retrieve cell phones. Another tone sounded, and a male and female voice alternated over the loudspeaker, providing tidbits about activities ranging from service opportunities to recent accomplishments in athletic and academic endeavors.

After announcements, Dan gave a mini-lecture about a quiz he had given in a previous meeting and some reading assignments students were supposed to have done before coming to class. I would learn later this instructional segment, commonly done at the beginning of all his classes, was Dan's way of "covering the prescribed curriculum" when engaged in "alternative" activities like PS.

A new frontier. After Dan's introduction, he "turned the students loose" to work on their newly minted PS projects. Students scattered to different parts of the room like ants. Some grabbed laptops from the cart and began logging on to the PS website, while others started making potting chambers from the plastic water bottles. Others sat almost motionless, peering passively at their busy classmates.

Although most were busy, it was obvious that many of Dan's students were inquiry novices. I also got the distinct impression that most had never worked with live plants. Even under Dan's skillful tutelage, some students lacked the ability to make potting chambers and plant seeds. Nevertheless, what they lacked in ability, many made up for in effort. The classroom was bursting with activity as students attempted to set up their projects.

A new fount of knowledge. The phrase, "I am not your primary source of information," resonates in my head to this day because I heard Dan repeat it so many times. Students struggled to shake off the mantra that teachers are supposed to give information and students are supposed to passively receive it. When students asked Dan simple questions, he consistently replied, “I’m not the answer man” or “It is not about assuming I know everything. I’m not the scientist, you are.” I witnessed students leaving the nest of traditional classroom norms for the first time, and most struggled to fly on their own. However, Dan painstakingly persevered in his efforts to pass the torch of control to his students and inspire them to autonomous action. “You need to be the scientist. You need to be looking at these things [variables].”

You don’t know the answer? In conjunction with students struggling to break free from reliance on Dan, they also had difficulty pursuing a question without a definitive, prescribed answer. Teams worked to refine their research questions, and I often heard Dan say, “We already know that,” or “What is the value of that?” Students wanted to design experiments that easily confirmed something they already knew. Dan playfully related how most of his students in the early stages of PS, wanted to “dump soda on a plant” and see what happens. He chuckled as he recalled his typical answer: “You already know what’s going to happen! It’s going to get sticky and stink!”

When students eased out into uncharted research waters, Dan persistently encouraged them to record as much data as possible. “Keep as much data as you can. You don’t really know what is going to be important.” He explicitly told learners to consider variables like temperature, distance from the light source, and light intensity. Over time, I noticed an increasing number of students who sauntered by the thermostat at the front of the room to get a temperature reading or carried a ruler along with their planting chamber to the light garden to get a quick distance measurement. The newfound responsibility of having their own projects seemed to slowly transform these students into conscientious, budding scientists!

My thoughts are valid. Dan constantly encouraged students to take charge of their experiments. “It is your experiment, think about it.” When a student complained about not being able to upload his own pictures to the website since the class was sharing a camera, Dan immediately replied, “If you want to upload one now, use your computer to do that.” While this exchange seemed trivial at the time, it reflected how eager and ready Dan was for students to take charge, even if it meant changing the plan or using resources in slightly different ways. “We’ve trained them to believe that what they have to say has very little value. So, that’s the way they act.”

During one exchange with a student-team, Dan asked, “Why are you doing this experiment?” A student responded, “So we can test how dry conditions affect plants.” Without hesitation, Dan affirmed this group’s choice of topic. “So this is a very valid experiment because of global warming, drought, etcetera, etcetera. It is something real scientists are really doing. So you want to talk about how this is related to that.” In a simple yet powerful statement, Dan validated the student-team’s decision and encouraged them to not only pursue that line of questioning, but be prepared to tell the world about it through the PS website.

At the end of this particular class period, student-teams, albeit reluctantly, went to the front of the room and shared their fledgling research questions. Three girls explained how their research question about the effects of chlorine on plants was spawned from one girl's camping experiences. Her family added chlorine tablets to the natural water in order to disinfect it before drinking. As she relayed this experience to her team, they decided to investigate how chlorine affected plants. For this group, affirmation came from their scientist-mentor who posted, "So your question has great practical importance. If the city is adding chlorine to water, then how will it affect the plants we water it with?"

Another student-team decided to investigate whether weeds grew faster than ornamental flowering plants. When asked by classmates why they chose this question, a team-member mused, "I was just wondering, and it had to do with this project." Probing further, Dan asked, "Where does the wonder come from?" When the student replied, "Seeing it, observing it," I realized afresh how PS enabled students, maybe for the first time in their school experiences, to pursue answers to their own questions and experience just a little taste of the joy and wonder of scientific pursuit and discovery.

Taking it to a deeper level. When I spoke with Dan about why he chose to be involved in the PS program, he referred to his driving passion to take students deeper into scientific pursuits. With intensity gleaming in his eyes, he said,

> I know that there are examples of kids having done that [gone deeper], even within…*PlantingScience*, where kids made some discoveries where they [PS scientists and developers] had to say, "Wait a minute," and then the scientific community had to look at that and say, "Wow, that's a pretty interesting way to look at that."

In addition to challenging students to go deeper in their projects, Dan intentionally tried to impress upon his students that their projects were bigger and more important than typical classroom work. “Remember your online journals!,” Dan bellowed out during the chaos. “You are not only communicating with your mentor, but with the world!” The sell to students proved challenging. “They [students] always think it is just another exercise that we do in class.”

Building a relationship. According to Dan, scientist-mentors played a pivotal role in stimulating students to go deeper. However, Dan recognized several challenges associated with the unique online relationship between scientists and students. “Your mentor is a real, live person that you are talking to and who is talking to you about his project. You need to get deeper in these projects than you’ve gone so far,” Dan interjected loudly in the middle of one class. In an attempt to jump-start the relationship between his students and their mentors, Dan reached out to the scientists assigned to his students before beginning the PS unit.

“We tried to get some support out of them [mentors] on how to do the questioning, which is the weakest area we deal with in terms of creating a meaningful experiment.” During class, Dan constantly reminded students to communicate with their mentors for suggestions and guidance. “You need to talk to your mentor,” “Look and see if there are any suggestions that you might want to incorporate [from your mentor’s comments].”

One of the challenges Dan faced was helping students overcome apprehensions about responding to scientists. Even though students had never met the scientist-mentors personally and more than likely never would, they were sometimes conscientious about how mentors perceived them online. One student-team argued about what to post, with one student demanding, “Don’t post that. He’ll think we are stupid!” The next day, this same group, the Fantastic Four (pseudonym), expressed frustration to Dan about their scientist-mentor. “He’s not talking back,” claimed one of the students. “I don’t think he understands us,” chimed in another. Putting the responsibility back on the students, Dan defused the situation by encouraging the team to consider how they could better express themselves to the scientist.

It’s hard, but it’s worth it. Over the course of the PS project, Dan’s student-teams developed their own research questions and methods to test those questions. It was not an easy process, as evidenced by student-teams who could not explain the purpose of their projects. Through intervention, Dan helped them understand, and over the term of the project, he had opportunities to share applicable science content and process. In the end, the students gained knowledge of some basic plant processes and principles of experimental design, although it was time consuming and labor intensive. Nevertheless, Dan resolved to break the mold of typical science teaching and help students reach new depths of understanding.

> We have issues in the way we do science as a country, younger kids just don't have these experiences and they don't get this idea that they could create scientific experiments that would give them knowledge that other people do not have or that would allow them to see the world in different ways and share that back with the world.

Do I have to do it? In the beginning stages of PS, many of Dan's students were apathetic toward science. Some students wrote in their online dialogues, "Science isn't one of my favorite subjects," and "To tell you the truth, not many plants interest me, so I'm not looking forward to this project." In response, a scientist-mentor responded, "I always disliked doing science projects in school, mostly because I did not like doing extra work." However, the remainder of his post was quite enlightening. "What I realize now is that this is a chance to be creative and get to see something you imagine play out and tell you something."

As I read those comments, it hit me like a ton of bricks. This was just the beginning! What I was witnessing was not the end product, but the germinating seed of science being planted in the hearts and minds of novice inquirers. By Dan's own admission, these students had not been exposed to anything remotely similar to PS. What many of us figured out only after working at the graduate-level in science, these students were learning in high school. In large part, the opportunity was theirs because of a supportive teacher willing to go against the grain and engage them in an innovative curriculum. With the support of scientists who had already undergone the metamorphosis, how could these learners fail?

Kelly's Classroom

I met Kelly at the PS Summer Institute where she was returning for the second time to serve as a mentor for the program. Kelly was a nine-year educator, teaching science at a rural high school in the northwestern United States. She earned a B.A. in communications from a large Midwestern university and a M.S. in natural resources from a different Midwestern university. While earning her degrees, Kelly accumulated 45 hours in science and science pedagogy.

Kelly was like the Energizer Bunny from the old battery commercials. Even in her leisure time, which some of the Institute participants were privy to through social media, she traveled around mountain biking and whitewater rafting. A few of the PS participants claimed they lived vicariously through her! In the classroom, Kelly described herself as an innovator, and she valued collaborative learning in her classrooms. She also wanted to develop a more authentic learning environment, so she looked for opportunities to introduce ambiguous activities and allow learners to "fail on a small scale." PS was a natural fit to her teaching style. I was ecstatic when she made her classroom available for observations.

First impressions. Upon arrival at the school, I wound my way through the corridors of the majestic building to a classroom in the back corner of the facility. As I entered, I was greeted by a huge space lined with glass-fronted wooden cabinets along the lateral walls. To the right, beakers, graduated cylinders, and various other pieces of glassware sat on shelves behind the glass panes. To the left, books, microscopes, and various teaching aids such as mitosis/meiosis manipulatives and disarticulated flower models crowded the shelves. The back of the room offered a generous amount of counter-top space sitting atop storage cabinets. A door in the right-hand corner led to an adjacent greenhouse where most students kept their PS projects. Stand up tables with black, shiny tops and metal stools with no backs dotted the interior of the classroom. A whiteboard and a projection screen hung in tandem on the front wall, and a permanentlymounted projector was suspended from the ceiling in the middle of the room. Whiteboard and bulletin boards covered every other available wall space around the room. Bulletin boards were neatly decorated with scientific sayings and other "sciency" things, effectively announcing this was a space reserved for scientific study.

Did he say imbibe? Students in Kelly's classes had been involved in their PS projects for several weeks prior to my visit, so they were much farther along than Dan's class had been. In the weeks leading up to my visit, I had kept up with Kelly's student projects through the PS website. Students were buzzing online, posting comments like, "I can't wait to start our project," "Biology is my strong subject," and "I love science and plan on continuing science after high school and throughout college." Not all comments were positive (I will share some of these later), but I was excited to see what was going on in the classroom and anxiously awaited the start of class.

Well before the tone announcing the beginning of class sounded, a tall, curly-headed young man with emerging facial hair bounced into the classroom. As he passed my position in the back corner of the classroom, he enthusiastically reported, "I need to imbibe!" and rushed off through the greenhouse door. "Did he just say imbibe?" I thought to myself. My thoughts were interrupted by a new flow of students through the door. As they entered, most immediately went to work on their projects.

Kelly entered the room with several laptop computers, but the atmosphere remained unchanged as students busily got out their experiments and booted up the computers. Kelly announced that students needed to either set up their experiments or continue to collect data, depending on their particular stage. She projected a task list on the front screen with reminders for the day, but students hardly seemed to notice as they purposefully went about their business.

Saving the babies. Many of the cups and planters sported new growth, and students could not contain their excitement. One student pointed his finger at the emerging seedlings in the cup and shouted, "Boom!" Apparently, reactions such as this were not uncommon during PS experiments. Kelly shared,

> What I have been excited about is, boy, as soon as those seeds started to germinate, those kids are bought in….The kids whose seeds have not germinated, they are a little more disconnected...Two students who came up to me during class, their seeds have not germinated, and you can tell the disappointment. So they are not as engaged as the kids whose seeds have germinated. It's as if they feel a sense of responsibility towards the seeds.

In most cases, students quickly communicated their excitement to their scientist-mentors on the asynchronous blog. "We had crazy germination!" "[Scientist-mentor's name]! Some of our seeds have started to germinate." One girl was especially passionate about her new seedling, posting, "We have germination! We are saving our babies :)"

Joy and wonder. Students were optimistic about most parts of the PS experience, even about little things like being able to use digital cameras and upload pictures to the PS website. "They love the cameras. They feel very independent with the cameras," beamed Kelly. She also felt students voluntarily took on more responsibility than normal during a PS project. "Did you notice how they do cleanup? The cameras are put back up where they are supposed to be. I'm not missing batteries or memory cards…I don't have to get on anybody about cleaning up."

Although Kelly described herself as a teacher who was "all about content," her goals with PS were somewhat different. Kelly used PS as a tool to develop students' capacity to love and appreciate science in ways they had not experienced before in school settings.

> The real value with this [*PlantingScience*] is they are feeling empowered about science. They are curious, they're unabashedly asking questions. And even though some of their methodology is naive, to me, I'm ok with that because, if I slam them with a tight rein, I'm going to turn them off to science. And I'm not saying science should all be fun and games, but they've got to experience the joy and wonder. Otherwise, they are not going to have the tenacity to set up an experiment again or to count and measure. You've got to buoy them with some joy and wonder to get them to do the nitty-gritty stuff….I mean we are building joy and wonder and capacity in kids.

Kelly's students exhibited tremendous "nitty-gritty" determination. In one situation, a student-team's project went awry, forcing the team to totally change course. Though they were disappointed, Kelly verbally encouraged the team.

> Why don't you guys talk about what is going to work easiest and make the changes? And then let your mentor know. That happens all the time, where, you know what, the things we are doing are actually not working so we've got to go back to the drawing board.

These students fought through the disappointment, worked diligently over the next several days, and totally reconstructed their experiment.

Another student-team struggled with how to measure their newly emerged, twisted seedlings. After collaborating with Kelly and another group in the class, they decided to use string as an intermediate, carefully converting the string lengths to accurate measurements and posting their results in a spreadsheet. To keep their mentor in the loop, they meticulously took pictures of their seed cups at every possible angle and posted them online. When they realized the weekend would prevent them from watering their plants, they discussed and conceptualized a plastic wrap tent to encircle the cups and reduce evaporation. Afterwards, they pipetted precise amounts of water into each cup with astute precision and erected the tent. When they finally left after staying late, Kelly commented, “I mean, those boys who stayed late that one hour, to make a little saran wrap tent around it, I mean they are so...they are pretty excited.”

Science in the making. At times, Kelly’s classroom seemed chaotic. The consistent droning of voices, the “pinging” of glass beakers, and the clicking of planting pots on hardtop lab tables provided background noise indicative of busyness. While some may have associated the noise with undisciplined behavior, I referred to it as “science in the making.”

As young scientists, Kelly’s students learned that things do not always go as planned. They learned to expect the unexpected. “Our water turned brown!” proclaimed one student in dismay as she saw her team’s experiment for the first time that day. Kelly smiled and responded, “So you’re surprised by what happened?” I actually think Kelly was as surprised as her students on most occasions. In one instance, she walked over to a team with newly germinated plants and gleefully proclaimed, “Oh my gosh, what’s going on? Holy Smokes!” As she continued to walk around the room, Kelly exclaimed, “I see lots of people getting some interesting results!” After a few more steps, she came to another team and shouted, “Wow! I was not expecting that!”

Maybe for the first time in their formal school experiences, students worked in situations where they and the teacher did not have the “right” answers. In addition, the right answers did not exist because the experiments were novel with many variables at work in the systems. Although the projects in Kelly’s class were not cutting edge plant science, they were cutting edge from the perspectives of students. They did not know what the results were *supposed* to be, and they were forced to grapple with ambiguity, especially when things did not go as planned. Phrases such as, “Our experiment did not turn out as we thought it would” and “How that happened, we do not know” were commonplace both in classroom discussions and in the online dialogues with scientists. “I don't think there is anybody asking a question that they necessarily know the answer to. They are surprised by some of their results,” Kelly confided.

Across the board, student-teams eagerly shared their results with scientist-mentors in the online forum, often seeking help and advice from the mentors. The team surprised about the brown water wrote, “The water in the salt water turned a gross orangish-brown color. Our tap water has a slight tint of brown…what are your thoughts?” Scientist-mentors, in this case and in many others, took the opportunity to share how unexpected results were part of the scientific process.

"Part of the fun of science is finding things you never expected to find, and that may happen," shared one scientist-mentor. Another wrote, "It's pretty common for a scientist's original prediction to not be supported by the data (that's why we need to do the experiment in the first place), and it often leads to new hypotheses or ideas." Under these circumstances, scientist-mentors encouraged student-teams to record as much data as possible related to the event. The mentor of the brown water team offered, "Don't forget to record these observations when they happen (what had mold, when, etc.). These are important data, too…" Later, the same scientist-mentor wrote, "Keep recording data. Zero growth is still a result that you will want to talk about!" Students appreciated these exchanges with their scientist-mentors, and their interest was piqued by the responses they received. The classroom and online interactions in Kelly's classroom were indicative of motivated students engaged in scientific activities.

The Focus Group

The magic of PS. As focus group discussions opened with thoughts of why PS was successful, teachers and scientists shared their perspectives on this important question. Teachers quickly pointed out how valuable the mentor component was to the success of the project. Some commented on how mentor input, particularly in the early stages of a project, helped their students develop better research questions that set the stage for better experiments. Another teacher stated that mentor feedback was much more important to students than her comments. Without a doubt, focus group teachers believed the mentor component was vital to the success of PS.

Teachers in the group underscored the significance of mentor-student communication: “Kids race to the classroom to see if their mentor posted.” “If the mentor does not talk to the team, the students feel bad. [If they do respond], the kids talk, enjoy studying.” “It is a huge deal when the students get a response.” Over the course of the PS experience, teachers claimed students began to see scientists as “cool,” shattering some entrenched stereotypes.

On more than one occasion, participants in the focus group used the term “magic” to describe PS. “There is something so unique and almost magical about the interaction of that group [scientists and students],” stated one participant. One of the PS Support Team members reiterated this sentiment later in discussions: “It seems to me, that there is, on occasion, some real magic there. And, there are some students who get very motivated about it.” A long-time PS teacher added, “I had kids who continued to pursue their question because after the time was up, they were not done.” These discussions left little doubt about the value of the mentor component to the overall PS experience. When developed and nurtured, the bond between scientist-mentors and students seemed to push students to higher levels of engagement and excitement.

It takes a scientist to make a scientist. The opportunity to have your own scientist as a mentor was a unique opportunity for students. In K-12 science, learners most often interact with their science teachers and maybe with classmates, but discussing science with “real” scientists is rare. This fact was not lost on focus group participants. One participant reflected:

> When we see these incredible comments…where else can kids get that kind of support from someone who is not their parents? By middle school and high school, that [parental interaction] diminishes. And not from their teacher, I mean, by high school, kids are looking for other kinds of mentors and significant others. But they get mentoring from a scientist. It's a legitimate interaction with another adult and it's just very, very unique and it's science-related, so that's the uniqueness.

The impact of this unique relationship was not lost on one scientist-mentor in the group who immediately responded, "That is what we have to preserve."

We got to choose the experiment. While the mentor piece was cited as a critical component of success, teachers also pointed to the ownership that students felt when engaged in PS projects. One teacher related how she always asked her classes what they liked most about PS, and they always exclaimed, "We got to choose the experiment!" Another teacher reiterated the importance of this feature by stating, "Having a class project is not as good as having students that have individual projects because they really take ownership." As the discussion continued, participants alluded to how curiosity and the students' ability to pursue questions of interest was an important feature of PS. Students, it seemed, felt they were doing more "real world" science than classroom science. The revelation was not lost on one scientist-mentor who claimed, "What I really like about the *PlantingScience* experience is they [students] are doing it to go through the project and do it for its own sake."

Real science. A senior education researcher in the group commented, “What I love about it right now is…that *PlantingScience* provides students in the classroom with a real life experience working with a real life mentor.” Several teachers in the group agreed, reporting that for perhaps the first time in a school, students felt as if their ideas were valued and appreciated by others. Teachers, in particular, felt the authenticity of the experience and the public nature of the interactions provided students with an uncommon sense of success. Teachers also liked the long-term connection that PS provided for their students. Instead of having a scientist visit for the day, students engaged in discussions with scientists over several weeks and possibly months.

It’s not all roses. Focus group participants identified lack of communication between students and mentors as a detrimental force in PS. “If the mentor does not reply, the mood is down,” a teacher reported. Teachers claimed lack of scientist-mentor input was one of the greatest amotivators for their students when doing PS. “When mentors don’t respond, kids get frustrated. Kids sometimes quit because of no mentor feedback.” Likewise, scientist-mentors expressed frustrations about “being left in the dark” when students failed to reveal enough information about the experiments.

Teachers offered several explanations why students sometimes failed to post. One teacher confided, “The kids don’t want to look stupid, and they don’t always know what to post.” Many teachers were in agreement, adding that students stumped by a mentor’s comment or suggestion “do not know how to answer posts.” In other cases, students were reluctant to share their results online because experimental results did not come out the way they anticipated. Nevertheless, another teacher commented, “The experiment may not work, but the teacher and mentor need to encourage the students to talk [online] about it."

In addition to embarrassment and lack of confidence, teachers disclosed that scheduling and lack of time in class were barriers preventing online discourse. "It can be hard to try to get the students to post...schedules get in the way…there are reasons why students do not reply to their mentor's questions." At other times, students got impatient waiting on responses. "Students want an immediate response. They don't want to wait for a few days." The asynchronous nature of the platform was not familiar to students used to real-time conversational speed. One mentor was particularly frustrated with this disclosure and retorted, "The messages are important, but students do not understand if I can't message them right away."

We learn from each other. I believe both teachers and scientists gained new insights into the difficulties they each faced when implementing PS. Oftentimes, the perspectives shared by one group enlightened members of the other group and promoted mutual understanding. For example, a simple discussion about school schedules opened the scientists' eyes to the fact that students did not always meet everyday for class and therefore were not able to check results daily. Scientists were also somewhat surprised to find out that even a 24-hour delay in response can make a huge difference in whether a student-team considers a scientist's suggestions. Classroom time restraints are a unique reality in the science teacher's everyday planning. On the contrary, these kinds of time restraints are not considered when a typical scientist develops a research schedule.

Likewise, teachers came to appreciate some of the difficulties scientist-mentors faced. Teachers were able to monitor students' progress regularly and ask questions to get clarification in real time. Scientists, on the other hand, were limited to whatever students and/or teachers posted. Important details were often left out of these postings, leaving scientist-mentors in the dark and unsure of how to advise students.

Evidences of Motivation

One of the research questions pursued in this study considered whether motivated behavior was observed in students through classroom interactions and online dialogues with scientist-mentors. While the accounts of Dan's and Kelly's classrooms and the overview of the focus group unequivocally provide evidence to answer this question affirmatively, I wish to share one particularly powerful illustration of motivation and engaged behavior.

Baird (pseudonym), a student in Kelly's classroom, introduced himself on the online portal as a 16-year-old junior. Early on, he admitted to his mentor that, "I don't know much about plants, and science is not my favorite subject." I was drawn to Baird's PS story and wondered if the PS experience worked for him since he was not "sold out" to the project from the beginning.

Baird seemed to recognize his team's ownership of the PS project. He often began his posts with the phrase, "We have decided…" This ritual suggested (not affirmed) Baird felt confident enough in his team's decision-making to assertively inform their scientist-mentor about their project and its direction. Baird's team developed a great relationship with their scientist-mentor, Mona (pseudonym), and she showed a personal interest in the team. For example, Mona posted, “I enjoyed reading your introductions” and “I see you won your first football game last week.” In response to some of Baird’s and his teammates’ negativism, Mona empathetically tried to explain the universality of scientific principles.

> I know that some of you are interested in fields that you feel may have nothing to do with science. But, being able to collect and analyze data is an important skill you can learn from projects like this and apply to many other fields.

Along their journey together, Mona valued the student-team’s questions and showed interest in partnering with them for the duration of the PS experiment. When Baird’s team posted its research question, Mona responded, “Your question is very similar to the same kinds of questions environmental science consulting firms address when they look at levels of contaminants in water or soil.” Mona was not controlling in her comments, often insinuating ownership of the project belonged to the students. “I look forward to hearing about your ideas for designing your experiment.” While explicitly understanding of their ownership, Mona was quick to offer her help. “We can then work together to flesh out your experimental design.”

Throughout the process, Baird reached out to Mona and often asked her for help. “We have decided to do intervals of 5 starting at no fertilizer and going to 25. Do you think that is an appropriate interval? Does it go high enough?” On another day, Baird posted, “My concern is that we have not imbibed our seeds until today, and we are not going to have enough time this week to observe much.” Mona provided suggestions and encouragement such as, “You are making great progress, and I will be checking back soon." In addition, Mona mentioned students by name when appropriate, writing things such as, "In regards to Baird: I would suggest recording how many seeds successfully germinated and then just determining growth rates for the individual plants. I look forward to seeing more of your results this coming week."

In spite of some apathy early on, Baird expressed excitement along the way, proudly proclaiming to the world on the online portal, "Our plants are growing really fast!" Baird also commented on other students' projects, indicating interest extending past his own student-team's project. He took interest in a team's project from another section at his school who were studying the effects of green tea on plants. Baird posted the following on their page: "Great job!!!! I think that this was a cool experiment. It's interesting to find out that green tea helped the growth." The most telling bit of evidence indicating an increase in Baird's motivation for the project was his last post. "We will be uploading our final project soon. It has been an interesting experiment. I'm sad to see this come to an end." The story of Baird and Mona is just one of many success stories associated with PS.

What Does It Mean? Interpretation Using Grounded Theory

Classroom observations and focus group discussions suggested PS was a significant experience for many students and motivated them in ways not typical of classroom science. In the 2011 *Science* article announcing *PlantingScience* as a prestigious SPORE (Science Prize for Online Resources in Education) award winner, PS program developers noted, "Talking online with a scientist is exciting and motivating to students. Teachers commonly relate that their students develop a new level of confidence and responsibility toward their experiments" (Hemingway et al., 2011, p. 1536). While evidence for motivation abounds, the question remains, "*How* does PS motivate students?"

Eisner (1985) simply defined interpretation as an effort to understand what is going on. To that end, I systematically and carefully examined the data, looking for relationships and "discerning critical elements from casual ones" (Wolcott, 1994, p. 25). What precisely occurred during a PS project to prompt a student to write, "We are all very excited" in an asynchronous post to her scientist-mentor? What caused students who were sick at home to log into personal computers and report to their teammates and mentors that, "This is the first day I have been out of bed since Monday night. I am excited to read about the progress of our plants" or "I am sick and could not make it to school but I will be on the computer at the same time you will be so you can tell me what you are doing with the plant and stuff"? These statements are powerful indicators of the magic that sometimes occurred in PS, and I began my efforts to develop a grounded theory (Strauss & Corbin, 1990) to put the pieces of the story together to explain the magic. Table 3.3 details the categories that emerged from the grounded theory analysis.

The Central Phenomenon: Student Motivation and Engagement in Science

Motivation has been defined in several different ways. For example, some claim motivation is the reason why a person chooses to behave in a certain manner (Ratelle et al., 2007). Alternatively, others view motivation as the presence of an energy or persistence driving a behavior (Ryan & Deci, 2000b). Taken altogether, these definitions

Table 3.3

Open and Axial Coding Categories With Corresponding Properties and Dimensions

Category	Properties	Dimensions
PS motivates and engages students in science	Intensity Connection to project	Low – High Superficial – Vested
Student empowerment	Ability to choose Attention to ideas Personal endorsement	Low – High Ignored – Valued Low – High
Online mentor interaction	Frequency and timing Tone and demeanor Style (subset of tone/demeanor)	Delayed/Few – Prompt/Many Controlling – Partnering Declarative – Questioning
Authenticity of experience	Context of study Collaborative opportunities	Books –Living Plants Low – High
Curricular Module	Ambiguity (# of variables) Novelty Freedom for creativity	Low – High Low – High Scripted – Open-ended
Orchestration	Expectations of actors Scheduling Experience of actors Communication between actors Scaffolding	Unclear – Clear Poor – Appropriate Novice – Experienced Low – High Poor – Adequate
Student Characteristics	Initial motivation level Inquiry experience	Low – High Novice – Experienced

imply “to be motivated means to be moved to do something. A person who feels no impetus or inspiration to act is thus characterized as unmotivated, whereas someone who is energized or activated toward an end is considered motivated” (Ryan & Deci, 2000a, p. 54).

While some may differ on their definitions of motivation, few would argue that motivated student behavior is highly desirable in school. The *Science* article, SPORE award, and popularity of the PS program at large indicate PS is a successful program. In this study, data collected from multiple sources indicate PS is successful because of its tendency to motivate and engage students. Many teachers who step out and use PS report back, “The level of engagement in the class is high. I have a few in the class that are not engaged, but it’s not for very long.” Figure 3.1 illustrates the theoretical framework I generated in this study to explain the central phenomenon of student motivation and engagement, as suggested by Strauss and Corbin (1990). Several causal conditions contributed to student motivation, and both teachers and scientist-mentors used various strategies and actions to facilitate motivation. These strategies and actions were influenced by changing contexts and intervening conditions, thereby leading to various student outcomes.

Causal Conditions Related to Student Motivation in PS

Three causal conditions influencing the phenomenon of increased student motivation were identified in this study: student empowerment, online mentor interaction, and authentic scientific experiences for students (Table 3.3; Figure 3.1).

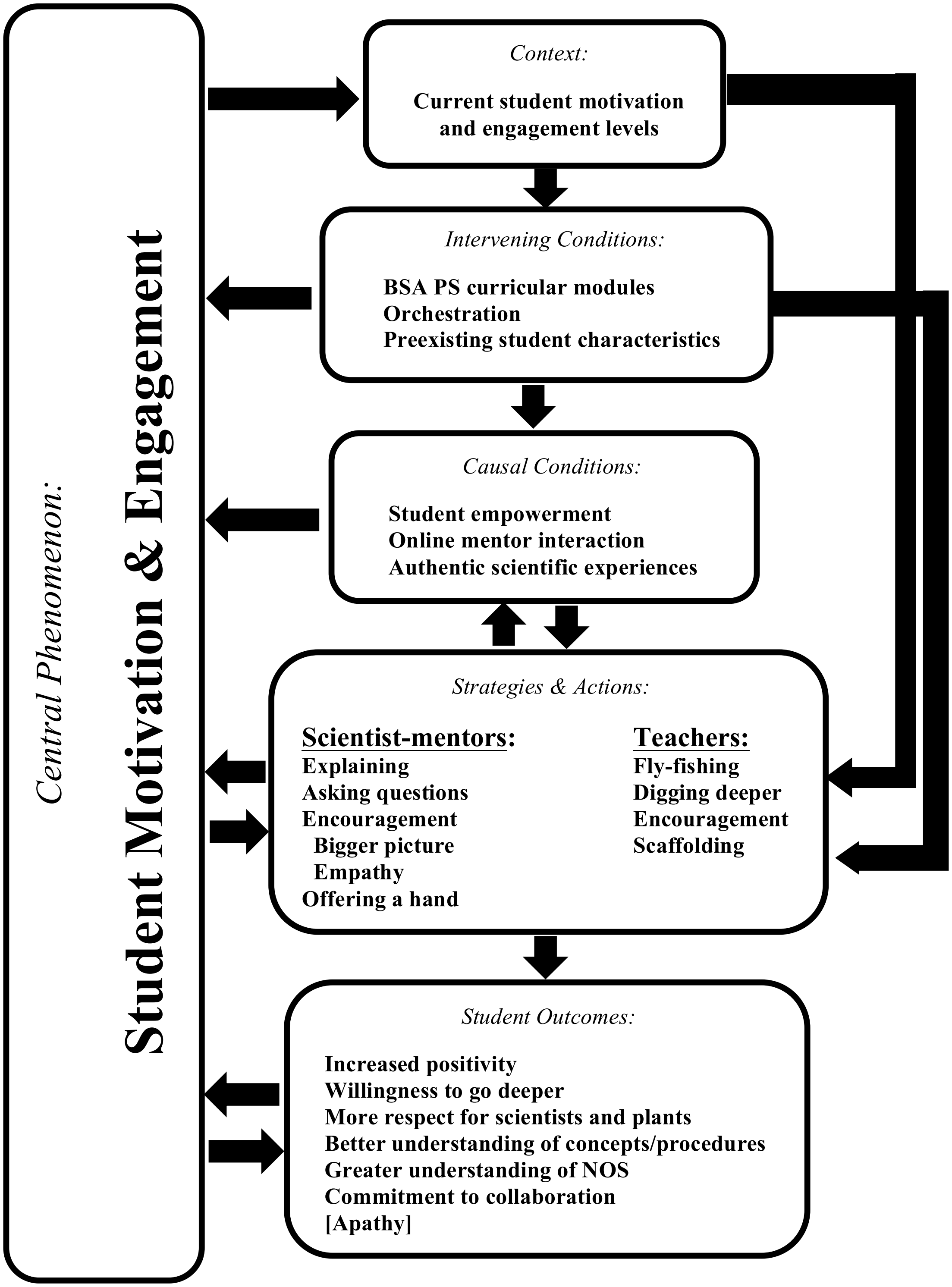


Figure 3.1. Overview of emergent categories arranged using Strauss and Corbin's (1990) paradigm model.

Student empowerment. According to focus group participants, students reveled in the ability to choose the contexts for their experiments. Students had positive attitudes and took more responsibility in taking care of their projects. Students owned the experience because they were empowered to ask questions, design experiments to answer those questions, and ultimately evaluate their own projects. One teacher excitedly announced how her students always answered her question, "What do you like most about *PlantingScience*?" with the response, "We got to choose the experiment!"

Classroom observations revealed that Dan and Kelly empowered students to follow their interests when choosing a PS project. Kelly specifically mentioned the significance of handing over control to students during a PS project. "They are empowered. Those kids are empowered. I mean those kids walked in and they had their seeds before the bell even rang. So I feel pretty good about that." Teachers like Dan and Kelly worked hard to reverse the trend of didactic teaching by empowering kids to pursue their interests.

In the online dialogues, student-teams often referred to their experiments in possessive terms, claiming this was "our experiment" and referring to scientist-mentor participation as supplemental to their own. "Thank you for mentoring us on our plant experiment. We are excited to work with you." Interestingly (and contrary to intuition), the relationships between students and scientist-mentors seemed to enhance students' feelings of ownership.

Online mentor interaction. Many academic mentoring programs provide one-time or short-term mentoring. However, PS mentors assisted students from the start of an inquiry project to its completion. The online platform offered scientists the opportunity for prolonged engagement with their mentored students, affording time to develop familiarity not only with the experiment but also with student-team members. Over time, many scientist-mentors referred to individual students by name and engaged as partners in the inquiry process.

Evidence of the motivational sway scientist-mentors had with students was tangible in many different ways. It was not uncommon to see students burst into the room before class started, boot up computers, and check for mentor feedback. If the scientist-mentor responded, students celebrated with “hallelujah” dances! Without a response, students dropped their shoulders and sighed. Some students lamented, “He didn’t respond again!” or “Our mentor doesn’t like us!” The “mentor effect” as I came to know it, signified the motivation scientist-mentors provided for student-teams through participation in the online dialogues. According to Kelly,

> It [the mentoring component] is huge. Huge. You saw those kids. Man, if their mentor doesn’t talk to them, it’s, “Our mentor doesn’t like us, they haven’t communicated with us.” The mentor thing is huge, huge, huge. They are so excited when the mentor says something to them. And you know, the level of excitement that is in the room would not be there if it was just me commenting on their experiments. In fact, they would be sabotaging their experiments. The behavior would be completely different. They [mentors] have elevated the seriousness of the experiments.

From the outset of many experiments, even unenthused students looked to their scientist-mentors for inspiration. “I’m not ready to do this project,” wrote one student, “but hopefully you can change my mind.” Another student on the same team echoed similar sentiments. “I am not looking forward to the project, but maybe you will get me excited to do it.” These comments and similar ones indicated students *expected* to be motivated by scientists. Perhaps knowing these mentors had dedicated their lives to science in one way or another made students realize there were potentially some interesting facets of science. Regardless, the data revealed mentor feedback had a strong influence on student motivation, so I began to inductively investigate the properties of scientist-mentors’ feedback to see how it affected students. The frequency and timing, tone, style, and demeanor of scientist-mentors’ responses proved important (Table 3.3).

Frequency and timing. Without question, the frequency and timing of scientist-mentors’ responses in the online dialogues were important properties. At times, students begged scientist-mentors for a response. “Will you at least give us some positive feedback…or some sign that you’re alive?” Kelly understood the importance of frequent and timely mentor feedback on her students’ motivation. “Our emphasis has been on their dialogue with the mentor…I have focused more on making sure they are communicating with their mentor. Unfortunately, some of the mentors are not communicating with them.”

When mentors’ responses were frequent and timely, student motivation skyrocketed. In Kelly’s classroom, a student logged on to the PS website and exclaimed, “Holy cow! He gave us a really long reply!” Students from other teams immediately clustered around the laptop, eager to get a view. As the student read the comments, Kelly offered encouragement. “I’m glad he replied! Yay!” When another student from the same team returned from the greenhouse and saw the crowd around his table, he asked, “Hey, what did [scientist’s name] say?” After reading the response and having some conversation with his team, he enthusiastically asked, “So, who is going to type the response? We all did it last time.” This scene illustrated the motivational value of scientist-mentors’ responses.

In like manner, students were amotivated by lack of responses or delayed responses. Some student-teams implored their scientist-mentors to “reply back to us soon!” Other teams expressed their frustrations with scientist-mentors who did not respond. A student from another school commented on one of Kelly’s student-team’s page: “Your communication with your mentor is awesome. You’re lucky to have one that is interested in your project. Very creative! Congrats to your mentor for being so involved.”

It also seemed some scientist-mentors recognized how important frequent and timely feedback was to students. For example, one scientist-mentor wrote, “I’ll make sure to check back here tonight, in case you get back right away.” When posting after a long delay, another scientist-mentor apologized to his team. “Sorry about not responding on Friday.”

Tone and demeanor. Earlier, I introduced a student-team from Dan’s class, the Fantastic Four, who felt their scientist-mentor did not understand them. Examination of the dialogues between this student-team and the scientist-mentor revealed an impatient and demanding mentor, two qualities that may have quenched student motivation. Comments such as, “Hurry up and come up with any ideas,” and “Why did you start with only six seeds? Wouldn’t it be better to have at least 10?” did not endear this mentor to his student-team. Kelly also relayed a similar experience in her class.

> One of the kids said, “Our mentor is not very nice to us.” And so I read her comments, and she is not very nice. She’s just like “Roar, roar, roar!” And I don’t want them [scientist-mentors] to be cheerleaders, but at the same time I think the kids are excited. And when they get nothing but, “Yeah, but” [from their mentors], I think it is hard for them to maintain their joy and wonder.

Authentic scientific experiences for students. PS provided students with an authentic scientific experience because students had opportunities to participate in authentic scientific tasks such as developing research questions, devising analytical methods, performing analyses, and generating conclusions (Chinn & Malhotra, 2002) using real specimens.

Use of living organisms. The authenticity associated with PS projects was a contributing factor to increased student motivation and engagement. In fact, the use of living plants in experiments was one of the most prominent contributors to authenticity for students. As mentioned previously, some students felt like they were “saving the babies” when their seeds germinated. Additionally, teachers in the focus group revealed how PS provided many students with a first-time, hands-on experience with plants. Many students did not know what plant science was before their PS experience. As students learned about plants and plant science, they often made connections between humans and plants. Students also wrote in the online dialogues about the excitement generated by the inclusion of plants. “I am sooo happy because our seed actually sprouted over the weekend…I went out into the hall and said ‘I have not failed!’”

Collaborative opportunities. The opportunities for collaboration also contributed to the authenticity of the experience for students. As Dan eloquently said, “Science is not done in a vacuum, and it’s certainly not done in secret.” Science is a collaborative endeavor (NRC, 2007), and unlike typical schoolwork, PS provided a collaborative context for scientific inquiry. Teachers in the focus group loved how PS enabled students to switch from individual activities to more collaborative and group-based scientific inquiry activities in which they communicated and exchanged ideas with other groups and with real scientists. In some cases, students got interested in other groups’ work and exchanged ideas in online discussions. Consider the following comment posted on an exemplary research project site by a student from a different school:

> I wish I would have caught on to your experiment earlier. It looks pretty awesome! I’m interesting in hearing what your results are. Just earlier today I was thinking about my own experiment and wondering if I should have used more phosphorus to stress my plants out in the “too much” group. Your experiment follows along with my thinking, only for all fertilizer and not just phosphorus….You guys have done an excellent job! I’ll be eagerly waiting for the results of your experiment. And thanks for commenting on my own team’s experiment!

Students in PS crossed classroom and school boundaries to not only communicate with scientists, but also share with other students involved in the same types of projects. In effect, they were participating in authentic scientific practices (Chinn & Malhotra, 2002) in a school classroom which led to increased engagement and motivation.

The Context Most Affecting Teachers' and Scientist-Mentors' Strategies and Actions

Context refers to the conditions within which participants take action and devise strategies (Strauss & Corbin, 1990). One of the main variables affecting teachers' and scientist-mentors' strategies was the motivational level of their students at a given time. Not only did students start PS with different levels of motivation, their motivations also fluctuated over the course of the experiment. The strategies and actions used by teachers and scientist-mentors, whether in person (i.e., teachers) or online (i.e., scientist-mentors), were dependent upon the engagement and motivation levels of their students at a given time. In other words, teachers and scientist-mentors tailored their strategies to fit the particular context. However, the end goal for both teachers and scientist-mentors was increased student engagement and motivation in the PS project.

Strategies and Actions Affecting Student Motivation and Engagement in *PlantingScience*

Teacher strategies. It is no surprise students most often turn to teachers for help in traditional school contexts (Zimmerman & Schunk, 2008). As a result, the strategies and actions teachers use to help students are of paramount importance. From a motivational standpoint, teachers can play a huge role in how students feel about school. Perhaps the pressure on teachers to motivate students has grown, particularly in light of recent research revealing that many teachers believe one of their most important jobs is to motivate students and help them become responsible for their own learning (Bryan et al., 2011). While engaged in PS, teachers used several different strategies and actions to promote student motivation and engagement in the classroom (Figure 3.1).

Fly-fishing. The pressures associated with standardized testing, for example, sometimes lead science teachers to "take control" of their classes and prepare students for upcoming tests through rote methods. Exerting greater control, however, can alienate students (Urdan & Turner, 2005). As students lose autonomy in learning, they become increasingly less confident in their abilities to do science (Schunk & Pajares, 2005), thereby explaining why motivation drops as students matriculate through grade levels. Eventually, these conditions contribute to highly controlled school environments that no longer resemble positive, motivating learning environments (Deci et al, 1991).

In contrast to controlling environments, successful PS teachers incorporated strategies of "letting go." By letting go, teachers turned the responsibility of learning over to students and allowed them to exert more independence and creativity. Kelly used the following analogy to explain what she meant by letting go.

> I kind of see it like fly-fishing. You let it out a little ways and maybe they are working on one or two parts of an inquiry. Then you pull it back in and debrief it. This [*PlantingScience*] is an example of where I have let my line out all the way, let them do what they need to do, then we will debrief it.

Similarly, Dan believed in letting students explore. He felt strongly that letting go was a necessary pedagogical strategy to develop students who were capable of going deeper in their learning.

> You have to let the kids do their thing. You have to let them pour dirt all over your floor, because that is what happens. …It's not the end of the world. But you also need to teach them that you need to be accountable for that, you need to be more careful about that so it doesn't happen more often. And then you have to let them come up with their dumb ideas and work them in to higher level thinking ideas. They are just so used to grabbing these low level thoughts and calling that education because that is what they have gotten away with for so long.

According to Dan, meaningful learning was much more important than task completion, and teaching science as a process was critical if students were to understand scientific thinking.

Digging deeper. Dan pushed students to go beyond the superficial and wrestle with larger ideas and explanations. "You need to explain why you think what is going to happen is going to happen. You need to do science." He elaborated, "I always want their questions to be higher level questions. I always want them to look more deeply than they do." Dan implemented PS to create an environment ripe for deeper engagement and less superficiality. Reflecting on this process, he mused,

> Most kids walk around with more content in their pocket than we can ever begin to teach...if you can Google it up, you don't need to memorize it...and we need to

> allow that in the way that we educate. We need to teach kids to think. And *PlantingScience* is a way of thinking, a way of doing things that allows you, forces you to think, that causes you to be creative and that sort of thing. Those are the things, the benefits that we get from *PlantingScience*.

In like manner, Kelly challenged her students, but in a slightly different way. Her style differences were more than likely the product of two factors: (1) different personality and, (2) the fact that her students were more experienced with inquiry and were further along in the inquiry cycle than Dan's. Kelly was a masterful questioner, probing students on each team to take their analysis to another level, either by going deeper in their current direction or changing directions all together.

From the beginning of PS implementation, Kelly established a culture of high expectations. She provided an immersion time before students started their experiments, effectively driving students to the literature, raising the levels of their research questions, and providing a solid foundation for subsequent research.

> I think that giving the first two to three weeks over to just letting them fish around has made all the difference in the world. At first they were coming up with real lame, basic questions, and they were not wedded to the questions. I just kept telling them, "Let's learn more about seeds and talk to your mentors." And, I gave them some articles to read about gravitropism, phototropism, showed them some examples of experiments done by Darwin where he cut off the root tip and looked at the meristem growth. So then it piqued their interest more, and they've created questions they are more committed to.

While both Dan and Kelly expected more from their students, they also provided them with the necessary support to keep students engaged and not frustrated. In their own unique ways, both teachers used encouragement to keep motivation levels high and attitudes positive.

Encouragement. Although intervening conditions will be discussed shortly, it is useful to interject that one intervening condition in particular, preexisting student characteristics, greatly influenced the specific encouragement strategies used by Dan and Kelly. Dan's freshman biology students, by his own account and my observations, were not experienced with open-ended inquiry. As a result, Dan's strategies in the classroom were somewhat different than those employed by Kelly, whose upper level high school students had more experience.

Dan did not employ a "rah, rah" cheerleader-type of encouragement. Instead, he confidently challenged students to step up to new levels of responsibility and learning.

> I told them [students] very specifically at the outset [of the PS unit], "Now we are going to diverge, and we are going to be doing two things at one time. So we're essentially doing what the other classes are doing [i.e., the standardized curriculum], but we are also doing this experiment. So that is going to be challenging for you all, but I think you are up to that challenge, and I think you will get it."

As mentioned previously, this was difficult for many students, and Dan constantly reminded them to be independent and quit using him as their primary source of information. Basically, Dan used a "heavy-handed independence" style of encouragement. While he certainly did not dictate to students what to do and how to do it, he was demanding and persistent with his explicit reminders to “do science.”

In contrast, Kelly used more traditional strategies of encouragement including positive reinforcement. Her students had enough experience with inquiry to be somewhat comfortable with the ambiguity, and they often needed just a positive comment to keep them going. Kelly did not use many heavy-handed independence tactics to push her students, an observation in stark contrast to Dan’s classroom.

Scaffolding. Scaffolding is the term describing the assistance provided to learners by teachers as learners perform difficult tasks. Scaffolding helps students reach above their current proficiency level, but it is not a "permanent structure" within a learning environment. Instead, scaffolds are reduced over time to enable students to eventually learn and do things on their own (NRC, 2007). Effective scaffolding, therefore, is appropriate when it matches a learner’s current level of expertise. In novel and/or complex environments such as PS, scaffolding is particularly important.

According to focus group teachers, scaffolding was necessary for effective PS implementation. New inquiry learners required more scaffolding, and the added complexity of online communication with scientists made the PS environment particularly challenging. One teacher commented, “The PS site is both novel and complex. Not only are students doing rigorous science, but they are also communicating with a new person. I do scaffolding so that the environment is not as novel or complex for my students.” Another teacher added, “For PS to work, scaffolding is critical. If students get frustrated, it is over.” Obviously, teachers employed scaffolding in an effort to keep students engaged and motivated while participating in all of the nuances of PS.

Specific scaffolding strategies varied by teacher. One teacher related, "Scaffolding can vary depending on the type of questions that are being asked. You make assumptions about what the students know and what they may not know." These assumptions are dependent upon teachers' knowledge of students' preexisting characteristics and how students are progressing through the inquiry cycle.

Kelly was great at scaffolding, always asking the right question at the right time. She also provided students with early supports for using the PS platform by incorporating innovative activities such as an online scavenger hunt.

> I had students conduct a scavenger hunt that was very successful. I had them look at the STAR [exemplary] projects and identify the dependent and independent variables, for example. Tell your students to familiarize themselves with other projects. Tell them to go see other projects.

From all accounts, students became more independent in their learning over time through scaffolding efforts. This trend was reiterated by focus group teachers who shared how familiarity with the PS program reduced the complexity and increased the engagement of students over time. "When they do two grade-level projects in a row, there is an increase in their ability to do the experiments and use the platform," one teacher commented.

Mentor strategies. Without question, scientist-mentors are an integral and important part of the unique PS program. According to Ensher et al. (2003), good mentors provide informational support, encouragement, and positive examples for mentees. In addition, mentors empower mentees to become self-sufficient through scaffolding. Ensher et al. (2003) also reported online mentoring provides additional benefits beyond traditional face-to-face interactions. For example, when online mentors communicate asynchronously through the Internet, limitations such as geography and time are neutralized.

Many scientist-mentors involved in PS may have been unaware of their specific contributions to student motivation. However, several strategies were discovered that seemed to facilitate greater student motivation and engagement (Figure 3.1).

Explaining complex concepts. Previous research involving the 17 exemplary scientist-mentor and student dialogues divulged that scientist-mentors explained and provided examples to students more often than they acted as authorities, confirmed student ideas, shared their own experiences, or offered advice (Scogin, Stuessy, et al., 2013). Explanations varied, but scientist-mentors often used their time online to explain scientific processes and procedures to students.

> By four pots I mean 2 that have soil with barley seeds planted in them and 2 that [have] sand with barley seeds. This is what we call replicates. We replicate each treatment so we can determine whether or not our results are applicable in general. If we only had one pot of each treatment and something really weird happened like all the plants died or they never germinate, we wouldn't have another one just like it to look at and figure out if what happened is normal [or] if there was something weird going on with those particular seeds or soil. Replicates make your results more reliable.

In some situations, scientist-mentors were unsure how to follow up after students' posts. For example, a focus group scientist-mentor relayed an experience when a student-team made the improper observation about seedlings growing faster when under stress. The scientist-mentor was in a quandary deciding whether to introduce the topic of stress: Were the students ready for that information? Had students covered the topic of stress in plants before? In these situations, the limitations of the online-only connection between scientists and the classroom were evident. As one teacher realized, "It must be difficult for the mentors to have disembodied information from the students and [not know the source of] some of the questions that students ask." Nevertheless, scientist-mentors attempted to explain concepts regularly to their student-teams.

Asking questions. Many scientist-mentors chose to engage students with questions instead of directives. Questions can be less threatening than direct comments, particularly when other social indicators such as body language and voice inflection are missing (like in asynchronous online textual dialogues). Questions such as, "What kind of data will you collect to determine which grows better?" and "What else do you think about this experimental design?," did not infringe on student autonomy. In addition, questions required students to think carefully about their experiments and results.

In one dialogue, a scientist-mentor, perhaps sensing students lacked relevant background knowledge, asked a provoking question to persuade students to think carefully about their interpretations of an outcome from their experiment. "Sugar is a good source of energy, but what do boron and calcium provide to the pollen tube? How do they help the pollen tube to grow, or do they?" In this example, the scientist-mentor used a questioning strategy to provide some additional information but simultaneously challenged students to seek more information on their own.

Encouraging students. Scientist-mentors also encouraged students often in the online dialogues. Exemplary project scientist-mentors frequently made comments such as, "I can't wait to see what happens," and "I look forward to seeing what you find out." General encouragement was common, but scientist-mentors sometimes used more explicit strategies of encouragement, usually in response to students' apathetic comments.

Look at the bigger picture. When students posted disparaging comments, many scientist-mentors responded by providing connections between the science going on in the PS project with scientific endeavors occurring in the real world. For example, students on the Kitty Kats (pseudonym) student-team in Dan's class wrote, "Personally I'm not a fan of science" and "I personally don't like science. Science is kind of hard for me." In response, their scientist-mentor offered a greater vision of scientific discovery and also outlined the historical and contemporary contributions of plants to the world.

> Just imagine all the questions you can ask and answer with science! And plants, oh the plants, they are so amazing! We wouldn't be here without them! Early in our world's history, small plants in the ocean converted carbon dioxide to oxygen, drastically changing the atmosphere and allowing animals to live and breathe. They are still today essential in converting carbon dioxide to oxygen, and without them we would all suffocate!...Besides just breathing, we depend on them for food and purifying our water….Take a minute and think about how

> many different plants you eat everyday. Of course there are fruits, vegetables, but anything you eat with wheat, or corn is also made from plants! Even the meat you eat (if you eat meat) depends on plants!...So, plants in a word, are awesome. Do you believe me yet? I can go on and on if you are interested ;).

Instead of berating the students for their short-sightedness and apathy, this scientist-mentor tried to connect them to a bigger picture and see the relevance of plants and plant science.

In other cases, scientist-mentors expanded students' perspectives by making connections between what the students were doing in the classroom and what scientist were doing in the field. For example, one exemplary scientist-mentor explained to his student-team, "I am a plant ecologist with a big interest in the effects of herbivores on plants, and your approach is very interesting to me because there are often times that herbivores can promote seed germination by munching through the seed coat." Through this simple communication, the scientist was able to express how the students' approach was similar to what she was doing as a professional scientist, thereby connecting students' perspectives with a bigger picture.

Showing empathy toward learners. In addition to painting a bigger picture, scientist-mentors also expressed empathy for students who disliked science. In response to derogatory remarks about science from his assigned student-team, a mentor posted, "I'm sorry to hear you ladies aren't excited about science, but I understand. I know it can be hard and frustrating, but it can also be really fun."

In another case, a student-team was unable to form a research question and posted their frustrations. Their scientist-mentor empathetically stated, “I know that getting started on a research project is the hardest part.” In a different dialogue, a student-team expressed annoyance regarding the unexpected demise of their fledgling plants. Instead of pointing out what they could have done better to keep the plants alive, the scientist-mentor responded with a gentle, “I am disappointed too, for you, but I am glad that you are carrying on!” Other scientist-mentors acknowledged difficulties with statements such as, “Science is always a challenge (even a small experiment)” and, “[Software program] is not easy to learn!” In most cases, scientist-mentors combated student-team frustrations with empathy and understanding as opposed to disgust and/or condemnation.

Offering a hand. Few curricular programs offer K-12 students the opportunity to engage in regular and poignant conversations with professional scientists. These open and unique relationships do not form by happenstance, however. Scientist-mentors must be intentional and explicit in their efforts to build partnerships with their student-teams through the online portal. The online dialogues revealed several examples of scientist-mentors extending their digital hands to students in partnership.

“I hope we will enjoy this together,” wrote one scientist-mentor from Dan’s class. When student-teams invariably came up against challenges, scientist-mentors emphasized how they were partners in the process and would help the team get through the difficulty. “Together we can determine whether the problem of drying out of plants is a general problem or not, and just how to proceed to deal with it," explained one scientist-mentor.

When the inquiry project was drawing to a close, many scientist-mentors offered general statements about how much they enjoyed the experience of working together with student-teams: "I really enjoyed working with you, and wish you both the best of luck finishing the school year." "It has been my pleasure working with all of you…Good luck in your future scientific endeavors!" All of these statements served as positive reflections of the relationships forged over several weeks of scientific partnership.

Student Outcomes As a Result of Teacher and Scientist-Mentor Strategies

Teachers and scientist-mentors used many applicable and diverse strategies and actions while doing PS. Think back to the examples of students who were not motivated about science at the beginning of their PS projects. When students struggled, scientist-mentors explained, asked questions, encouraged, and offered a helping hand. Teachers provided more freedom, challenged students to go deeper, scaffolded, and encouraged. Student-teams' responses to these actions and strategies were deemed student outcomes according to Strauss and Corbin's (1990) paradigm model (Figure 3.1). The student outcomes as a result of PS participation formed a critical part of the grounded theory generated in this study.

Sometimes, the actions and strategies of teachers and scientist-mentors made a difference in students' motivation. For example, three weeks after their scientist-mentor made an empathetic post and tried to connect their work to a bigger picture, the Kitty Kats shared their changes in their experiment. "We changed our research question and our research prediction. We decided to change it because of your [mentor's] comments. We thought that we should change it after talking to you and our teacher." In other words, the efforts of Dan and their scientist-mentor ultimately had an impact on how these students approached their project. The input of the scientist-mentor and teacher prompted students to put in extra effort to improve their project. This is only one general example of how the strategies and actions of teachers and scientist-mentors made a difference in student outcomes, but several additional student outcomes were uncovered including: (1) increased positivity, (2) willingness to take projects deeper, (3) more respect for scientists and plants, (4) better understanding of scientific concepts and procedures, (5) greater understanding of the nature of science (NOS), (6) commitment to collaboration and, unfortunately, (7) apathy toward science.

Increased positivity. Baird's journey exemplified how a student can become more positive after engaging in a PS project. Also, the Kitty Kats from Dan's class exemplified increased positivity when they ended their online dialogue with, "Our experiment has ended, but it turned out very exciting." The "saving our babies" team in Kelly's class also expressed increased excitement as a result of participating in PS.

Moreover, students often posted positively in response to mentor feedback. Many thanked their scientist-mentors with simple expressions like, "It was good to hear back from you. Thank you for giving us good advice." Others expressed positive thoughts about the feedback itself. "I think that sounds like a good idea. I like it." Some student-teams used more affective expression than others when thanking scientists. One student-team in Kelly's class was especially affectionate toward their scientist-mentor, posting

“Thanks for complimenting our photos and giving us some suggestions…We greatly appreciate it! And we will also take you up on those suggestions to better our data. Thanks again [scientist-mentor’s name], you are so inspiring…;).”

Willingness to go deeper. Dan spoke frequently about using PS as a way to motivate students to go deeper in research and knowledge-seeking. It was evident many student-teams went above and beyond basic engagement during their PS projects. For example, one student-team was surprised to find that green tea extract helped their plants grow faster. When asked by their scientist-mentor why they felt this was occurring, they responded, “Antioxidants could have been a factor helping the green tea [treatment]. Antioxidants help plants protect themselves from stress from intense sunlight and growing in harsh conditions.” These students had completed outside research to come to this conclusion, indicating a willingness to go deeper.

Students were also willing to use new equipment to answer their research questions. One student-team had a long conversation with Kelly about how to measure the rhizoids of their tiny plants without damaging them. Ultimately, with direction from Kelly, they decided to use a special software program to analyze pictures of the plants and determine lengths of the rhizoids in an unobtrusive fashion. They gleefully reported to their scientist-mentor, “We are planning on taking pictures of the seeds, then with a certain software we have we will be able to measure the length of the rhizoids.”

Through collaboration, another student-team in the class adopted this method and reported to their scientist-mentor:

> We will be using Logger Pro and a camera to show the growth and direction of the seeds. By using a ruler in the pictures, we think we can scale it in the computer program so that we can see even the smallest change in the direction and growth. Logger Pro will also help us make graphs that show our data clearly. Please comment back and tell us what you think!

The willingness of these students to learn a new software program signified their willingness to go deeper. The excitement with which they shared these ideas with their scientist-mentors was also indicative of the motivation and buy-in they had for their respective PS projects.

A final piece of evidence indicative of deeper engagement on the part of students was how willing students were to question their procedures and collaborate within their student-teams and with their scientist-mentors on ways to improve the process. Students were extremely conscious of their work, often going to painstaking lengths to insure consistency and accuracy in both the care of the plants and in data collection. Instead of blowing through the procedures and having a “whatever” attitude, many student-teams systematically identified potential problems and were willing to redo things when necessary. For example, after imbibing seeds for almost half of a class period, one team member spontaneously threw up his hands and shouted, “We should have measured them before putting them in water!” After a quick collaboration, the team agreed to start over with new seeds, this time making sure to mass the seeds before starting imbibition. Similarly, other students were willing to go the extra mile during the PS project, often coming in outside of their normal class hours to check results and take care of their plants.

More respect for scientists and plants. Good communication between scientist-mentors and student-teams helped students realize scientists were "real people with real jobs." Teachers reported students saw scientists as “cool” after a PS project. Also, several teachers remarked how PS changed learners’ attitudes about plants. Instead of “boring,” students came to view plants as “neat” and interesting.

Better understanding of scientific concepts and procedures. In most cases, student-teams were eager for scientist-mentors’ help, whether it was related to content questions or procedural issues. General questions like, “Should we limit ourselves to two different seeds, or should we try to experiment with more than that? How many would you recommend?” and, “Do you have any suggestions for us this far?” were common. Students also looked for support on more specific questions. “Do you think that they need more sunlight because they were slightly covered with the paper towel while in the dish? We don’t know what to do…”

In many instances, students acknowledged that scientists’ explanations helped them understand concepts and scientific procedures better. Common student feedback included comments like, “I learned a lot from your comments and will be sure to take the advice and the things I have learned into account in future experiments” and, “Your knowledge is a gift, and it was so helpful.”

Greater understanding of NOS. Students also became familiar with the culture of authentic science through their participation in PS. Feedback emphasizing the nature of science was commonly provided by scientist-mentors in the online dialogues. Learning about NOS issues was new for many students. One teacher expressed, “In class they [students] do not get what science is. PS provides opportunities for them.” Another focus group participant echoed the sentiment that PS offered more real-world experience than what students normally got in the science classroom. Although students were taught science process skills and scientific methods at school, PS gave them real variables within the context of scientific inquiry and allowed them to have conversations with scientists about their authentic projects.

Dan emphatically heralded the way PS provided relevant experiences to supplement book knowledge.

> I like the fact we were able to take this experiment that we are doing and relate it back to what we studied. To remember that the scientific method that we studied first talks about observing, questioning, creating a hypothesis, then doing the experiment. So here are these steps that we just did in real life, based on what we were talking about. And this is one way we do science. Trying to directly connect what we are doing with the fact that science is a way of knowing, science is a collaborative effort. We are collaborating with scientists, we are showing our work to the world.

Commitment to collaboration. Dan offered an insightful reflection on the value of teaching students about collaboration. “Science is not done in a vacuum, and it’s certainly not done in secret,” he mused after a day of PS activities. “Talk to the class about it [PS project]. Talk to the world about it!” he constantly encouraged his students.

Other teachers agreed that students needed to participate productively in science through collaboration, and, by all indications, students enjoyed doing so through their participation in PS.

I was especially impressed with how Kelly's students showed genuine interest in other student-teams' projects. One particularly novel project in her class was an investigation of the effects of motion on seed germination rates and subsequent seedling growth. Students in other sections who saw the project began to actively communicate with this group via the asynchronous portal. One student posted, "I'm excited to find out why that is doing that [beans are losing mass]."

Kelly's students consistently cross-pollinated other online dialogues with relevant observations and questions. In most cases, it was evident students had taken time to familiarize themselves with the project before posting. Comments included, "You have good questions. I think the most interesting question is if seeds can still be planted and grown after they have been cooked." Other students asked questions, such as, "What kind of seeds do you think you could use? Would anything depend on the size of the seed?" and "Saran wrap was probably the best way to go. Great job! Looking forward to your results (:."

Apathy. Although PS was and is an overtly successful program that has been called many superlatives such as "magical," it is not a cure-all for student apathy. On occasion, in spite of the best strategies and efforts of PS curriculum developers, teachers, and scientist-mentors, students responded apathetically to the program.

For some of the learners in Dan’s classroom, the novelty of the project and the fact that it required a lot of independent action was too much to handle. Some of these students apathetically crawled along, constantly needing Dan’s prodding verbiage to get anything accomplished. These students included one girl who constantly complained and sat in her chair with her hoodie pulled over her head. Another was a boy who sat at the back of the room, directly in front of the observation video camera. He had to be awakened multiple times by his tablemates who enthusiastically kicked the table leg to disrupt his restful slumber.

One entire student-team in Dan’s class never really engaged in their project. They introduced themselves to their scientist-mentor and began as any other team with their projects. Their scientist-mentor was responsive, consistently posting appropriately and trying to generate some enthusiasm. Dan even posted in the online forum, which was very uncommon. He wrote, “You are currently way behind…you need to show the world what’s up.” Instead, this student-team never posted again, leaving their scientist-mentor to write, “I haven’t heard from you in a while, and I’m interested in knowing how your work is going.”

It is interesting to note that halfway through the project, this student-team posted, “Our Canadian thistle hasn’t sprouted yet, there is something wrong.” The next day, they followed with, “The Canadian thistle still hasn’t sprouted, even though the book said it would in two days. We even put more in a Petri dish and they didn’t sprout either. We did some research and found out that they had been heat treated.” While it is beyond the scope of this study to ascertain what happened to this team, it stands to reason that they may have lost their motivation due to their plant's failed germination. As I discussed in previous parts of this manuscript, working with live plants motivated students, and the inability to successfully germinate a living plant may be demotivating. Without a plant, the students had nothing to share with their mentor.

While these examples show PS is not perfect, I think it is appropriate to mention that in spite of these shortcomings, I witnessed a palpable difference in classroom climate when students worked on PS versus when they worked on other assignments. As mentioned previously, both Dan and Kelly used other activities at times to "keep up with the standardized curriculum." When students were involved in these activities, conversations were more disparate, off-task behavior was more common, and student attention waned noticeably more than when students engaged in PS work.

Intervening Conditions Influencing Teacher and Scientist-Mentor Engagement Strategies

Strauss and Corbin (1990) defined intervening conditions as "structural conditions bearing on action/interactional strategies that pertain to a phenomenon" (p. 96). Three intervening conditions emerged in this study that affected the strategies used by teachers and scientist-mentors. These intervening conditions included the curricular module, orchestration of the learning environment, and preexisting student characteristics.

Curricular modules. PS curricular modules included the content and formed the basic structure of the botanical investigations. According to focus group teachers, well-constructed modules provided scaffolding for learners, direction for the teacher, and opportunities for the involvement of scientist-mentors. Successful modules, according to the focus group, allowed for maximum student creativity through open-ended inquiry. A successful module combined novelty, discrepant events, and multiple variables in such a way that students could “muck around” to learn how the variables affected each other.

Both Kelly’s and Dan’s students were involved in *The Wonder of Seeds* germination module. Focus group participants noted how this module, in particular, met all of the necessary criteria for good inquiry. As a result, the module was a positive intervening condition in both sets of classroom observations performed in this study. Under differing circumstances, however, a module allowing less freedom or opportunities for students and scientists to communicate might contribute negatively to student motivation.

Orchestration. While orchestration traditionally refers to the role of the classroom teacher in managing the science-learning environment (e.g., see NRC, 2007; Michaels, Shouse, & Schweingruber, 2008), the complexity of blended environments such as PS requires orchestration be shared amongst all participants. Focus group participants agreed that orchestration of the complex learning environment was an important condition related to the success of PS. Orchestration was easier when participants understood their roles, established clear channels of communication, and developed their own strategies for managing time. In contrast, breakdowns in communication and unclear expectations severely limited the effectiveness of PS and led to problems with teachers letting go and scientists having the opportunity and the foreknowledge to effectively mentor students. Consequently, student motivation suffered when orchestration weakened.

One of the most obvious ways Dan and Kelly orchestrated the PS project was by providing time on the computers for students to communicate with scientist-mentors. Both teachers were explicit in their instructions to keep scientist-mentors in the loop. Both classrooms had access to technology through laptops brought into the classroom on mobile carts or by hand. Keeping open lines of communication with scientists was an obvious priority for both teachers.

Focus group teachers echoed the importance of orchestrating time and opportunity for students to communicate with scientists. One teacher said her role was “to encourage kids to interact with their mentors.” Another teacher stated, “I try to basically reinforce the idea that the mentor is the expert.” Another explained how she often gave students explicit directions to “complete their posters and speak to the mentor and post in their journal.” When all parties recognized the “need for deeper communication all around” and took steps to keep communication open and consistent, students seemed more engaged in the PS projects.

Successful orchestration was also dependent on experience. For some teachers, particularly those who micromanage student behavior, PS is not a good fit. Even Kelly admitted having trouble adjusting in her early years of PS implementation. “You have to lower your expectations on control and management because this goes on longer than any other inquiry I have done with my students…I now view that as a positive, but I didn’t the first year.”

In general, PS seemed far less complex as participants became more familiar with the program. For teachers who chose to persevere, orchestration became simpler as they discovered and developed new strategies to reduce the overall complexity of the innovative PS learning environment. One teacher admitted, “It was difficult for my first classes, but I have persisted and it has gotten better.”

The same can be said of the relationship between scientist-mentors and PS. Although mentors never physically entered the classroom, complexity decreased for them over time. Orchestration became simpler when they developed their own strategies and game plans to communicate with and support students through the online portal.

Student characteristics. Two preexisting qualities of students served as intervening conditions affecting how teachers and scientist-mentors interacted with students and how students engaged in the PS project. The first was student experience with inquiry in general and perhaps PS in particular. When focus group teachers discussed this factor, they agreed that more experience typically associated with greater engagement and motivation. One veteran teacher shared, “When they do two grade-level projects in a row, there is an increase in their ability to do the experiments and use the platform.” These teachers also discussed how students built on previous year’s studies to create even better projects. “Students who talk to each other from year to year or repeat PS during the same school year increase project quality.” However, teachers were quick to point out that just because students were new to the project did not mean they could not produce quality projects and be excited about PS. “There is a steep learning curve, but you know when they get it,” offered one teacher.

The second property of preexisting student characteristics affecting strategies and engagement was students' motivation level at the beginning of the project. When students were apathetic in the beginning, as evidenced by comments such as, "Botany isn't my favorite subject in school," and "Science is not my strongest class," teachers and scientist-mentors used different strategies than when the students came into the project motivated and excited. For example, scientist-mentors facing apathetic students used strategies of encouragement such as looking at the bigger picture and empathy (Figure 3.1). Contrarily, when dealing with students who "love plants and am very excited to do this project!" scientist-mentors were more likely to ask questions and offer their partnership.

Lots of Moving Pieces

PS is a complex learning environment composed of sophisticated cogs that intricately fit together to form a complex system that, in the best cases, leads to student motivation and engagement (Figure 3.1). While several causal conditions were identified, they were not independent components. To the contrary, the causal conditions were influenced by the strategies and actions of teachers and scientist-mentors. The strategies and actions of teachers and scientist-mentors depended upon intervening conditions that were affected by context. Moreover, all components had properties and dimensions that changed in real-time and consequently affected all other variables in a slightly different way (Table 3.3). Nevertheless, the grounded theory outlined in this study provided a robust understanding of why PS was successful in many cases.

However, further insight was sought through evaluation of PS using a well-developed theory of motivation.

Putting the Pieces Together: Evaluating PS With Self-Determination Theory

Motivation should be an important consideration for the development and delivery of science instruction because evidence suggests a relationship between student motivation and better academic performance (Lepper, Iyengar, & Corpus, 2005; Pintrich & De Groot, 1990), increased conceptual learning and enhanced memory (Grolnick & Ryan, 1987), greater enjoyment of school (Ryan & Connell, 1989), and reduced anxiety (Deci et al., 1994; Deci et al., 1991). Systematically evaluating motivation allows researchers to study motivational supports and develop ways to enhance the motivational conduciveness of learning environments. By filtering the grounded theory developed in this study through SDT, the explanatory power of the model explaining PS's success is increased, and the specific factors contributing to student motivation can be seen in light of their contribution to students' motivational resources (i.e., autonomy, competence, and relatedness).

However, I must note that some students' motivation for engaging in PS may be intrinsic in nature. Intrinsically motivated people engage in a given behavior or activity strictly for the satisfaction or pleasure of the behavior or activity itself (Deci et al., 1991; Ratelle et al., 2007; Ryan & Deci, 2000a). In these situations, people may participate in an activity or behavior even in the absence of autonomy, competence, or relatedness supports (Deci & Ryan, 2000). I mention intrinsic motivation because many teachers reported students were engaged by the novelty and intrigue of working with live plants.

Since novelty usually wears off quickly (Ryan & Deci, 2000b), it is unlikely students sustained their motivation based strictly on the novelty of working with plants. However, the possibility exists that some students liked PS for reasons other than how it supported their psychological needs of autonomy, competence, and relatedness.

In this evaluation stage using Eisner's (1985) model, the strengths, weaknesses, opportunities, and threats to student motivation were evaluated using a deductive coding approach (Miles et al., 2014). I used the preexisting codes of autonomy, competence, and relatedness to analyze the data streams and determine how the various factors associated with PS contributed to students' motivational resources. Internal factors were defined as those inherent in the structure of the PS program such as curricular modules, the online portal, etc. External factors were defined as the variables outside of the PS program's immediate control such as teachers' and scientist-mentors' strategies. Results are reported using a SWOT analysis format (Helms & Nixon, 2010).

Strengths and weaknesses were internal factors either contributing to or detracting from the support of students' psychological needs according to principles of SDT. Each basic psychological need (i.e., autonomy, competence, relatedness) was considered separately.

Autonomy

Strengths. According to SDT, nothing promotes motivation like autonomy (Deci & Ryan, 2000). Focus group participants reported how students' attitudes about their projects improved and their sense of responsibility increased through PS participation. Evaluation uncovered many autonomy-supporting strengths of the PS program (Table

3.4).

Students owned the experience because they were empowered to ask questions, design experiments to answer those questions, and ultimately evaluate their own projects. The opportunity to do so was, in part, from the open-endedness of most PS curricular modules. The sense of freedom and empowerment satisfied the basic psychological need of autonomy. From an SDT perspective, there is little wonder that *Student Empowerment* was identified as one of the causal conditions leading to student motivation (Figure 3.1).

Students' responses to autonomy in a science class are not surprising because even professional scientists are influenced by autonomy. Many scientists choose to pursue questions of their own choosing. The autonomy scientific pursuit provides can be invigorating, and PS has managed to capture a little magic for students. Students engaged in tasks that were new and exciting from their perspectives, pursued answers to questions of their own making, and had the full partnership of professional scientists. Few science classroom activities provide the amount of autonomy students feel when engaged in authentic experiences like PS.

Another autonomy-supportive strength of PS was related to online interactions. *Online Mentor Interaction* was identified in the grounded theory as a causal condition (Figure 3.1). *Online Mentor Interaction* obviously had a strong connection to relatedness, but the online part related directly to autonomy. Scientist-mentors communicated with students strictly through the online portal, and research suggests this type of interaction can be supportive of student autonomy because students are less

Table 3.4

Results of SWOT Analysis

	Basic Psychological Needs		
	Autonomy	Competence	Relatedness
Strengths	• Most modules open-ended and provide student choice • Students empowered to own projects • Students experiencing authentic scientific pursuit • Online interaction with scientists can be less intimidating for students	• Students develop sense of success • Most modules provide ideal challenge • Posting requires metacognitive thinking before responding	• Students working in collaborative groups • Students partnering with scientists • Public sharing of student work on website
Weaknesses	• Some modules are less open-ended, providing reduced student choice	• Online communication can be intimidating • Some modules have complicated setups and difficult analytical procedures	• Some students unable to get accurate perceptions of online scientist-mentors
Opportunities	• Teachers relinquishing control and giving responsibility to students (fly-fishing) • Teachers valuing student ideas • Scientist-mentors partnering with students in autonomy-supportive manner	• Teachers challenging and scaffolding students • Scientist-mentors explaining and asking questions • Teachers and scientist-mentors giving positive reinforcements to students	• Teachers willing to start programs like PS • Teachers promoting collaboration • Scientist-mentors acting as significant others who foster internalization
Threats	• Teachers and/or scientist-mentors exerting too much control over students	• Teacher and/or scientist-mentors “talking over heads” of students • Student misconceptions about “failure”	• Communication breakdowns on the part of students, teachers, and/or scientist-mentors

likely to be intimidated by “experts” in online communication as opposed to face-to-face (Ensher et al., 2003). In the PS program, this fact could play a key role in students’ willingness to share openly with scientists. If scientists were present in the classrooms, students may be less engaging and conversant because they feel threatened or intimidated by scientists’ physical presence.

In addition to physical absence, scientists do not participate in disciplinary correction and grading, two activities known to suppress feelings of autonomy (Deci et al., 1996). The roles of teachers and scientists may therefore be separate in the minds of students, a phenomenon allowing scientists to provide autonomy support for students in atypical ways.

Weaknesses. Few things about the internal workings of PS infringed on student autonomy. Most threats to autonomy were external factors and will be discussed in a forthcoming section. However, one factor mentioned by focus group participants as somewhat threatening to autonomy was how certain curricular modules provided less freedom for students to choose their own experimental path. Students were not as motivated when modules followed a more traditional, structured activity format. Since both Dan and Kelly’s students used an autonomy-supporting module, *The Wonder of Seeds*, I did not observe this weakness in classroom observations.

Competence

Strengths. According to SDT, participating in an activity with confidence supports competence and fosters motivation. Urdan and Turner (2005) wrote, “Students are more likely to engage in and persist in an activity, and they exert more effort during the activity, when they believe they are able to succeed at the activity" (p. 301). In PS classrooms, learners gained competence over time, in part because of the accomplishment they felt from being successful "scientists." A focus group teacher shared her personal evolutionary experience of watching a classroom of timid, unsure students transform into confident and excited learners. I also witnessed increasing competence in Dan and Kelly's students.

In addition to feelings of success, PS challenged students with its content and process requirements. Plant science is often left out of state curriculums, so many students do not have experiences working with living plants or direct knowledge about plants. For the most part, focus group teachers believed PS modules provided enough novelty and complexity to challenge students, yet were not so complicated that students got overwhelmed. Challenges that do not overwhelm support competence (Reeve, 2002).

One final way PS supported student competence was by requiring students to consider online feedback carefully before responding through the asynchronous portal. Because students were required to read scientist-mentor comments before responding, most underwent a metacognitive process requiring them to reflect and revise their thinking before typing. According to Garrison (2011), this step is a unique feature of online asynchronous learning environments and promotes competence in students.

Weaknesses. The student-team mentioned earlier, the Fantastic Four, was a team who felt inadequate at times during PS. Their comments during class like, "We don't want to look stupid," were indicative of a group who may have been intimidated by communicating with a scientist online. While some students see this arrangement as autonomy-supportive (Table 3.4), others can be intimidated by a professional reading their comments. Teachers from the focus group verified that many students were sometimes afraid to post because they thought their responses might reflect poorly on them.

Another potential weakness relative to competence was the claim by some teachers that certain PS modules required students to use complicated setup and analytical procedures. Under these conditions, students sometimes got overwhelmed, lost motivation, and quit. I did not observe this particular challenge with students engaged in *The Wonder of Seeds* module, but upon inspection of other modules, *The Wonder of Seeds* did appear to be one of the least setup-intensive modules offered by PS.

Relatedness

Strengths. Students enjoy working in groups (Patrick & Middleton, 2002), and PS allowed students to work in collaborative groups as they engaged in authentic science learning in the classroom. Students were not limited to interaction inside the classroom, however, because the online portal connected them to scientists working all over the world. Most students were excited about communicating with a mentor, and they relished the opportunity to connect with "scientist celebrities."

Evaluating from a SDT perspective, the feelings of inclusiveness fostered by PS helped explain its power to motivate and engage students. "Human beings are fundamentally and pervasively motivated by a need to belong…" (Baumeister & Leary, 1995, p. 522). PS opened doors for multiple opportunities to interact both in the classroom and through the Internet, therefore fully supporting student needs of relatedness.

Students also enjoyed connecting with others through the public website. Focus group teachers reported how much students loved to see their projects online and expressed excitement about “going public” with their experiments. While visiting Kelly’s classroom, I witnessed boosted morale when two of her teams were featured in the exemplary (STAR) section of the PS website. When the student-teams heard they were featured, they immediately went to the PS website to see their pictures and project. These students were visibly excited by this unique taste of participative science.

Weaknesses. While the text-only asynchronous communication associated with PS was both autonomy- and competence-supporting (Table 3.4), it sometimes limited students’ ability to connect with their scientist-mentors. Some students harbored misconceptions about scientists that were hard to overcome with text-only communication and no face-to-face interactions.

For example, a teacher admitted, “Even with the mentor's picture online and a profile, the students do not connect their mentors with being real people.” Another commented, “It’s hard to get students to see mentors as real.” Dan was also challenged by the difficulties involved in getting students to realize their mentors were real people. “The connection between what they do online and real people, I don’t know if students ever make that connection completely....If we can make that transition with students, I’d be happy.” I must mention, however, that without the online communication offered by PS, many of the students in this study would not have had the chance to be mentored at all, much less by a professional scientist.

In addition to internal factors, external factors affecting students' basic psychological needs were also considered. Opportunities and threats referred to external characteristics either contributing to or detracting from support of students' psychological needs. More specifically, consideration of external factors was limited to variables outside of the PS program's immediate control (e.g., frequency of scientist-mentor comments, etc.) and directly related to teachers' and scientist-mentors' strategies and actions. Each psychological need (i.e., autonomy, competence, relatedness) was considered separately.

Autonomy

Opportunities. Teachers have a great opportunity to contribute to student autonomy by the fly-fishing method. Fly-fishing, remember, was the name given by Kelly to letting go in the classroom and turning responsibility for learning over to students. In most cases, PS provided opportunities for students to experience freedom in their selection of research questions, methods, and interpretations. However, teachers must respect students' choices, and teachers must work hard to develop a classroom environment that is non-controlling and autonomy-supportive. When teachers value students' ideas and opinions, a climate of cooperation is established, and the opportunity for students to take charge and flourish is realized.

Scientist-mentors best supported autonomy when offering a hand in partnership to students over the course of the inquiry projects. By partnering and not exerting control or authority over the projects, scientist-mentors helped maintain and even enhance student feelings of autonomy.

Threats. From both teacher and scientist-mentor perspectives, controlling behavior was the greatest threat to student autonomy. Control alienates students, causing them to lose motivation (Urdan & Turner, 2005). In this study, controlling behavior on the part of the scientist-mentors was associated with at least some of the frustrations experienced by student-teams. While controlling behavior was not observed often in classrooms, the fact that so many teachers in the focus group admitted how letting go was difficult for them indicated control can be an issue, even for experienced PS teachers.

Competence

Opportunities. From the findings of this study, competence support comes naturally to educators. The vast number of strategies and actions used by teachers and scientist-mentors were associated with competence support. For example, teachers supported student competence by scaffolding, challenging students to go deeper, and providing encouragement. Similarly, scientist-mentors supported competence by explaining, asking questions, and encouraging (Table 3.4).

Both teachers and scientist-mentors used encouragement as a strategy. According to SDT, positive reinforcement is the best competence-supporting form of encouragement (Reeve et al., 2004). According to Reeve et al. (2004), positive reinforcement is giving praise to another in a way that preserves a sense of autonomy and specifically refers to an action or skill on the part of the person receiving the compliment. For example, in PS, mentors sometimes posted comments like, “I’m impressed with your observations and the questions you have developed,” “Good deductions on my question," or "You have done a very nice job stating your research prediction and describing your independent and dependent variables…a very solid experimental design." These comments illustrated positive feedback because they specifically identified something the student did well (e.g., developed a good research question). Comments linked to specific traits and actions are much more competence-supportive than a general comment like, "Good job" (Deci & Ryan, 2000). Therefore, teachers and scientist-mentors should take the opportunity to use positive reinforcement because it increases motivation (Deci et al., 1996; Ryan & Deci, 2002).

Threats. As mentioned earlier, some curricular modules may be too complex and overwhelm students, thus reducing feelings of competence. Teachers and scientist-mentors can also overwhelm students by "talking over the heads" of students. This action on the part of teachers and scientist-mentors represents a legitimate threat to student competence.

Another threat to student competence was related to students' perceptions of failure. When students did not obtain results confirming their original scientific predictions, they sometimes thought the experiment was a failure and lost confidence. Scientists in the focus group were adamant about teaching students the benefits of failure, particularly emphasizing the difference between failing in an achievement context (i.e., tests) versus getting unpredicted results in a scientific investigation. So, while this misconception is a huge threat, there is also an enormous opportunity for teachers and scientists to correct it by intentionally addressing it with students.

Relatedness

Opportunities. Teachers have opportunities to foster relatedness by orchestrating collaborative, open environments where students are free to engage each other while conducting PS experiments. Likewise, scientist-mentors have opportunities to speak into the lives of young people by establishing meaningful relationships with students. Although the difficulties associated with online relationships have been noted in this study, the relationship between students and scientists is perhaps the greatest contributor to student motivation. Mentors can nourish the motivational resources of students, and the implications for the development of future learning environments is exciting.

One of the enduring mysteries of education is how to engage learners. According to the SDT framework, motivation suffers in school environments because school is typically not intrinsically motivating, and the school environment does not usually support student autonomy, competence, or relatedness. However, if certain conditions changed, SDT predicts students could develop motivation for tasks that were not previously motivating (Ryan & Deci, 2002). This process, known as internalization, occurs in individuals when a value or action that is not intrinsically motivating becomes personally endorsed over time (Deci & Ryan, 2000; Ryan & Deci, 2000a).

In several SDT studies, three primary conditions were reported to increase internalization. These conditions included: (1) providing a rationale for the activity or behavior, (2) establishing interpersonal relationships emphasizing choice over control, and (3) acknowledging negative affect (Deci et al., 1994; Deci & Moller, 2005; Reeve, 2002). Interestingly, all three conditions require input from a significant other. Someone provides a rationale to the unmotivated person, someone develops a relationship with the unmotivated person and provides choice, and someone acknowledges the negative feelings of the unmotivated person. Relatedness, therefore, plays a critical role in internalization (Ryan & Deci, 2002). In educational contexts, the significant other is often a parent, teacher, coach, or mentor (Koestner & Losier, 2002).

The strategies and actions of scientist-mentors discovered in this study (Figure 3.1) indicate that mentors used many internalizing strategies, whether conscious of the fact or not. For example, empathetic comments closely paralleled the principle of providing a rationale for an activity as defined by SDT. When scientist-mentors connected student-teams' experiments with their own work or described how plants were important to all life on earth (i.e., providing a bigger picture; Figure 3.1), they provided a rationale by helping students understand the importance of that particular part about plants or plant biology.

In like fashion, scientist-mentors who offered themselves as partners (not controlling authorities) to the student-teams were effectively establishing interpersonal relationships while protecting student autonomy. When students complained and scientist-mentors showed empathy, they were acknowledging the negative feelings of the students in a manner consistent with an internalizing strategy.

Internalization is of primary importance in schools because, as mentioned earlier, school for many students is not intrinsically motivating (Ratelle et al., 2007). As a result, internalization facilitated by relatedness may be the pathway to self-determined behavior. Since "the primary reason people are likely to be willing to do the behaviors [not interesting to them] is that they are valued by significant others to whom they feel (or would like to feel) connected" (Ryan & Deci, 2000a, p. 64), finding a significant other is paramount to promoting motivation in schools. Perhaps scientist-mentors filled this role as significant others. If so, the mentoring component used by PS provides a wonderful model to promote student motivation on a grander scale.

Threats. Since communication is absolutely essential to relatedness, it is not surprising that the biggest threat to relatedness and, therefore, motivation is lack of communication. PS has many moving parts, so several pieces must fit together to keep lines of communication open. Students, teachers, and scientist-mentors are all responsible for keeping lines of communication open.

For example, if student-teams do not post in the asynchronous forum, connections with scientist-mentors cannot be established. If teachers poorly orchestrate the learning environment and do not offer students either the time or the equipment to post online, communication ceases. If teachers do not allow students to collaborate in the classroom, relatedness suffers. Finally, when scientist-mentors fail to post, possibly due to busyness, forgetfulness, apathy, or lack of access to technology, they are directly responsible for communication breakdown. In all of these cases, communication falters and the connections and feelings of belongingness necessary for establishing relatedness are lost. Therefore, all threats to relatedness are potentially devastating to student motivation.

Final Thoughts

Motivation should be an important consideration for the development of science curriculum and the delivery of science instruction for one simple reason: “Motivation is highly valued because of its consequences: Motivation produces” (Ryan & Deci, 2000b, p. 69). Evidence suggests a relationship between student motivation in science classrooms and increased scientific literacy (Bryan et al., 2011), as well as with students’ perseverance in science learning (Patrick & Middleton, 2002). Systematic and in-depth qualitative studies, like this one using Eisner’s (1985) Connoisseurship/Criticism model, allow researchers to unobtrusively study motivation in genuine contexts and uncover specific factors relating to the motivational conduciveness of unique learning environments like PS.

Summary

The driving question for this study was, “Why is *PlantingScience* successful?” I analyzed multiple data sources using inductive and deductive qualitative methods. This analysis allowed me to describe, interpret, and evaluate the PS program and its implementation. My examination revealed specific factors contributing to the success of this innovative program which were assembled into a comprehensive theory using Strauss and Corbin’s (1990) paradigm model (Figure 3.1). Specifically, I linked the conditions, contexts, strategies, and actions contributing to student motivation to develop a grounded theory for student motivation and engagement.

I subsequently used deductive methods (Miles et al., 2014) and self-determination theory (Deci & Ryan, 1985) to analyze the results from an established theoretical perspective. The results of this step increased the power of the theory to explain why students experienced higher motivation levels when engaged in PS. Finally, I employed a SWOT analysis (Helms & Nixon, 2010) to connect the factors to autonomy, competence, and relatedness (Table 3.4).

The descriptions of Dan and Kelly's classrooms, in coordination with the focus group descriptions, revealed ample evidence suggesting most students were engaged and motivated when involved in PS. The grounded theory developed and used as an interpretation mechanism highlighted student empowerment, online mentor interaction, and authenticity of experience as causal conditions explaining why students were motivated to participate in PS (Figure 3.1). These causal conditions, along with the intervening conditions and strategies/actions, were evaluated in light of SDT and assessed based on their contributions to the basic psychological needs of autonomy, competence, and relatedness (Table 3.4).

Mentors Make a Difference

The findings in this study tell a story about three actors: teachers, students, and scientist-mentors. Teachers must let go and create environments where students feel free to engage in open-ended activities and pursue answers to their own questions. When teachers successfully accomplish this feat, students feel empowered and begin to take responsibility for their own learning. As students navigate the novelty and complexity of their new-found "free" world, scientist-mentors step in and become significant others who offer their hands in partnership with students as they go through the PS process together. The scientist-mentors are perhaps the greatest value-added component in the PS program.

Findings from this study and others (Scogin, Ozturk, & Stuessy, 2013) indicate scientists fill roles differently than those occupied by teachers. Teachers must direct and orchestrate the classroom, but scientists are free to connect to their mentored students in a manner quite unlike what classroom teachers can do. Without orchestration issues, scientists focus on mentoring and giving their student-teams undivided, individualized, and in-depth attention. Even within the constraints of the asynchronous environment, scientists are able to give formative feedback as problems arise, provided students communicate the problems to them on the website.

The mentor effect was a powerful driver behind PS's success. Students looked forward to working with mentors, enjoyed having mentors as a source of information, valued mentor feedback, and felt empowered through the partnerships that were forged over the course of their PS projects. Perhaps the most encouraging outcome of this study was the revelation that scientist-mentors may, through internalization, be able to help motivate students who are not intrinsically motivated about science.

Research indicates motivation can sometimes work in a "bottom-up" manner. In other words, positive experiences with one experiment or one lesson (i.e., situation) can lead to increased motivation for a class or subject area (i.e., context; Vallerand & Ratelle, 2002). In the context of PS, this would be the equivalent of a student having a positive inquiry experience with their PS project (i.e., situational motivation) and consequently developing more motivation for science in general (i.e., contextual motivation). Interestingly, it appears this scenario may have played out in the life of at least one mentor involved in this study. A scientist-mentor assigned to Dan’s class posted the following comment in the asynchronous forum to his student-team:

> I was not interested in this field [botany] till I got admitted to my M.S. program (about 10 years back). There I was fortunate to have a few great mentors. I can still remember their passion for plant science and the way they introduced it to students. I will try to continue my mentors’ efforts.

While this study does not make the claim that mentoring programs involving scientists are the key to turning around science education, the concrete factors contributing to the success of PS uncovered in this study are germane to ongoing discussions about increasing student motivation in science education.

CHAPTER IV

ASSOCIATIONS BETWEEN STUDENT ENGAGEMENT IN SCIENTIFIC INQUIRY AND MOTIVATIONAL SUPPORT: DO ONLINE SCIENTIST-MENTORS MAKE A DIFFERENCE?

Introduction

The impact of motivationally supportive online mentoring on science education remains largely unexplored. In 2003, Ensher et al. lamented there were "virtually no published academic studies to date examining the feasibility or effectiveness of cyberspace" (p. 274), even with the growth of online mentoring. In 2006, Xie et al. reiterated the void, claiming a lack of research addressing students' motivation to participate in online discussions. In 2010, Chen and Jang published a study specifically addressing the lack of research pertaining to motivational support in online contexts. In 2011, S.W.-Y. Lee et al. published a literature review of studies relating inquiry and technology, citing only one study (see Wang & Reeves, 2006) linking instructional design in Internet-based science learning environments to students' motivation. With the publication of a special issue of *Education Technology Research & Development* (see Volume 59, Issue 2) and a few other studies beginning in 2011 (e.g., see Moos & Honkomp, 2011; Rienties et al., 2012), we do begin to see that the topic of motivation is receiving a bit more attention in the research literature on online learning. While still not a current "hot topic" for research in educational technology, I concur with Mayer (2011) that concerns about motivation in online learning environments must be addressed.

The paucity of studies linking online education with motivation could be partially related to education researchers' lack of access to e-learning environments, as researchers are often dependent on developers who have the time and money to design and launch these environments. Mayer (2011) called for current online providers to increase access to their successful technology-supported learning environments for use by education researchers. In this investigation, we accessed a successful “testbed” (i.e., PS) to determine associations between motivation, online mentoring, and student inquiry engagement. Using self-determination theory (SDT) as a framework (Deci & Ryan, 1985), the purpose of this study was to investigate online scientist-mentors’ motivational support of junior high students and evaluate the potential impact of this support on students' inquiry engagement.

Literature Review

The importance of science literacy and critical thinking is recognized globally by many policy makers living in the 21st century, particularly those in modern societies with economies reliant on a well prepared citizenry and workforce to deal with the consequences of rapid advances in technology (Bryan et al., 2011). Organizations including the American Association of Colleges and Universities (AACU), the National Center for Educational Statistics (NCES), and the NRC have emphasized the need for increased scientific literacy and proficiencies in U.S. citizens (Sinatra & Taasoobshirazi, 2011). "Science for all" and workforce development share center stage in the latest call for science education reform. The *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013) in fact, were developed in response to the poor showings of U.S.

students in international studies examining student achievement in STEM-related subjects (NRC, 2013) and students' interests in STEM career fields (Welch & Huffman, 2011). Some experts attribute low interest and motivation toward STEM to an overemphasis in the U.S. on standardized testing (Koballa & Glynn, 2007), while others point to the lack of authentic contexts in learning classroom science (Hickey & Granade, 2004).

The *Next Generation Science Standards* (NGSS Lead States, 2013) proposed an integrated science and engineering framework for raising scientific literacy and encouraging students to seek STEM-related careers. The proposal also made calls for promoting active learning, developing authentic scientific communities of practice, and providing motivational support for science learners. Particularly, the NGSS called for students to work collaboratively and actively engage in authentic science investigations using empirical inquiry. In authentic science investigations, students ask their own scientific questions, derive their own hypotheses, develop methods for testing their hypotheses, and construct logical conclusions as evidence-based arguments to defend their conclusions (Chinn & Malhotra, 2002). This type of science learning allows learners to think and act like scientists; it is active, engaging, and provides opportunities for "communicating and critiquing ideas in a scientific community" (NRC, 2012a, p. 127).

Providing an authentic scientific learning community is not easy, however. Chinn and Malhotra (2002) established a comprehensive framework for evaluating authenticity in science classrooms. These researchers compared truly authentic science, such as that carried out by scientists in their laboratories, to classroom science. Due to the fact that space, time, finances, and expertise often limited classroom science, Chinn and Malhotra reasoned that science educators incorporated less complex tasks than those carried out by scientists. However, these researchers noted that science teachers can still emphasize authenticity by mimicking the cognitive tasks of real science, such as generating research questions, designing studies, explaining results, developing theories, and studying the research of others. Additionally, Chinn and Malhotra emphasized epistemological aspects of authentic science, including evidence-based reasoning, use of theory, discounting of anomalous data, heuristic reasoning, and social construction of knowledge through expert review and collaboration. Authenticity could be met, they concluded, in classrooms affording students opportunities to engage in tasks requiring authentic reasoning, providing frameworks to help students understand the strategies of scientists, and developing methods to teach students authentic reasoning.

In an effort to address the challenges of promoting authenticity in science education, the NRC (2012a) placed special emphasis on transforming classrooms into contexts for scientific communities to reflect science as "a body of established knowledge and a social process through which individual scientists and communities of scientists continually create, revise, and elaborate scientific theories and ideas" (p. 73). Mentoring, especially when conducted by professionals, is one practical way to build communities and increase authenticity by raising the level of expertise and the opportunities for collaboration (Mullen, 2011).

Scientists as Mentors

Programs uniting students with scientists in research apprenticeships have become increasingly popular. Sadler et al. (2010) identified 53 publications about scientist partnership programs designed for secondary students, undergraduate students, and teachers. Within programs designed for secondary students, student-scientist partnerships (SSP) were most often cited. Most of these programs involved students as collectors of data for use in scientific research. Technology was often used to facilitate collaboration between the students and scientists, but the involvement of the scientists ranged from "very limited (e.g., advisory role in the design of the project) to quite extensive (e.g., working with students as they learn data collection techniques)" (p. 240). While SSP models represent one way to implement scientist-student partnerships in the classroom, they sometimes lack comprehensive authenticity because participation is limited to one part of the scientific process (e.g., data collection). In contrast, Chinn and Malhotra (2002) called for a much broader scientific context in classroom environments to emphasize authenticity, both cognitively and epistemologically.

Within SSPs limited to data collection, Sadler et al. (2010) pointed out that students often became frustrated with the tedium of data collection. At other times, however, students responded positively to SSPs because they believed their efforts were purposeful and useful. Other studies of scientist-student partnerships also reported positive outcomes. For example, Bryan et al. (2011) reported high school students' perceptions of science as more relevant and science careers as more interesting when scientists from the community shared their experiences and challenges. Edelson (1998) also reported increased scientific authenticity in the classroom and significant learning gains in programs partnering high school students with atmospheric scientists in inquiry-based activities.

While connecting scientists with students can increase positive student outcomes in science, barriers of isolation often exist to prevent this practice from becoming widespread policy. A recent report from the NSF (2013) drew attention to the general lack of access of scientists for face-to-face mentoring of students learning science. While the report highlighted the economic ramifications of isolation, the NSF also discussed the logistical and geographical barriers limiting scientists' opportunities to work directly with students in face-to-face classroom learning environments. Capabilities do exist, however, for using the Internet to facilitate interactions and develop new relationships between students and scientists in classrooms across the world.

Online Mentoring

Online mentoring benefits students in many ways (Ensher et al., 2003). First, online mentoring provides access to scientists even when students are located in isolated environments. Garrison (2011), for example, stated an advantage of e-learning is increased access to others who can become members of a learning community. Second, Ensher et al. (2013) declared online mentoring “levels the playing field” by equalizing the status of all participants and preventing the unavoidable awkwardness students feel when third party experts enter the classroom. Reduced anxiety about partnering with scientists allows students the freedom to follow their natural desire “to feel connected to significant individuals” (Vallerand & Ratelle, 2002, p. 48). Third, online mentoring extends contact between scientists and students past the "one-time visit" status that Pekar and Dolan (2012) reported was typical of scientist-student interactions. Through asynchronous venues, students and scientists can communicate on a regular and ongoing basis at their own conveniences, anytime and anywhere. Sustained contact affords students and scientists time to develop comfort with each other. Regardless of the nature of the project, time is a necessary commodity if online mentor-protégé relationships are to evolve into productive scientific partnerships (Sadler et al., 2010).

While online mentoring has a powerful upside, challenges still exist. Ensher et al. (2003) reported many difficulties, including the absence of non-verbal cues and inability to gauge tone in text-only communications. In some situations, limitations such as these threaten to destroy online communication efforts. "Mentors and protégés who do not know each other well or communicate primarily via email may misunderstand attempts at humor, misread tone, or fail to clarify when they do not understand one another" (Ensher et al., 2003, p. 276). As a result of these delicate conditions, mentors need to employ specific strategies to establish a strong social presence while creating successful online relationships.

Social Presence

Social presence is a concept derived from the Community of Inquiry (CoI) framework (Garrison, 2011). Garrison (2011) defined a community of inquiry as "a group of individuals who collaboratively engage in purposeful critical discourse and reflection to construct personal meaning and confirm mutual understanding" (p. 15). Communities of inquiry include three interdependent parts: social presence, cognitive presence, and teaching presence. Specifically, social presence is "the ability of participants to identify with a group, communicate purposefully in a trusting environment, and develop personal and affective relationships progressively by way of projecting their individual personalities" (Garrison, 2011, p. 23). According to Garrison, quality learning in e-learning environments is optimized only after students identify with the group and feel they are genuinely part of the learning community.

In academic contexts, social presence is achieved by more than mere social interactions. Social presence is achieved within a "climate that supports and encourages probing questions, skepticism, and the contribution of explanatory ideas" (Garrison, 2011, p. 32). Social presence implies a mix in interpersonal communication, cohesive communication, and open communication (Akyol & Garrison, 2008). Although these three types of communication occur throughout the duration of an online relationship, Garrison (2011) indicated interpersonal connections typically occur first and set the tone for future interactions. Open communication pushes and drives the purposeful "academic" conversations. Cohesive communication unifies the group and sustains the relationship. Together, these types of communication promote social adhesion, serve as ways to build group identity, and foster problem-solving interests among group participants (Akyol & Garrison, 2008).

Motivating Students in Science

Modern learning theories recognize affective constructs, including motivation, as central to learning and deserving much more than peripheral considerations. Science education researchers, however, often overlook motivation research in favor of cognitive studies (Koballa & Glynn, 2007). Therefore, we have often turned to non-domain-specific findings from education research related to motivation and have attempted to relate these findings to what we might expect if more studies had been conducted in the domain of science.

Motivation deserves more than peripheral consideration because motivated students *want to learn* and *believe they can learn,* two critical factors contributing to the development of deeper learning outcomes (Patrick & Middleton, 2002). When students are motivated, regardless of the domain, they perform better, experience more positive emotions, and enjoy the school experience (Deci et al., 1991). Teachers successful in promoting student motivation in science, therefore, would lead their students to apply more effort in learning science, which would lead naturally to deeper understanding of essential science concepts (NRC, 2012a). While motivational practices are diverse, some specific applications in science classrooms are more effective than others in promoting positive student outcomes.

Providing opportunities for students to collaborate with others, especially when combined with online technology integration, is a motivational practice that effectively enhances science education. For example, Patrick and Middleton (2002) observed that group work and hands-on cooperative experiments led to positive student outcomes and better attitudes in science classrooms. With the addition of technology, Garrison (2011) learned collaboration with others via asynchronous venues was beneficial for some students because they were less intimidated and felt more freedom than when in face-to-face classrooms. Other research has confirmed online environments promote greater autonomy, increase intimacy, and improve communication between participants (Ensher et al., 2003).

Interestingly, asynchronous online communication contexts can promote greater engagement than face-to-face contexts (Ensher et al., 2003). According to Ensher et al. (2003), without the pressures of physical presence, many students became more comfortable with the online format (i.e., developed greater social presence) and engaged in more intellectual risk-taking. Additionally, the added wait time with asynchronous communication can lead to longer reflection on responses and recruitment of additional cognitive faculties (Garrison, 2011). These findings indicate online environments can be constructed to promote motivation leading to greater engagement and self-regulated learning.

While measuring motivation is difficult, particularly in online contexts, self-determination theory (SDT; Deci & Ryan, 1985) is a theoretical framework useful in explaining strong relationships between computer-supported collaborative learning (CSCL) and student motivation. SDT is an organismic-dialectic theory postulating people look for supportive social contexts in an effort to obtain the basic psychological needs of autonomy, competence, and relatedness (Ryan & Deci, 2002). SDT defines these needs as follows: (1) autonomy – desire to regulate and control their own behavior; (2) competence – desire to engage in challenging tasks and experience some effectance; and (3) relatedness – desire to seek attachments and experience feelings of belonging and connection (Deci & Ryan, 2000). When online environments fulfill the basic psychological needs, CSCL environments can become motivating to learners. A successful CSCL environment, PS, was evaluated in this study using SDT.

Context for the Current Study

PS is an innovative, blended curriculum developed by the BSA. Used internationally by over 11,000 students since 2005, PS provides advanced technology tools and supports to mix scientific inquiry, classroom instruction, and online mentoring by practicing scientists as students learn plant biology concepts within the context of contemporary middle and high school science classrooms. Students working in teams of 2-4 individuals design and carry out their own three- to ten-week long inquiry-based experiments related to plant biology. Specific topics include seed germination (i.e., *The Wonder of Seeds*), photosynthesis (i.e., *The Power of Sunlight*), and sexual reproduction and alternation of generations (i.e., *C-Ferns in the Open*), among several others.

Many facets of PS mimic authentic scientific inquiry as outlined by Chinn and Malhotra (2002). For example, students generate unique research questions originating from introductory "immersion experiences" with complex systems of variables. They plan and implement their own analytical procedures and make observations leading to evidence-based conclusions. Furthermore, students often transform their observations to other data formats (e.g., graphs, presentations, drawings, spreadsheets, reports, etc.) and share them with others on the PS website.

Perhaps one of the leading reasons why PS has achieved success as an authentic scientific inquiry is the incorporation of scientists as mentors who partner with student-teams for the duration of the inquiry projects. Over 900 professional scientists and science graduate students worldwide have volunteered for the program. These professionals provide key feedback to student-teams, often requiring students to clarify and defend their research questions, experimental designs, analytical methods, results, and conclusions. Using the language of Chinn and Malhotra (2002), PS can be viewed as a program providing scientist-mentors who help students engage in science more authentically by identifying potential flaws in student experiments and urging students to use evidence-based reasoning.

The scientists never physically visit the classroom. Instead, the PS website serves as an extension of the classroom, allowing student-teams and scientist-mentors to communicate in an asynchronous blog. The dialogues are archived on the PS website and are publically available (http://www.plantingscience.org). Additionally, student-teams communicate with scientists (and the public) by posting journals, photographs, spreadsheets, and other relevant inquiry-related data to their own website page. Scientists view students' uploaded products and communicate with their assigned student inquiry teams to get snapshots of what they are doing in the classroom in order to provide appropriate mentoring. In 2011, PS received the prestigious SPORE Award (acronym for Science Prize for Online Resources in Education) from the American Association for the Advancement of Science (AAAS) for its technology innovation and successful student engagement (Hemingway et al., 2011). PS combines student-scientist partnerships with online mentoring in an effort to improve scientific awareness, increase science classroom experience, and promote scientific proficiency (Hemingway et al., 2011). In the *Science* article, PS developers noted:

> Talking online with a scientist is exciting and motivating to students….The personal connection with an online mentor also holds promise for inspiring individual students. There is power in the collective commitment and expertise of scientist-school partnerships to efficiently raise engaging collaborative science learning to a national scale. (Hemingway et al., p. 1536)

Technology innovation by itself does not inevitably bring about learner satisfaction and engagement (Rienties et al., 2012). However, opportunities can exist within the innovation to provide a context for increased motivation and engagement (Xie et al., 2006). Furthermore, a blending of online and face-to-face contexts can have several advantages for learners, including greater participation, stronger feelings of community, and increased reflection time (Garrison, 2011). In PS, online scientist-mentors provide students with a component of authentic science rarely mimicked in K-12 science classrooms.

In the current study, seventh grade students in 10 student-teams partnered with scientists for six weeks to complete projects in *The Wonder of Seeds* module during a recent fall semester. I examined the interactions of scientists and students in each student-team as a separate case. Each student-team generated their own primary research question, which guided their scientific inquiries to investigate the effects of differing soils and watering regimines on seed germination, for example, or to investigate the effects of different light sources on phototropism or seedling growth rates. With scientist-mentor participation, students designed experiments to test their research predictions. They reported their progress to their scientist-mentors via the asynchronous blog on the PS website. Most students posted to the website during class time, although they did not post every class period due to time constraints. Scientists responded at their conveniences, with wait times between students and scientists varying from the same day to over one month. Most students and scientists, however, responded to each other's comments within three days. An example exchange between a scientist and student-team is included in Figure 4.1.

Justification for the Current Study

Over the last several years, the national push for greater science achievement has placed new emphasis on student motivation (Koballa & Glynn, 2007). With its emphasis on the social context, SDT is a powerful tool for evaluating the effectiveness of social environments in different formats. In particular, Chen and Jang (2010) stated online academic environments are especially suited to SDT studies, as online learning requires flexibility and choice (i.e., autonomy), technical skills (i.e., competence), and social interaction (i.e., relatedness). Within science learning contexts, online technology can afford scientists from all over the world the opportunity to partner with students in even the most geographically isolated classrooms. Practicing scientists interacting with students could promote higher scientific literacy, greater science engagement, and improved student motivation in science. When providing the proper motivational support, scientists can potentially add immense value to the classroom science experience. As PS integrates technology, mentoring, and collaborative science, this unique learning environment provides a rich context for studying motivational support.

October 10 8:37 PM (Scientist/Mentor)
Hypothesis
You have written a great hypothesis and I can't wait to find out what your results are. How will you measure growth rate? Are you sure that growth of your plants in different soils will be due only to the soil type? Do you [know] the terms we use for these different types of variables?
Can't wait to hear more! [Scientist's Name]

October 11 11:11 AM (Student-Team Member)
~Ms.[Scientist's Name],
Today we are starting our project!!!!! We will be measuring our plants growth by centimeters. We are positive that the plants in the soil will have a more rapid growth rate, because of the nutrients that are in it.
~ [Student-team Name] :))) (:~
~ [Students' Names](: ~
Thanks for all of the advice [*sic*]!!!!!!!!!!

October 13 10:22 AM (Scientist/Mentor)
Starting Project
Hey guys!
I like your explanation of your hypothesis. Have you learned about what types of nutrients plants require? I bet you could do a quick google search to find out.
How are your plants doing so far? Any cool observations?
~[Scientist's Name]

October 13 11:05 AM (Student-Team Member)
Ms. [Scientist's Name]~
Hey well our project is kinda over, since ALL of our seeds have germinated!!!!!!!!!!!!!!! It didn't take very long for the beans to grow a root and be classified in the germinating category!!!!!
~[Student-team Name]:))~
~[Students' Names]~ (:

October 13 11:06 AM (Student-Team Member)
all of our plants have grown since we have planted them! they all have a little root coming out of the bottom of them.
~[Student Name] [Student-team Name]~

October 13 11:14 AM (Student-Team Member)
nutrients
Ms.[Scientist's Name] ~
This is what we found on the internet about what nutrients mung beans need ...
However, once the seed begins to sprout and deplete this small storage of nutrients, it requires suitable soil to encourage continued growth. Mung bean sprouts prefer soils with pH levels between 6.2 and 7.2, as well as adequate amounts of sulfur, magnesium phosphorus and potassium. Fertile soils that contain a rich blend of sand and loam provide essential nutrients for healthy growth.

Sincerly [*sic*],
~[Student-team Name] :)) ~
[Students' Names]

October 17 8:47 AM (Scientist/Mentor)
Conclusions?
Hi Team [Student-team Name]!
I see you have uploaded a whole bunch of pictures and you tell me that your project is over. The last steps to every experiment is to draw conclusions and come up with future experiments. What sort of things did you learn from your experiment? Is there anything you would do differently next time?
Happy Concluding.
~[Scientist's Name]

October 19 11:32 AM (Student-Team Member)
Our Conclusions (So Far !!!)
Howdy Ms. [Scientist's Name] ~
Well our hypotesis [*sic*] was true at least up to today. The soil has grown AMAZING, the shortest root is 7 in.! I guess you can say we know what nutrients the soil has and the others don't. We were really suprised [*sic*] to see that the saw dust has actually grown some leaves and steams [*sic*]. Some of the seeds in the silt have MOLD ON THEM, HOW GROSS IS THAT ? When we saw that we all said EWWW!!! Our seeds have really grown quite FAST [We] were really suprised [*sic*] that over the weekend with no water and light that our plants sproted [*sic*] right up.
THANKS FOR ALL OF YOUR HELP!!!!!!!!!!!!!!
![Student-team Name]:))
~ [Students' Names]~

Figure 4.1. Example of an asynchronous dialogue between scientist-mentor and student-team (Case 10).

Purpose of the Study

The purpose of this multiple case study was to investigate the motivational aspects of the interactions between student-teams and their scientist-mentors within the PS online environment. This project was designed to address a void in our understanding of the relationship between motivational support provided in an online mentoring environment and student engagement in inquiry. The study is unique in that it centers specifically on motivational support as provided by scientists in an online context. I used SDT as the theoretical framework for guiding the design of the investigation, expecting that I might find evidence linking increased inquiry participation in students with increased motivational support from scientist-mentors. According to SDT, adults who play significant roles in students' lives can promote increased student motivation (Deci et al., 1991). While significant adults in students' lives are traditionally parents, teachers, or coaches, participation in PS brings new significant adults into the academic lives of students--scientist-mentors who join student-teams for collaborative inquiry projects, thus providing an ideal "test bed" for investigating relationships between online mentoring and students' inquiry engagement.

The objectives of this study were to: (1) identify and describe the types of online motivational support provided by scientists as they mentored students' classroom inquiry projects, and (2) investigate potential associations of this support with the quality of students' engagement in scientific inquiry. According to Sadler et al. (2010), "finer grain" analyses, like the current study, can significantly improve science education by providing specific feedback on *why* certain partnership arrangements work as opposed to more generalized studies that just determine *if* partnerships work.

Methods

Research Design

I used a multiple-case replication design for this study (Yin, 2009). In specific parts of the analysis, I grouped cases using an extreme group comparison strategy (Chase, 1964). Preacher, Rucker, MacCallum, and Nicewander (2005) recommended extreme group analysis where "little knowledge exists" and to "detect general trends in the data" (p. 188). By reporting on both individual cases and replicate groupings, I was able to provide specific descriptions of cases and determine some associations between scientist-mentors' motivational support and student-team inquiry engagement. The units of analysis (i.e., cases) for this study were 10 student-teams taught collectively by one science teacher in two classes. Each team was partnered with one scientist volunteer assigned by the BSA to mentor one or more student-teams. All students designed inquiries related to the PS seed germination unit, *The Wonder of Seeds*.

SDT served as the theoretical framework for the study employing methods of quantifying qualitative data according to Chi (1997). I developed a motivational support rubric based on SDT, which was used for hypothesis testing (see *Analysis* section in this chapter for full description).

Sample

Student-teams. I purposively selected 10 student-teams (i.e., cases) composed of seventh graders enrolled in two different science sections in a rural public school located in the southwestern region of the United States. The rural school district enrolled 430 K-

12 students. The teacher reported that approximately 65-70% of students in the district were from low socio-economic households and some students' families lacked transportation and rarely, if ever, ventured out of the community. As few students had ever interacted with scientists face-to-face, this rural district provided an ideal setting for evaluating online scientist mentoring.

While these 10 cases provided an intriguing geographical context for study, I pre-screened the sample to ensure adequate student participation and inquiry engagement levels, essentials in addressing the research questions posed for the study. Student participation and inquiry engagement levels in the 10 cases were compared to engagement levels in a baseline study of 263 PS student-teams (Peterson, 2012). Table 4.1 shows a comparison of participation levels (as indicated by number of posts in the dialogues) and inquiry engagement levels (as measured by the Online Elements of Inquiry Checklist – see *Methods-Measures* section in this chapter for description) between student-teams in the current study and the comparison group. Levels of participation and engagement in the current study were deemed adequate to proceed.

All student-teams in the current study worked on the same PS module under the direction of the same experienced teacher. Student-team members were novice inquiry learners, having had no previous experiences with scientific inquiry and only one collaborative group experience in learning science. Before beginning the PS project, the teacher familiarized students with the PS website and allowed students to list several classmates with whom they would like to work. From students' lists, the teacher chose the members for each student-team, assuring that at least one classmate in the group had

Table 4.1

Comparison of Participation and Student Inquiry Engagement Levels Between Current Study and Peterson (2012) Study

	Current Study (*n* = 10)	Peterson (2012) Study (*n* = 263)
Student-Team Participation Measures		
Mean number of posts by student-teams	20.4	8.5
SD of posts by student-teams	6.3	6.4
Minimum number of posts by student-teams	15	0
Maximum number of posts by student-teams	33	44
Student-Team Inquiry Engagement Scores (%)		
Immersion	60	33
Research Question	68	59
Prediction	73	64
Experimental Design and Procedures	30	34
Observations	63	33
Analysis and Results	45	45
Conclusions and Explanations	44	24
Future Research and Implications	50	14

appeared on another team member's list. In her selection of students for group membership, the teacher also tried to balance the group's distribution with her knowledge about each student’s strengths and skills (PS Teacher, 2012). Five student-teams with three to four students on each team were formed from each of two different class sections, making a total of 10 student-teams.

The two class sections met during consecutive class periods in the same lecture and laboratory classrooms. As a result of shared facilities and the culture of the small school, all 10 student-teams had opportunities to share ideas, methods, and results. In addition, the PS website design promoted productive participation between groups within and between the two class sections.

Scientist-mentors. Nine research scientists from across the U.S. served as mentors for the 10 student-teams (by chance, the BSA program assigned one scientist-mentor to two different teams in the study). Three scientists were professors, four were graduate students, and two worked in private industry. The scientists specialized in different botanical fields including plant genetics, plant ecology, plant physiology, and cellular biology. Additionally, the scientists had varying levels of experience with online mentoring, ranging from no experience to seven semesters of PS-specific mentoring. Information about each scientist's interests and background was available on the PS website for all to see, including students engaged in projects during any semester.

Teacher. The teacher in the study had taught science in rural middle and high schools for 25 years. She earned a master’s degree in science education from a large state university five years before she received professional training specifically to assist her in implementing PS in her classroom. The BSA, with support from the NSF, provided the training. She attended three different PS summer workshops and followed each one with a PS implementation during the school year. The teacher’s expertise and previous experiences with inquiry-based learning from her graduate work and continued refinement in the classroom with PS made the choice of her classes for this study even more appealing, as ongoing research studies examining teachers' implementation and orchestration of the PS inquiry environment have indicated great variability in teacher's abilities to handle the difficult and complex PS environment (Scogin, Stuessy, et al., 2013).

Measures

Motivational support. In this study, motivational support was operationally defined as scientist-mentors' words, phrases, thought segments, or textual expressions of emotions (e.g., capitalization, emoticons, exclamation points, etc.) appearing in the online dialogues and providing evidence of acknowledgement of and/or support for their student-team's autonomy, competence, and relatedness. Specifically for this study, I designed a motivational support rubric (Appendix A) using a two-stage process. First, I explored SDT and social presence theory literature to identify valid indicators applicable to text-only learning environments. Second, I pilot-tested the rubric on sample scientist-mentor/student-team dialogues to assure that the indicators identified from the literature were relevant when applied to the context of the PS online dialogue. The research team negotiated a final motivational support rubric to include specific indicators of motivational support likely to be provided by scientist-mentors within the three SDT categories of autonomy, competence, and relatedness.

Autonomy support. Autonomy support is defined as "the degree to which [socializing agents] encourage independent problem solving, choice, and participation in decisions" (Grolnick & Ryan, 1989, p. 144). While behaviors supportive of autonomy are well defined in SDT literature, identifying text-only supports for autonomy was particularly challenging. After careful consideration, I chose five indicators as evidence of scientist-mentors' autonomy support in online asynchronous dialogues. The five indicators included: (1) providing or acknowledging student-team choice (Deci et al., 1996; Reeve, 2002); (2) acknowledging student-team ownership/control of the project (Reeve et al., 2004; Ryan & Deci, 2002); (3) using autonomy-supportive phraseology (i.e., non-controlling language; Deci et al., 1996); (4) acknowledging negative student-team comments or outcomes (Deci & Moller, 2005; Reeve et al., 2004); and (5) providing a rationale for some aspect of science in general or the inquiry experiment in particular (Deci et al, 1994; Reeve, 2002; Reeve et al., 2004). Autonomy-supportive indicators with verbatim exemplary segments from the dialogues are included in Table 4.2.

Competence support. In educational contexts, instructional leaders provide competence support by giving attention to students and providing feedback/explanations that challenge students without offering definitive solutions (Newman, 2008). In the online PS context, I used three indicators of scientist-mentors' competence support. The three indicators included: (1) asking content or process questions specifically relevant to the inquiry project that provided challenges for the students, thereby supporting competence (Elliot et al., 2002; NRC, 2012a; Reeve et al., 2004; also see Sinatra and Taasoobshirazi, 2011, who stated environments promoting reflection and critical thinking are also competence-supporting); (2) offering explanations, typically in response to student-team questions (Ryan & Deci, 2000a, 2002; as well as Reeve, 2002, who discovered timely feedback as contributing to competence); and (3) providing

Table 4.2

Autonomy-Supportive Verbatim Statements From Scientist-Mentor/Student-Team Dialogues

Indicator	Example
Providing or acknowledging student-team choice	Let me know when you've chosen one question to focus on, and I can help you with experimental design. [Case 8 Scientist-mentor]
Acknowledging student-team ownership/control of the project	I have a few ideas and questions that may help in running your experiment. [Case 9 Scientist-mentor]
Autonomy-supportive phraseology (i.e., non-controlling)	You might want to research some plants that you want to work with (e.g. corn, beans, peas) and what types of minerals and nutrients they need to grow. [Case 4 Scientist-mentor]
Acknowledging negative student-team comments or outcomes	Unfortunately scientists deal with failed experiments all too often. [Case 4 Scientist-mentor]
Providing a rationale for some aspect of science or the project	A lab notebook updated daily is an important part of a scientist's job. It is important to have accurate and detailed notes - of both things that work and things that don't work. This way you can look for patterns and try to figure out what is happening. [Case 1 Scientist-mentor]

positive feedback specifically related to student-teams’ actions or statements (Deci & Ryan, 2002; Ryan & Deci, 2002; and Reeve et al., 2004, who further differentiated feedback to be competence-enhancing when it was tied to students’ specific activities rather than more general in nature). Table 4.3 contains verbatim examples of competence-supporting segments from the dialogues.

Table 4.3

Competence-Supportive Verbatim Statements From Scientist-Mentor/Student-Team Dialogues

Indicator	Example
Asking content or process questions	Why might one type of seed need a helicopter wing (maple seed) while another seed need to [be] really small (radish seed)? [Case 10 Scientist-mentor]
Offering explanations	Hi everyone, I am not surprised to hear about your results with the coke and vinegar. Let's think a bit about the properties of those two liquids. The Coke is something you like to drink because it tastes sweet. If you look on the label, you see that the sweetness comes from a type of sugar. Lots of things want to eat that sugar - including the mold and mildew that is growing on your seeds. The seeds don't need the sugar from the Coke, because they pack their own as starch in the seed to tide them over until they begin to photosynthesize to make more sugar on their own. Now that the fungus is established, it can start to kill the seeds by growing into them. This isn't a problem with the water, because it doesn't provide a good media for the fungus and it can't get established in the seeds. [Case 1 Scientist-mentor]
Providing positive feedback	I just noticed that you have now posted your research question and that you want to focus on the effect of vinegar on plant growth and that you are predicting that vinegar will decrease plant growth. That is a great start. [Case 3 Scientist-mentor]

Relatedness support. "Relatedness involves developing secure and satisfying connections with others in one's social milieu" (Deci et al., 1991, p. 327). In PS, the relationship between scientist-mentors and their student-teams evolved over the course of the students' inquiry project, thus providing an ongoing context supporting growth in relatedness.

Social presence theory (Garrison, 2011) informed my framework to evaluate relatedness support. In particular, interpersonal, open, and cohesive communication categories were adopted from Garrison (2011) and used as indicators of relatedness support. According to Garrison, these categories of communication are used throughout online discourses and provide the foundational elements of online relationships. Garrison stated that interpersonal communication, including self-disclosure, humor, and affective expressions (e.g., exclamation points and emoticons), sets the tone for participation in virtual environments. In comparison, open communication establishes trust between the online participants and involves reciprocity, acceptance, and inclusiveness. Open communication is the most “academic” of the three kinds of social presence communication. Furthermore, open communication includes inviting further participation and elaboration, complimenting previous contributions, expressing agreement, and recognizing previous contributions to the online discussion. Finally, in Garrison's estimation, cohesive communication is the goal of an online community: “It is cohesion that sustains the commitment and purpose of a community of inquiry, particularly in an e-learning group separated by time and space” (Garrison, 2011, p. 29).

References by name and team, and phatic or social conversation characterize cohesive communication.

In my construction of the motivational support rubric, I made several minor changes to Garrison's (2011) framework to enhance applicability within the context of PS scientist-mentor/student-team dialogues. I settled on three indicators to evaluate interpersonal communication: (1) affective expression, (2) use of humor, and (3) self-disclosure. I used three indicators to determine cohesive communication: (1) inclusive language, (2) use of salutations, greetings, or phatics, and (3) use of personal names. Finally, I decided on four indicators to determine open communication: (1) asking questions or inviting participation, (2) complimenting and expressing appreciation, (3) expressing agreement, and (4) making references to previous student-team posts. Table 4.4 includes exemplary relatedness-supportive segments from the student-team/scientist-mentor dialogues.

Student inquiry engagement. I chose student inquiry engagement as the outcome variable in this study. With new standards (e.g., NGSS) calling for increased student engagement in authentic scientific practices, this outcome seemed applicable and useful to the goals of science education. Student inquiry engagement was measured using the Online Elements of Inquiry Checklist (OEIC; Table 4.5) developed by Peterson and Stuessy (2011) for assessing inquiry engagement in online environments and specifically for assessing engagement in PS. The OEIC is grounded in established inquiry literature and has been confirmed as a valid and reliable instrument for assessing online inquiry engagement (Peterson, 2012). Additionally, the items in the OEIC closely

Table 4.4

Relatedness-Supportive Verbatim Statements From Scientist-Mentor/Student-Team Dialogues

Type	Indicator	Example
Interpersonal	Affective expression	I'm glad that you guys had fun working on your experiment! I hope you all learned a lot. Plants are really interesting systems to study. Good luck on your classes this year! :) [Case 9 Scientist-mentor]
	Use of humor	All scientists do this, even us old ones! [Case 8 Scientist-mentor]
	Self-disclosure	Where do you live? I live in Nova Scotia which is on the east coast of Canada, just North east of Maine. Nova Scotia is like Maine in many respects. Fishing and forestry are important industries. In my area, the Annapolis Valley, agriculture is also important. We grow apples, grapes, blueberries, raspberries, strawberries, etc. Nova Scotia is in the Acadian Forest region. This is an area where the natural vegetation is a mixture of deciduous and evergreen trees. This time of year the leaves of the deciduous trees are turning color (red, orange, yellow) and the forest looks very pretty.2) What kind of music do you like? I like all kinds of music, but I especially like old rock and roll music from the 50's and 60's. I am afraid I don't know any rap music, but I do listen to it sometimes as my youngest daughter is a fan. [Case 3 Scientist-mentor]
Cohesive	Inclusive language	I'm glad that you're a part of the experiment as well! I can't wait to work with you more. [Case 9 Scientist-mentor]
	Salutations/greetings/ phatics	It's been cool and rainy here lately. How is the weather in Texas? [Case 9 Scientist-mentor]
	Use of Names	Hello Plant Rockers! Summer Rose, thanks for telling me which seeds you've looked at and how you sprouted the seeds last week. [Case 2 Scientist-mentor]
Open	Asking questions/ inviting participation	Have you started your experiment yet? How is it going? Are all the seeds still alive? Have there been any surprises? [Case 8 Scientist-mentor]
	Complimenting and appreciation	I appreciate you giving your project some thought and coming up with a question that intrigues you. [Case 8 Scientist-mentor]
	Expressing agreement	The numbering sounds like a good way to keep track of your seeds! [Case 2 Scientist-mentor]
	References to previous posts	I just noticed that you have now posted your research question and that you want to focus on the effect of vinegar on plant growth and that you are predicting that vinegar will decrease plant growth. That is a great start. [Case 3 Scientist-mentor]

mirror the eight desirable scientific practices outlined in the NGSS.

The OEIC divides scientific inquiry into eight phases: *Immersion*, *Research Question*, *Prediction*, *Experimental Design and Procedures*, *Observations*, *Analysis and Results*, *Conclusions and Explanations*, and *Future Research and Implications*. Forty

Table 4.5

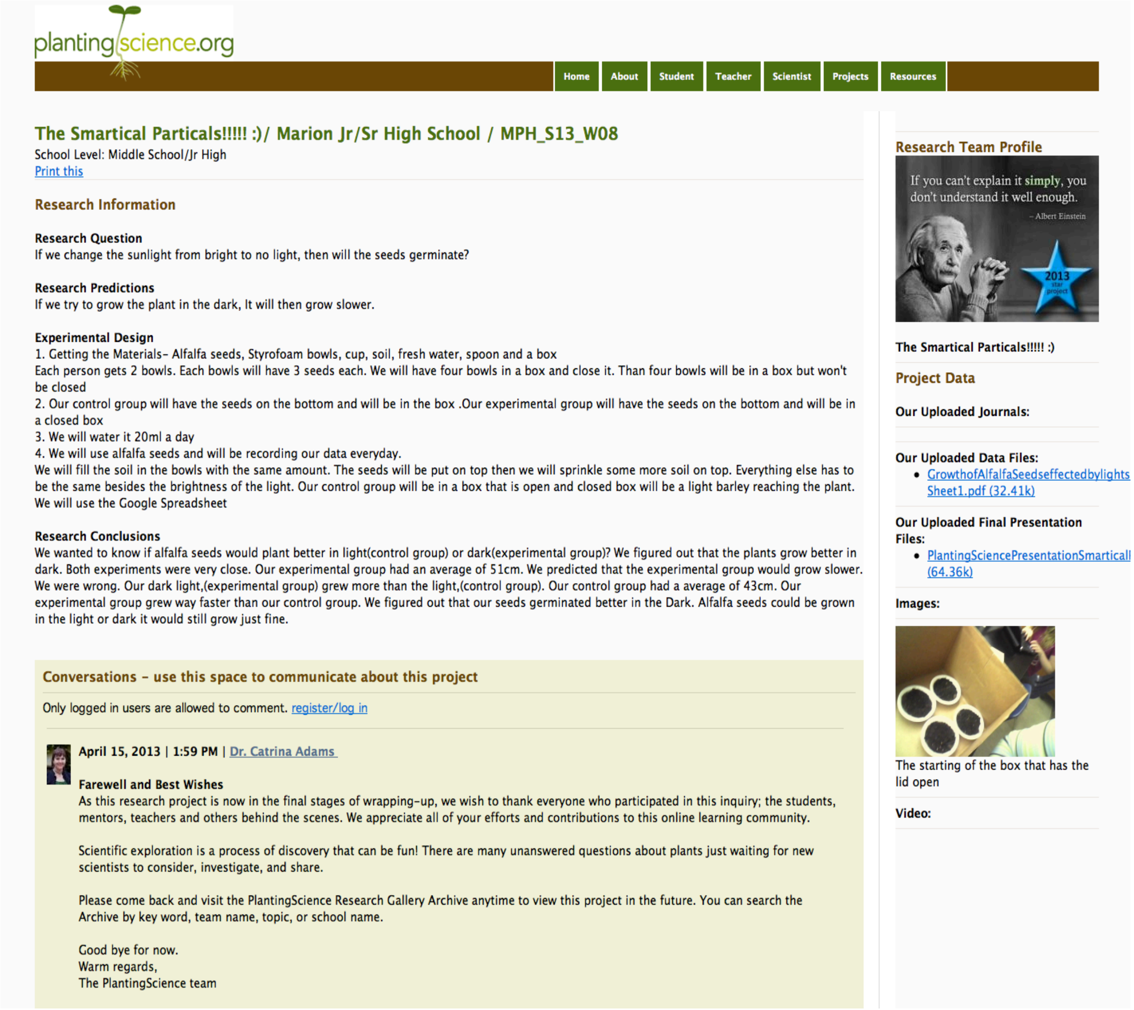
Forty Items of the Online Elements of Inquiry Checklist (OEIC; Peterson & Stuessy, 2011)

Inquiry Stage	Questions
Immersion	Is there mention of information-gathering efforts that occurred before students posed their research questions? Is there mention of prior knowledge or experiences that enabled the learners to question the relationship between variables?
Research Question	Is the research question appropriate for the context of the study? Are variables of interest observable and/or measureable? Is there explicit evidence that the research question is tied to prior knowledge or experience? Is there evidence that the students chose their own research question? Can the research question be answered within the scope and boundaries of the inquiry setting? Is the research question logically linked to a prediction, hypothesis, or expectation? If the question is causal in nature, is the research question testable through a scientific investigation? If the question is causal, is a relationship between the variables the focus of the research question?
Prediction	Is there evidence that the learners have considered possible or probable outcomes to their investigation? Is their evidence that a project outcome is based on prior knowledge or experience? Is the predicted outcome reasonable in light of the research question that is being asked?
Experimental Design	Did the research design enable the learners to answer the research question? Is there evidence that students themselves developed research methods? Is there a description of research methods in enough detail so that another research group could replicate them? Did the learners mention confounding variables? Are controls of variables mentioned? Is there mention that the learners controlled for possible sources of error in their observation methods?
Observations	Is there evidence that research events were recorded? Did the learners describe what they observed? Are data tables included in the inquiry project? Did the learners describe or discuss the data table(s)? Did the learners provide visual displays of their data such as graphs, charts, or pictures? Did the learners describe or discuss the visual displays? Do the visual displays follow accepted conventions?
Analysis and Results	Did the learners mention patterns or trends in the data? Did the learners compare data across multiple studies from other student groups? Did the learners mention unexpected results? Was the data used to answer the research question?
Conclusions	Are the conclusions of the experiment connected to the data that was collected? Are the conclusions consistent with the data that was collected? Did the learners support ideas about causality with data? Is there mention of alternative explanations? Did the learners compare their results to other studies' results? Did the learners discuss the limitations of their research? Did the learners justify their conclusions using data? Is there evidence of an expressed model or knowledge claim that explains relationships among variables with the natural phenomenon under investigation?
Future Research and Implications	Did the learners discuss the implications of their study? Is there mention of possible study revisions?

elements distributed within each of the eight phases further characterize the extent to which students demonstrate successful engagement in the phase. The instrument was applied to all online evidence confirming that a student-team had successfully engaged in each of the single elements subsumed within each phase of the inquiry. Percentages of phase completion were calculated using number of elements successfully completed divided by the total possible number of elements within the phase. These completion percentages served as the outcome variables in this study.

Data Sources and Collection

The PS website contains many areas for collecting uploaded data. For example, the *Research Information* section contains student-teams' research questions, research predictions, experimental design, and research conclusions (Figure 4.2). Additionally, journals (e.g., word processor files), data files (e.g., spreadsheet files), final presentation files (e.g., PowerPoint files), and images (e.g., photographs) are found in the *Project Data* section. I also consulted reflection memos completed by the teacher after the projects were completed to help describe the context of the study from the classroom perspective (PS Teacher, 2012). The PS website also archives the dialogues between student-teams and scientist-mentors via the asynchronous blog in the *Conversations* section. The dialogues contain typed comments made by students and scientist-mentors throughout the PS project. The dialogues were used as the data source for determining the motivation support provided by scientist-mentors. Data sources for determining student-teams' inquiry engagement included the dialogues as well, but also included



The Smartical Particals!!!!! :)/ Marion Jr/Sr High School / MPH_S13_W08
School Level: Middle School/Jr High
Print this

Research Information

Research Question
If we change the sunlight from bright to no light, then will the seeds germinate?

Research Predictions
If we try to grow the plant in the dark, It will then grow slower.

Experimental Design
1. Getting the Materials- Alfalfa seeds, Styrofoam bowls, cup, soil, fresh water, spoon and a box
Each person gets 2 bowls. Each bowls will have 3 seeds each. We will have four bowls in a box and close it. Than four bowls will be in a box but won't be closed
2. Our control group will have the seeds on the bottom and will be in the box .Our experimental group will have the seeds on the bottom and will be in a closed box
3. We will water it 20ml a day
4. We will use alfalfa seeds and will be recording our data everyday.
We will fill the soil in the bowls with the same amount. The seeds will be put on top then we will sprinkle some more soil on top. Everything else has to be the same besides the brightness of the light. Our control group will be in a box that is open and closed box will be a light barley reaching the plant. We will use the Google Spreadsheet

Research Conclusions
We wanted to know if alfalfa seeds would plant better in light(control group) or dark(experimental group)? We figured out that the plants grow better in dark. Both experiments were very close. Our experimental group had an average of 51cm. We predicted that the experimental group would grow slower. We were wrong. Our dark light,(experimental group) grew more than the light,(control group). Our control group had a average of 43cm. Our experimental group grew way faster than our control group. We figured out that our seeds germinated better in the Dark. Alfalfa seeds could be grown in the light or dark it would still grow just fine.

Conversations – use this space to communicate about this project

Only logged in users are allowed to comment. register/log in

April 15, 2013 | 1:59 PM | Dr. Catrina Adams

Farewell and Best Wishes
As this research project is now in the final stages of wrapping-up, we wish to thank everyone who participated in this inquiry; the students, mentors, teachers and others behind the scenes. We appreciate all of your efforts and contributions to this online learning community.

Scientific exploration is a process of discovery that can be fun! There are many unanswered questions about plants just waiting for new scientists to consider, investigate, and share.

Please come back and visit the PlantingScience Research Gallery Archive anytime to view this project in the future. You can search the Archive by key word, team name, topic, or school name.

Good bye for now.
Warm regards,
The PlantingScience team

Research Team Profile

The Smartical Particals!!!!! :)

Project Data

Our Uploaded Journals:

Our Uploaded Data Files:
- GrowthofAlfalfaSeedseffectedbylights Sheet1.pdf (32.41k)

Our Uploaded Final Presentation Files:
- PlantingSciencePresentationSmarticall (64.36k)

Images:

The starting of the box that has the lid open

Video:

Figure 4.2. Screenshot of a *PlantingScience* student-team project page. All projects are available to the public through the PS website (www.plantingscience.org).

evidence from student-teams' products (e.g., journals, charts, written reports) uploaded to the PS website.

Validity

Construct validity was established on several levels as recommended for case research by Yin (2009). First, both instruments used in this study (i.e., motivational support rubric and OEIC) were based on well-established research literature. Second, specific terms and concepts (e.g., autonomy support) were operationally defined using theoretical grounding. These definitions were supplemented with low inference descriptors (i.e., verbatim examples) as recommended by Johnson (1997; see Tables 4.2-4.4). Third, multiple data sources generated independently by student-teams and scientist-mentors were used in the study.

Internal validity was also established as recommended by Yin (2009) for case study research. First, SDT, an established motivation theory, served as the theoretical framework for the study. Second, mixed methods (i.e., multiple analytic techniques from both quantitative and qualitative paradigms) were used to evaluate the data and draw conclusions. Third, alternative explanations (i.e., rival hypotheses) for the final results were considered (see *Discussion* section in this chapter). Fourth, a predicted relationship between motivational support and student inquiry engagement was compared to empirical results from this study (i.e., pattern matching). Fifth, literal replicates (i.e., multiple cases) were included in each extreme grouping for specific parts of the analysis.

Analysis

I measured motivational support by quantifying the verbal dialogues (Chi, 1997) using an exploratory sequential mixed methods design (Creswell & Plano Clark, 2011). In the first phase, I qualitatively coded all scientist-mentor comments in the 10 case dialogues using the motivational support rubric (Appendix A). The dialogue for each case, as well as codes and indicators from the rubric, were entered into Dedoose 4.5.95, an online mixed methods analytical software. I used a deductive coding approach (Miles et al., 2014) with pre-determined indicators from the motivational support rubric.

Coding the scientists' dialogues was particularly challenging for several of the reasons mentioned by Strijbos, Martens, Prins, and Jochems (2006). First, asynchronous discussions are typically more complex (i.e., contain compound sentences) and contain longer posts than do synchronous discussions. As a result, segmentation of the dialogues for coding is more difficult. Second, project-based collaborations, which served as the context for the current study, occur over a longer period of time and contain more fragmentation than topic-based discussions. This type of discourse makes segmentation of the data more difficult since certain themes may be spread across several entries over an extended period of time.

In addition, the fact that PS students worked in teams yet had the ability to post as individuals on the PS website presented coding challenges. When multiple students from the same team posted questions from their individual profiles, scientists sometimes responded to each student's particular question as a separate entry instead of addressing all the student-team's questions in one large entry. These inconsistencies within and between scientist-mentors' dialogue entries made it difficult to establish an *a priori* method of segmentation.

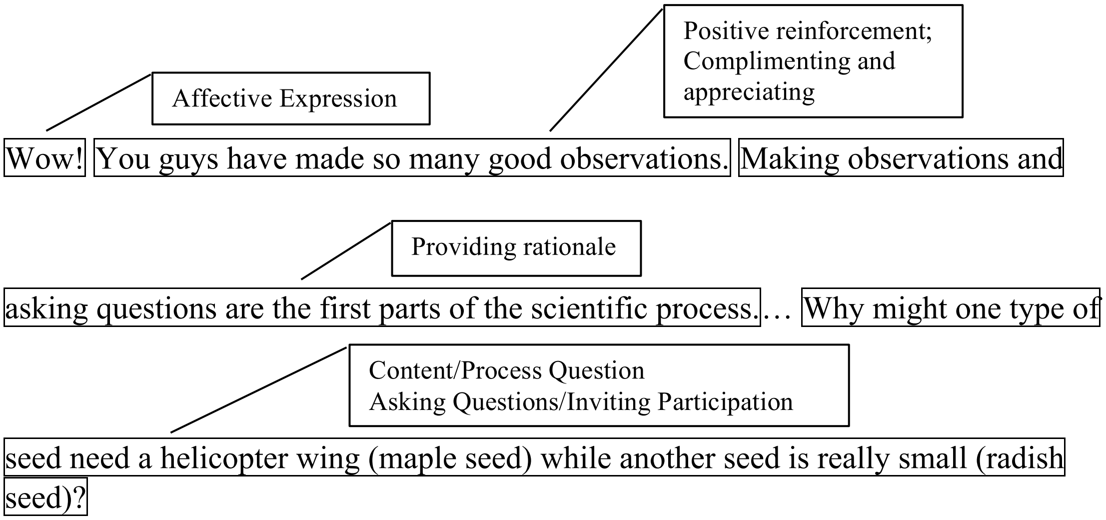
According to Chi (1997), a "searching rather than segmenting" (p. 12) approach can be used in situations where spontaneous occurrences of the phenomena in question are typical (e.g., Chi, Bassok, Lewis, Reimann, & Glaser, 1989). In the current study, scientist-mentors provided motivational support (i.e., autonomy, competence, and relatedness support) in a variety of ways including keystrokes, words, thought segments, sentences, and paragraphs. For example, the keystrokes “:)” were coded as *Affective Expression* and therefore illustrated relatedness support. Similarly, reference to a student-team name (i.e., words) by a scientist-mentor was coded as *Use of Names* and considered a relatedness support. While these two specific examples did not pose particular coding challenges, other entries did. For example, multiple, independent entries by scientist-mentors and large, single entries that were self-segmented by the scientist-mentors (e.g., sections set off by multiple blank lines) made it difficult to establish inter-coder reliability as it was impossible to establish segmentation rules beforehand. This challenge was exacerbated because coders had differing levels of expertise, which is almost always the case in large-scale research projects.

In an effort to address the challenges of these particular PS dialogues and present a robust and replicable coding framework, I utilized a coding procedure originally developed for semi-structured interviews by Campbell, Quincy, Osserman, and Pederson (2013). Like semi-structured interviews, the scientist-student dialogues used in the current study were much more diverse in their content when compared to transcripts generated from tight, structured interviews. The process developed by Campbell et al. (2013) was designed for these types of transcripts and provided a way to segment the transcripts using the expertise of the analyst as advocated by Krippendorf (2004). Campbell et al.’s coding process was developed to address the lack of standardized procedures for determining appropriate units of analysis for complex transcripts, as pointed out by Hruschka et al. (2004) and Kurasaki (2000).

As the most knowledgeable motivational researcher on the team, I identified meaningful units of analysis as I searched and coded the text using the motivational support rubric of prescribed codes. More specifically, I coded the smallest segments possible, or “raw data bits,” according to the procedure of Lincoln and Guba (1985). Simultaneous coding (i.e., co-occurring coding) was permissible, and only text corresponding to motivational support was coded. Next, I removed the codes and presented segments to two naïve coders in segmented form in order to establish reliability (see next section). While Campbell et al. (2013) acknowledged this method might inflate inter-coder reliability, they asserted this approach “eliminates a potential source of confusion when comparing the coding of two or more coders, especially when one is more knowledgeable than the rest” (p. 304). This method also provided a systematic way to address Krippendorff’s (2004) major concern that segmentation almost exclusively relies upon the qualifications of the coder. Figure 4.3 illustrates a coded excerpt from the current study using this methodology. After coding, I summed the numbers of codes for each motivational support category and calculated percentages.

Reliability

De Wever, Schellens, Valcke, and Van Keer (2006) consider inter-coder reliability as the primary indicator of objectivity in coding studies. As a result, these authors recommended calculating and reporting both a liberal index and a conservative index of agreement (De Wever et al., 2006). In the current study, both percent agreement (liberal index) and Fleiss’ kappa (conservative index) were used to indicate inter-coder reliability.



Wow! You guys have made so many good observations. Making observations and asking questions are the first parts of the scientific process.… Why might one type of seed need a helicopter wing (maple seed) while another seed is really small (radish seed)?

Figure 4.3. Example coding segment from Case 10 scientist-mentor.

Along with two naïve coders, I applied the motivational support rubric to a random sample of 50 excerpts generated from the 10 cases. Percent agreement values between the three coders were as follows: autonomy support – 85.3%; competence support – 88.9%; relatedness support – 85.3%. According to Lombard, Snyder-Duch, and Bracken (2002), over 80% agreement is acceptable.

Inter-coder reliability was also calculated using Fleiss’ (1971) kappa, a statistic appropriate for establishing multi-coder reliability and used in other science education studies with categorical variables (see Lee, 2010). Fleiss’ kappa, unlike percent agreement, corrects for chance agreement. Fleiss’ kappa values were as follows: autonomy support – 0.62; competence support – 0.72; relatedness support – 0.68. According to Cicchetti (1994), kappa values over 0.60 indicate good agreement. Similarly, Landis and Koch (1977) declared kappa values over 0.61 indicative of substantial agreement in categorically coded data. Based on these two indices, reliability of the motivational support rubric was established, and I coded the remaining dialogues from the 10 cases.

Research Questions

Using a mixed methods approach, I sought to answer the following four research questions:

1. How did autonomy, competence, and relatedness support differ between scientist-mentors in the 10 cases? What specific methods did scientist-mentors use to support motivation in student-teams?
2. What specific ways (based on social presence theory) did scientist-mentors establish relatedness with the 10 student-teams?
3. Did an association exist between the motivational support student-teams received from scientist-mentors and subsequent student-team engagement in the inquiry cycle among the 10 cases?
4. Using extreme group comparisons, what similarities and differences existed between highly engaged cases and less engaged cases? What similarities and differences existed between cases receiving high motivational support and cases receiving less motivational support?

Results

The purpose of this study was to evaluate online scientist-mentors’ motivational support of student-teams in a rural school district and investigate the potential associations of this support with students' inquiry engagement. Results are organized and reported according to the four research questions driving the study.

Research Question 1

How did autonomy, competence, and relatedness support differ between scientist-mentors in the 10 cases? What specific methods did scientist-mentors use to support motivation in student-teams?

Table 4.6 contains data about scientist-mentors' motivational support for all 10 cases. In most instances, cases 5 and 7 received the lowest amounts of motivational support while case 8 received the highest amount. Specifically, total motivational support varied from 31 total code segments in cases 5 and 7 to 132 code segments in case 8. On average, scientist-mentors provided 72 motivationally supportive assertions per project. Autonomy supportive code segments varied from 5 in cases 5 and 7 to 32 in case 8 with an average of 14. Similarly, competence supportive code segments varied from 7 in cases 5 and 7 to 37 in case 8 with an average of 18. Relatedness supportive code segments varied from 19 in cases 5 and 7 to 66 in case 2 (case 8 was a close second with 63) with an average of 40. These findings indicate a distinct "feast or famine" environment for student-teams in regard to the amount of motivational support they received from their scientist-mentors.

Equipped with the knowledge that scientist-mentors provided vastly differing *amounts* of motivational support, I turned my attention to how motivational support strategies differed within the cases. Based on the results in Table 4.6, I discovered only slight differences in relative uses of autonomy, competence, and relatedness-supportive codes between cases. In other words, relatedness-supportive codes were most common and autonomy-supportive codes were least common within each case (with the exception

Table 4.6

Scientist-Mentor Motivational Code Segment Counts

	SDT Category			
Cases	Autonomy Support	Competence Support	Relatedness Support	Total Support
1	12	21	30	63
2	17	26	66	109
3	14	18	34	66
4	18	16	47	81
5	5	7	19	31
6	13	13	34	60
7	5	7	19	31
8	32	37	63	132
9	8	13	34	55
10	12	26	52	90
Total	136	184	398	718
Mean	13.6	18.4	39.8	71.8
SD	7.8	9.4	16.6	32.1

of case 4), indicating scientist-mentors used similar patterns of motivational support but in vastly different quantities.

Also, within a given category of support (i.e., autonomy, competence, and relatedness), scientist-mentors, regardless of their overall amounts of support, sometimes used similar language in their dialogues with student-teams. For example, the scientist-mentor for case 8 (who provided the most motivational support of all 10 cases) provided autonomy support by encouraging the student-team to investigate something of interest to them. This scientist-mentor asked, “What have you always wondered about plants? Is there something about plants that you've always thought was interesting? If so, this may be something that your team can investigate with this seed project.” Similarly, the scientist-mentor for case 7 (who tied for lowest overall motivational support) asked, “What have you studied so far in class about germination? Do you have any ideas about what you might like to focus on?” In both cases, the scientist-mentors tried to inspire students to autonomously select a topic for their projects. The case 8 scientist-mentor, however, was much more suggestive of interests, even those outside of the students’ classroom experiences. In contrast, the scientist-mentor for case 7 suggested that students stick to things they previously covered in class. It is also helpful to remember that the case 8 scientist-mentor provided autonomy support six times more often than the case 7 scientist-mentor (i.e., 32 instances versus 5 instances).

Another difference with regard to autonomy support was the contrast between autonomy-supportive versus controlling language. For example, the scientist-mentor in case 8 often gave the student-team “space” to work through their own questions without providing prescriptive solutions. In the early stages of the project when students were possibly looking for the “right answer” as to which research question to pursue, the case 8 scientist-mentor stated, “Let me know when you’ve chosen one question to focus on, and I can help you with experimental design.” Conversely, the case 5 scientist-mentor (who tied for lowest autonomy and overall motivational support) sometimes presented ideas in a controlling fashion. “Set up some kind of air circulation near your potted seeds… Don’t point the fan directly towards the soil, point it horizontally across the surface of all your pots.”

A qualitative examination of competence support also revealed some interesting trends in the dialogues. Some scientist-mentors went to great lengths to expound on information, while others used a facilitator approach, providing students with direction but encouraging the students to do the “leg work” themselves. An example of this contrast in competence support is in Table 4.7.

In addition to offering explanations, scientist-mentors also supported student competence through content and process questions. As a matter of fact, content and process questions were the most common ways competence support was provided by the top three motivationally supportive scientist-mentors (cases 2, 8, and 10; Table 4.8).

Specifically, scientist-mentors used these questions for a variety of reasons including: (1) ascertaining background knowledge of the student-teams, (2) requiring students to clarify statements, (3) asking students to justify decisions, and (4) encouraging students to draw conclusions. Examples of the questions scientist-mentors asked are found in Table 4.9.

Scientist-mentors also differed in the ways they provided relatedness support in the dialogues. Since relatedness support was measured using indicators informed by social presence theory, these differences were investigated as part of a separate research question.

Table 4.7

Examples of Explicit Versus Facilitator Approaches by Scientist-Mentors

Approach	Examples
Explicit	I have looked into the differences between light bulbs and found the following: regular incandescent bulbs (typical old light bulbs) produce light by sending electricity through a thin filament of metal. This causes the filament to radiate light and heat. Incandescent bulbs actually create more heat (infrared wavelengths) than light (visible wavelengths) which is why most people are switching to new compact fluorescent lights (CFLs) to save energy and reduce power costs. Heat lamps are almost identical to incandescent light bulbs except that more electricity flows through the filament so that additional heat is created. These bulbs may also use reflectors to focus the generated heat in one direction. Additionally some heat lamps have tinted glass which blocks certain wavelengths (mainly visible wavelengths) allowing only infrared wavelengths (heat) to escape the bulb. Plants absorb certain wavelengths of light during photosynthesis to create usable energy. Heat lamps and regular light bulbs may release different amounts of these wavelengths causing differences between plants grown under heat lamps and regular bulbs. [Case 6 Scientist-mentor]
Facilitator	Another option is to look at the components of various brands or types of fertilizers. Miracle Grow is one example and it comes in a variety of nutrient components. [Case 4 Scientist-mentor] You might want to research some plants that you want to work with (e.g. corn, beans, peas) and what types of minerals and nutrients they need to grow. Then, you can look up with the nutritional components are of Gatorade. This can help aid in your hypothesis. [Case 4 Scientist-mentor]

Table 4.8

Scientist-Mentor Competence-Supportive Motivational Code Segment Counts

	Competence-Supportive Code Segments				
Cases	Content/Process Questions	Offering Explanations	Positive Feedback	Total Competence	Overall Motivational Support Ranking
Case 1	12	8	1	21	6
Case 2	21	2	3	26	2
Case 3	8	7	3	18	5
Case 4	3	11	2	16	4
Case 5	3	4	0	7	9.5
Case 6	6	5	2	13	7
Case 7	6	0	1	7	9.5
Case 8	21	11	5	37	1
Case 9	7	4	2	13	8
Case 10	20	2	4	26	3
Total	107	54	23	184	
Mean	10.7	5.4	2.3	18.4	
SD	7.3	3.8	1.5	9.4	

Table 4.9

Example Content and Process Questions Asked by Scientist-Mentors in the Dialogues

Purpose of Question	Examples
Background Knowledge	Have you learned about what types of nutrients plants require? [Case 10 Scientist-mentor]
	What things or materials do you think seeds need to germinate and grow in the wild? [Case 8 Scientist-mentor]
	Why might one type of seed need a helicopter wing (maple seed) while another seed need to really small (radish seed)? [Case 10 Scientist-mentor]
Clarify	What are you going to measure to see if your hypothesis is supported or not? [Case 7 Scientist-mentor]
	What size containers are you using to grow your plants? [Case 3 Scientist-mentor]
	How much water was in the cup? (Was there a lot of water in the cup, so that the seeds were covered? Just tiny bit of water? Or something in between?) [Case 2 Scientist-mentor]
Justify	Why did you choose to compare potting soil and perlite? Why do you think the seeds will grow faster in potting soil? [Case 2 Scientist-mentor]
	Why did you make your predictions the way you did (sunflower fastest, alfalfa next, radish slowest)? [Case 8 Scientist-mentor]
	Are you sure that growth of your plants in different soils will be due only to the soil type? [Case 10 Scientist-mentor]
Draw Conclusions	Can you think of another reason why plants grown under a heat lamp may turn out different than those grown under regular light bulbs? [Case 6 Scientist-mentor]
	What sort of things did you learn from your experiment? Is there anything you would do differently next time? [Case 10 Scientist-mentor]
	Have you begun looking at your results and drawing any potential conclusions? [Case 4 Scientist-mentor]

Research Question 2

What specific ways (based on social presence theory) did scientist-mentors establish relatedness with the 10 student-teams?

Table 4.10 contains raw counts, means, and standard deviations of interpersonal, cohesive, and open communication codes for all 10 cases. Overall, relatedness-supportive codes ranged from 19 in cases 5 and 7 to 66 in case 2, with an average of 40 codes. Specifically, interpersonal communication codes ranged from 3 in case 7 to 16 in case 8, with an average of 10. Cohesive communication codes ranged from 9 in case 5 to 29 in case 2, with an average of 17. Open communication ranged from 4 in cases 5, 7, and 9 to 25 in case 2, with an average of 12. In 8 of 10 cases, cohesive communication was the most common form of relatedness support. Additionally, in 8 of 10 cases, scientist-mentors used open communication more often than interpersonal communication.

Of the three forms of interpersonal communication, affective expression was used most often. This fact is not surprising as affective expression is the easiest of the three to share in a text-based medium. Inclusion of the keystrokes ":)," symbolic of a smiley face, is a simple affective expression. On the contrary, scientist-mentors rarely used humor, with only 5 occurrences in all 10 cases. Self-disclosure was much more common, with 19 instances occurring in the 10 cases. Only two scientist-mentors (cases 5 and 7) failed to share any personal information through self-disclosure with their student-teams.

Table 4.10

Scientist-Mentor Relatedness-Supportive Code Segment Counts

	Relatedness-Supportive Code Segments			
Cases	Interpersonal Communication	Cohesive Communication	Open Communication	Total Relatedness
1	9	10	11	30
2	12	29	25	66
3	10	12	12	34
4	12	21	14	47
5	6	9	4	19
6	7	12	15	34
7	3	12	4	19
8	16	27	20	63
9	14	16	4	34
10	12	25	15	52
Total	101	173	124	398
Mean	10.1	17.3	12.4	39.8
SD	3.9	7.5	7.0	16.6

When self-disclosing, scientist-mentors often included information about their professional lives as scientists. Typically, these dialogues occurred at the beginning of the online relationship, although scientist-mentors sometimes disclosed additional information about themselves in response to specific student questions. In addition, scientist-mentors sometimes disclosed personal things unrelated to either their profession or the PS project. These "off topic" comments ranged from music preferences to information about where the scientist lived and worked. Examples of scientist-mentor comments related to self-disclosure are located in Table 4.11.

In addition to interpersonal communication, all scientist-mentors used various forms of cohesive communication in their dialogues with student-teams. Not surprisingly, *Use of Names* was the most common form of cohesive communication,

Table 4.11

Examples of Self-Disclosure by Scientist-Mentors in the Dialogues

Type of Disclosure	Examples
Personal Information	I like all kinds of music, but I especially like old rock and roll music from the 50's and 60's. I am afraid I don't know any rap music, but I do listen to it sometimes as my youngest daughter is a fan. [Case 3 Scientist-mentor]
Professional Background	We do experiments to research issues that are important to farming and the environment in the US. The site I work at focuses on plants and particularly on subjects like food safety and quality improvement, disease and pest management, control of invasive species, and energy applications. We have our own research projects, but usually work in groups and collaboration is highly encouraged. That way we can take advantage of the expertise of our coworkers and can apply what they know to better our own work. We also do a lot of talking to get many opinions and perspectives as we are planning research. I work on a small grass that is the "lab rat" for other grasses such as corn, wheat, rice, and switchgrass. These plants may seem different at first, but they all share a common ancestor and in the system that scientists use to classify groups of plants, they share similar appearance, growth characteristics, and genomes. For this reason, what you learn about one, can often be applied to all of them. [Case 1 Scientist-mentor]
Past Experiences as a Student	Although I don't think frog dissections will come into play with THIS experiment, I remember having fun when I finally got to do that in 7th grade biology class. My lab partner didn't like it at all, so I got to do all the dissecting! [Case 8 Scientist-mentor]
Connections Between Students' Work and Scientist's Work	My lab is going great. I'm mainly doing work with DNA this semester. I will start my fieldwork in the spring. I'm doing a much different experiment than your group, but I do perform seed germinations fairly frequently. [Case 9 Scientist-mentor]

probably due to easy inclusion. *Salutations/greetings/phatics* was the next most common, with scientist-mentors' comments ranging from, "Hi everyone!" to "How's the weather?" *Inclusive language* was also found in the dialogues, with scientist-mentors often referring to themselves as "part of the team" and expressing the idea of a shared partnership in PS inquiry project (e.g., "I'm glad that you're part of the experiment as well! I can't wait to work with you more." – case 9 scientist-mentor). Again, many of these comments were made early in the online relationship, but others were made as student-teams and scientist-mentors engaged in discussions about the project itself. For example, the scientist-mentor in case 1 commented, "Let's think [together] about the properties of those two liquids."

Scientist-mentors typically asked questions and invited participation when engaging in open communication (48% of all codes in the open communication category were related to asking/inviting participation). Scientist-mentors were sometimes general in their invitation, stating, "I can't wait to hear more. Let me know if you have any questions" (case 10 scientist-mentor). In other instances, invitations were much more specific and probed for feedback about particular results from the experiment, such as the comment by the case 2 scientist-mentor: "Have you observed your plants this week? I'm curious about how they're doing—but especially wondering if the perlite seeds have germinated or not."

Student response times to these questions and invitations varied. In both of the examples from the preceding paragraph, student-teams responded the next day. Other invitations, such as "Let me know what you think about these questions" (case 9 scientist-mentor) were not answered until one full week later. In an extreme case, the scientist-mentor in case 7 never received a response related to a posed question.

Interestingly, the case 7 student-team had the lowest OEIC score of all 10 cases, indicating little engagement in the inquiry process.

Research Question 3

Did an association exist between the motivational support student-teams received from scientist-mentors and subsequent student-team engagement in the inquiry cycle among the 10 cases?

Student-team engagement in the inquiry cycle was measured using the 40 elements of the OEIC (see Table 4.5). OEIC scores were calculated for each of the 10 cases by two researchers involved primarily in other aspects of PS research. Relative percentages of student engagement in the eight inquiry phases were calculated. See Table 4.12 for student-team OEIC scores by case. Overall OEIC scores ranged from 8 (case 7) to 85 (case 10), with an average of 53. Student-teams averaged the highest OEIC score during the *Prediction* phase. The lowest mean scores were recorded during the *Experimental Design and Procedures* phase.

Spearman's *rho* was calculated to determine potential associations between scientist-mentor motivational support and student-team inquiry engagement for each element of inquiry (Table 4.13). Autonomy support showed no significant associations with student inquiry engagement in any phase, a finding contrary to SDT. A significant and moderate association was found between competence support and the *Research Question* phase. Moderate correlations were also found between competence support and *Observations*, *Conclusions*, and *Future Research and Implications*, but these correlations were not statistically significant. Relatedness support was highly associated

Table 4.12

Percentages of Student-Team Inquiry Engagement By Inquiry Stage

	Cases										
Inquiry stage	1	2	3	4	5	6	7	8	9	10	*Mean*
Immersion	0	100	50	50	50	100	0	50	100	100	60
Research Question	75	100	38	88	63	50	13	75	75	100	68
Prediction	67	67	67	33	67	100	33	100	100	100	73
Experimental Design	50	33	0	0	33	50	17	0	50	67	30
Observations	57	86	71	71	57	57	0	57	71	100	63
Analysis and Results	25	25	25	50	75	75	0	50	50	75	45
Conclusions	63	63	13	50	25	63	0	50	50	63	44
Future Research	50	50	50	50	50	50	0	50	50	100	50
Mean	55	68	35	53	50	63	8	53	65	85	53

Note. Numbers represent percentage of OEIC completion for the elements within each inquiry stage. The overall mean OEIC score was calculated on the basis of total number of elements within the entire checklist without reference to scores on individual stages.

Table 4.13

Spearman's Rho Correlations Between Scientist-Mentor Motivational Support and Student-Team Inquiry Engagement

	Motivational Support Category		
Inquiry stage	Autonomy Support	Competence Support	Relatedness Support
Immersion	.170	.204	.573
Research Question	.406	.685*	.738*
Prediction	.098	.342	.362
Experimental Design	-.492	-.032	-.092
Observations	.331	.500	.679*
Analysis and Results	-.032	-.032	.121
Conclusions	.293	.555	.508
Future Research	.235	.552	.514

Note. $^*p < .05$

with the *Research Question* phase and moderately associated with the *Observations* phase. While moderate correlations occurred between relatedness support and *Immersion*, *Conclusions*, and *Future Research and Implications*, these correlations were not statistically significant.

Research Question 4

Using extreme group comparison, what similarities and differences existed between highly engaged cases and less engaged cases? What similarities and differences existed between cases receiving high motivational support and cases receiving less motivational support?

For this particular question, I used an extreme group comparison strategy (Chase, 1964) to replicate cases and create disparate groupings for mixed methods comparison. According to Chase (1964), extreme group comparison is useful when comparing high and low scorers on a given characteristic on some other characteristic. As a form of triangulation, I formed two different extreme groupings based on two different criteria: scientist-mentor motivational support (as determined by the motivational support rubric) and student inquiry engagement (as determined by the OEIC).

In the first grouping, I divided the 10 cases based on total scientist-mentor motivational support as determined by the number of motivationally supportive codes. The top three and bottom three cases in regard to total scientist-mentor motivational support were grouped together. Table 4.14 provides information about the specific cases (i.e., replicates) included in this first grouping. I identified these cases as highest motivational support (HMS) and lowest motivational support (LMS).

In the second grouping, I divided the 10 cases based on student inquiry engagement as determined by total OEIC scores. The top three and bottom three cases in regard to total OEIC scores were grouped together. Table 4.14 provides information about the specific cases (i.e., replicates) included in this second grouping. I identified these cases as highest engagement (HE) and lowest engagement (LE).

Table 4.14

Breakdown of Extreme Group Comparisons Based on Amount of Scientist-Mentor Motivational Support (First Grouping) and Student-Team Inquiry Engagement (Second Grouping)

	First Grouping		Second Grouping	
	Highest Scientist Motivational Support (HMS)	Lowest Scientist Motivational Support (LMS)	Highest Student Engagement (HE)	Lowest Student Engagement (LE)
Cases	Case 2 Case 8 Case 10	Case 5 Case 7 Case 9	Case 2 Case 9 Case 10	Case 3 Case 5 Case 7
Mean	110.3	39.0	72.6	30.9
SD	21.0	13.9	10.8	24.2

Note. *Mean* and *SD* based on number of motivationally supportive code segments of each case in grouping

Note. *Mean* and *SD* based on total OEIC score of each case in grouping

Quantitative results from extreme group comparisons. From the first grouping, I compared HMS and LMS cases in regard to student-team inquiry engagement in the eight phases of inquiry (Table 4.15). Overall, HMS cases scored 68 on the OEIC compared to 41 in LMS cases. In other words, HMS student-teams showed evidence of engagement in 68% of the items on the OEIC compared to 41% for LMS

Table 4.15

Percentages of Student-Team Inquiry Engagement (as Determined by OEIC) by Extreme Group

	Extreme Groups (based on motivational support)	
Inquiry stage	HMS Cases (n = 3)	LMS Cases (n = 3)
Immersion	83	50
Research Question	92	50
Prediction	89	67
Experimental Design and Procedures	33	33
Observations	81	43
Analysis and Results	50	42
Conclusions and Explanations	59	25
Future Research and Implications	67	33
Mean Inquiry Engagement	68	41

Note. Numbers represent percentage of OEIC completion for the elements within each inquiry stage. The mean OEIC score was calculated on the basis of total number of elements within the entire checklist without reference to scores on individual stages.

student-teams. Specifically, with the exception of *Experimental Design and Procedures*, HMS case student-teams showed higher engagement in all phases of the inquiry cycle when compared to the LMS cases. The equal scores in *Experimental Design and Procedures* for the two groups were unexpected. The greatest differentiations (> 30 percentage points) in engagement between the HMS cases and LMS cases were in 5 of the 8 inquiry phases (i.e., *Immersion*, *Research Question*, *Observations, Conclusions and Explanations,* and *Future Research and Implications*). HMS cases scored over 20 percentage points higher in *Prediction*. I also found a small difference (< 10 percentage points) between the HMS cases and the LMS cases in *Analysis and Results*. The overall trend of HMS cases engaging in inquiry at higher levels was apparent.

One puzzling finding was the discovery that student-teams across the board did not engage well in the *Experimental Design & Procedures* phase of inquiry. However, this trend has been documented in other research about PS (Peterson, 2012). The Peterson (2012) study revealed that even though scientist-mentors emphasized experimental design more often than any other stage of inquiry, student-teams consistently showed less evidence of engagement in this phase. Also, in the current study, lack of engagement in *Experimental Design & Procedures* may be a limitation posed by the purpose of the OEIC to evaluate only information posted on the PS website, thereby providing no way of recording students' actual in-class engagement in inquiry. While engagement in this phase may be occurring at a much higher level in actual classroom practice, only student-teams who make online references to their classroom engagement receive credit on the OEIC.

From the second grouping, I compared HE and LE cases in regard to the amount and type of motivational support they received from scientist-mentors (Table 4.16). Overall, HE cases received more motivational autonomy, competence, and relatedness support than LE cases. The greatest differentiations were found in competence and relatedness support. Overall, HE cases received almost twice as much motivational support as LE cases. The association between higher engagement and more motivational support was also apparent from this group comparison.

Trends in the cases. The information in Table 4.14 revealed trends that formed the basis of subsequent qualitative comparisons. First, cases 2 and 10 were both HMS and HE cases, indicating they received the highest amounts of scientist-mentor

Table 4.16

Number of Motivationally Supportive Coding Segments (as Determined by Motivational Support Rubric) and Amount of Scientist-Mentor Motivational Support by Case Grouping

	Extreme Groups (Based on OEIC Scores for Inquiry Engagement)	
Type of Motivational Support	HE Cases (*n* = 3)	LE Cases (*n* = 3)
Autonomy Support	37	24
Competence Support	65	32
Relatedness Support	152	72
Total Motivational Support	254	128

motivational support and exhibited the highest inquiry engagement. I referred to these two cases as *Exemplary*. A professor of plant genetics with no PS mentoring experience mentored case 2. A graduate student in cellular biology with four semesters of PS mentoring experience mentored case 10.

In contrast to the *Exemplary* cases, cases 5 and 7 were included as LMS and LE cases, indicative of the lowest amounts of scientist-mentor motivational support and least amount of inquiry engagement. I referred to these two cases as *Unsatisfactory*. Case 5 was mentored by a graduate student in plant physiology with no experience mentoring in PS. Case 7 was mentored by a graduate student in cellular biology with two semesters of PS mentoring experience.

The *Exemplary* and *Unsatisfactory* cases followed an expected pattern. Figure 4.4 illustrates the proposed relationship between scientist-mentors' motivational support and student inquiry engagement. SDT postulates motivation occurs on a continuum

(Ryan & Deci, 2000a), and differing contextual support levels have effects on overall motivation (Ryan & Deci, 2002). Therefore, SDT predicts students who receive more motivational support will be more engaged (Deci & Ryan, 2000). Likewise, less motivational support can lead to less engagement. According to my hypothesis, when scientist-mentors' motivational support increased (as measured by the motivational support rubric), I predicted an associated increase in student inquiry engagement (as measured by the OEIC). Both the *Exemplary* and *Unsatisfactory* cases supported this prediction.

However, case 9 was unique because it was included in the LMS and HE groups. In other words, the student-team received low amounts of scientist-mentor motivational support yet exhibited high inquiry engagement. I referred to this case as *Atypical*. A graduate student in plant physiology with no PS mentoring experience mentored case 9.

Qualitative comparison of *Exemplary* and *Unsatisfactory* cases. The scientist-mentors in the *Exemplary* cases were similar in how they provided motivational support to their student-teams. Both scientist-mentors set the stage for building relationships with students from the first post. Table 4.17 contains verbatim first posts from both the *Exemplary* and *Unsatisfactory* cases. Both *Exemplary* scientist-mentors opened their posts with affective expressions. They also expressed excitement about partnering with students in the inquiry projects (an example of relatedness support) and tried to engage learners with questions. In addition, the scientist-mentor in case 2 provided specific information indicating knowledge about what the student-teams had already done in class. While this may seem trivial, this acknowledgement indicated the scientist-mentor

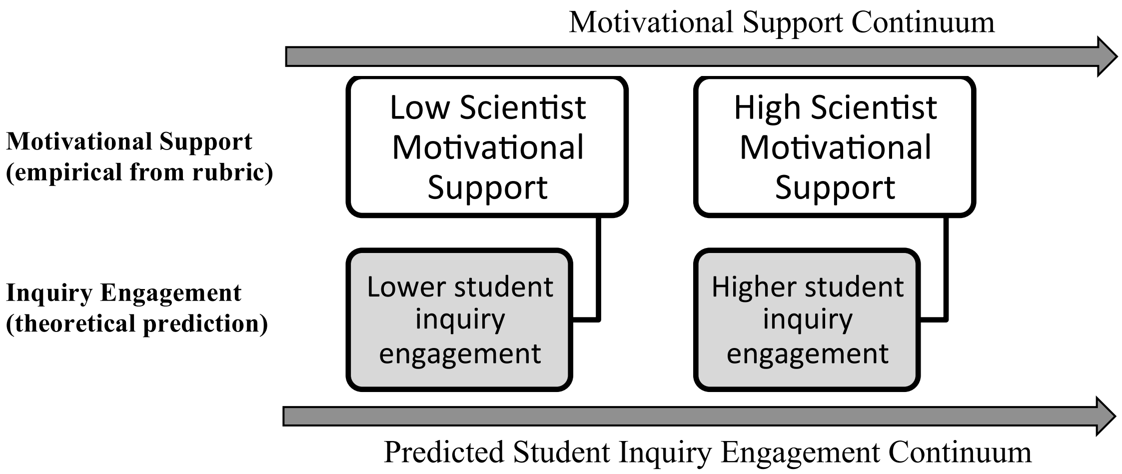


Figure 4.4. Proposed hypothetical framework based on SDT.

communicated with the teacher before the project began (which shows special interest). Both *Exemplary* case mentors also showed a personal interest in their student-teams, with the case 2 mentor asking, “What were the most interesting things that you noticed about seeds?” and the case 10 mentor asking, “What is your favorite plant?” Both *Exemplary* mentors also shared personal information (i.e., self-disclosure) in this important first contact and signed off using their first names (i.e., cohesive communication).

The mentors in the *Unsatisfactory* cases (5 and 7) also opened their first posts with affective expressions and closed their posts with first names. In addition, they expressed excitement about working with students. However, neither *Unsatisfactory* case scientist-mentor asked any questions to either support competence or promote future engagement (i.e., support relatedness). The case 7 scientist-mentor did little to support motivation (or anything else) in the first post.

Table 4.17

Verbatim "First Posts" from Exemplary and Unsatisfactory Cases

Case Type	Case	Examples
Exemplary	2	Hello [Team Name]! Thanks for telling me a little bit about yourselves. I have never been in a band, but I do mostly listen to rock music. I even sometimes listen to rock music while I'm studying plants in my laboratory! I'm excited to be working with you, too. I work at [college], which is in [town]. Part of my job is to teach biology classes to college students. The other big part of my job is to work with college students to conduct experiments in my laboratory. Most of my research focuses on a part of the plant called the "shoot apical meristem" (SAM, for short). Have you heard of the SAM? [Teacher's name] mentioned to me that last week you observed some germinating seeds. What were the most interesting things that you noticed about the seeds? [First name of scientist-mentor]
	10	Hiya! My name is [first name of scientist-mentor] and I will be your mentor for the next few weeks. I am super excited to find out what questions you will have for me. Do you know what project you will be working on? What have you learned about plants? What is your favorite plant? Mine is the Sunflower. ~[First name of scientist-mentor]
Unsatisfactory	5	Hello All Hope you all are doing well. I'm excited to work with you on your experiment! @[student name]: Yes, all plants have structures in the seed. This link shows the major parts of the internal structure of seedshttp://www.landlearn.net.au/newsletter/2008term2/images/Seed-rotated.jpg. @[student name]: Yes seeds have an embryo inside, that's what the small plant comes from. @[student name]: The seeds form inside the watermelon. A watermelon is like a apple or an orange. The seeds are inside the fruit where the develop into mature seeds. The actual part of the watermelon that you eat is the plants ovary. In some of these types of plants the purpose of the fruit is to attract animals which eat the fruit and its seeds and excrete them in feces in another location. This carries seeds to other areas for the plant to grow. If you all have any other questions feel free to ask :) [First name of scientist-mentor]
	7	Hello team! Greetings! I can't wait to hear from you. -[First name of scientist-mentor]

As the projects matured, further differences were noted between the *Exemplary* and *Unsatisfactory* cases. Student-teams in both of the *Exemplary* cases seemed to develop a comfortable relationship with their scientist-mentors. Student-teams in these cases included their scientist-mentors as part of the research team, often asking the scientist-mentors for help. For example, the students in case 2 asked, “We are not sure how much water to put in it, can you help us?” In these cases, students considered advice from the mentors and made some decisions based on the feedback. In another example, the case 10 students commented to their scientist-mentor, “Thank you for all the info, it really helped us come to the decision of comparing the rate of germination.” Over the course of the project, these *Exemplary* student-teams seemed to look forward to hearing from their mentors and seriously considered any advice they received.

I also noticed that mentors of *Exemplary* student-teams treated students’ questions as important. When *Exemplary* student-teams asked questions, their scientist-mentors spoke directly and relevantly to those questions. In one instance, the scientist-mentor in case 2 responded to a student-team’s request with the following:

> A few of you said that you’re curious about whether seeds grow faster in soil or without. Can you tell me a little more about how you and [teacher’s name] grew the seeds that you looked at last week?....Some of you also wondered whether a seed could sprout or keep growing after you cut it in half. This made me wonder three things: (1) What kinds of seeds did you observe last week?, (2) Did you…cut open any of the seeds?..., (3) What do you all think might happen if you cut a seed in half?

This response exudes thought, concern, and a desire for continued discourse on the matter. In contrast, the response of the scientist-mentor from case 5 (see Table 4.17) were factual "answers" to questions posed by students and provided no connections to the project at hand, indicating little thought about the project. In another instance from the *Unsatisfactory* case dialogues, the case 7 student-team expressed interest in looking at the effects of varying sugar concentrations on seed germination and plant growth. In a response the next day, the case 7 scientist-mentor asked, "Do you have any ideas about what you might like to focus on?" and never indicated she read the students' previous comments. This lack of relatedness support could have affected the students' motivation to engage their scientist-mentor in future discussions. As a matter of fact, after this particular exchange, the student-team in case 7 did not post for nine days. When the team did post, it was to inform the scientist-mentor they had already started their experiment.

Qualitative results for the *Atypical* case. The discourse for Case 9, the *Atypical* case, started out with both students and the scientist-mentor engaged in ongoing conversation. The scientist-mentor's opening post was rich. The post contained a salutation, affective expression, self-disclosure, inclusive language, acknowledgment of ownership/interest, use of names, a rationale, and references to previous student posts. The scientist-mentor encouraged students and asked many questions to bolster both competence and relatedness. Early on, the student-team responded to comments by the scientist-mentor in positive ways such as, "Thank you very much for the recommendations. We are using the same water conditions for each. Oh yeah, and thank you for reminding me about the lighting conditions," and "Thank you for the suggestions. We do not have them in strong sunlight, but they are doing great."

One of the most interesting aspects of this conversation was the revelation by one member of the student-team that, "I have been working on the experiment at my house." While it is impossible to ascertain from the dialogues if this was an accurate statement, its plausibility may help explain why student inquiry engagement levels for this case were high when scientist-mentor motivational support was low. Working on the project at home is indicative of intrinsic interest on the part of the student(s). As a result, perhaps the student(s) in this team were not affected by the overall lack of outside motivational support from the scientist-mentor.

The puzzling results from this *Atypical* case may also point to a potential shortcoming of our measure of motivational support. Since the motivational support rubric is based on quantitative counts, it may sometimes fail to capture the essence of specific, targeted, high quality motivational support. While the amount of motivational support was low, qualitative analysis of the dialogue indicates members of the student-team may have developed a sense of relatedness with the scientist-mentor anyway. For example, one of the last student-team comments for case 9 was as follows:

> Dear [Scientist-mentor name]. Hi, I am happy that I got a chance to work on here with you as my mentor. I just want to say THANK YOU!!! :) I really appreciate all of your suggestions. We were so happy to have you following us on our project. I'm sad that we aren't doing our project any more, but once again I just

> want to say thank you, thank you, thank you very much. Sincerely, your "science buddy" :) [Student name] <3

In this particular case, the results were confounded but yet speak to the value of looking at the data from multiple perspectives and using different techniques and methodologies.

Discussion

This study was designed to evaluate associations between online scientist-mentor motivational support and student inquiry engagement. The hypothesis proposed at the beginning of this chapter (see Figure 4.4) stated increased motivational support from online scientist-mentors would associate with greater student-team inquiry engagement. While not claiming causality, this multiple-case replication study provides strong evidence supporting the existence of a relationship between the two variables. However, several interesting and unexpected aberrations were uncovered, providing valuable insight into the complex world of online mentoring. These findings can inform future strategies for supporting students' motivational resources in online environments.

Challenges and Benefits of Using Scientists as Online Mentors

Analyses indicated scientists-mentors provided vastly different *amounts* of motivational support to their student-teams. While explicit reasons for this disparity in motivational support cannot be determined from this study, I carefully offer some insights. Scientists involved in PS are typically research scientists and not educators. They volunteer their time as mentors in classroom science projects. Other than some mentoring-related training resources on the PS website, most scientists are not trained to facilitate online learning and/or establish social presence in virtual environments.

Additionally, they are not trained in motivational theory or self-determination. This study indicates some scientists are quite adept at providing motivational support through online communication in spite of the circumstances. However, thoughts that student engagement will automatically increase with indiscriminate recruiting and placement of scientists in classrooms, whether virtual or face-to-face, are limited at best.

In order to make online programs like PS more effective and equitable for all participants, preparing online mentors to deliver motivational support seems warranted. Previous research documents the challenges of facilitating online learning environments (Rovai, 2007). As previous PS-specific research shows, orchestrating the complexities of a blended environment incorporating inquiry with technology is extremely complex, even for seasoned educators (Scogin, Stuessy, et al., 2013). Scientists, and all other online mentors, need training in online-specific strategies to provide appreciable choice, engage students in challenging conversation, and establish connectedness between people through social presence. In the cases studied here, mentors who used these strategies made a difference. Based on the varying propensities of scientists to provide motivational support, the skills needed to support vibrant and engaging online environments are not necessarily intuitive. Therefore, we must give explicit attention to developing online mentors who will provide motivationally supportive assistance to science learners.

Previous research on PS revealed training teachers to orchestrate the complex PS environment had positive impacts on student inquiry engagement (Peterson, 2012). If training had an impact on teachers, it stands to reason that additional training for scientist-mentors would also increase student inquiry engagement. Research by Pekar and Dolan (2012) revealed that scientists operating in classroom partnerships typically occupy different roles from classroom teachers. In the Pekar and Dolan study, scientists provided conceptual and epistemological support, while teachers necessarily made sure students had access to the new knowledge. In other words, teachers were “better prepared and positioned” to offer pedagogical support, while scientists were more equipped to integrate scientific terminology, relate issues of the nature of science, and make real-world connections to science. These findings show the potential importance and value of using trained scientists as online mentors who, as Edelson (1998) might say, provide authenticity not often experienced in science classrooms.

The Roles of Autonomy, Competence, and Relatedness Supports in Online Mentoring

The correlational analysis (Table 4.13) revealed no significant associations of autonomy support with student engagement at any inquiry stage in this study. In addition, one of the HMS cases (case 10) actually had an autonomy support count less than the mean of all 10 cases (see Table 4.6). The lack of statistical evidence of a relationship between autonomy support and student engagement was unexpected. SDT research claims that autonomy is the most important factor in self-determined motivation (Deci & Ryan, 2000). Entering the study, we thought autonomy support by scientist-mentors would be a critical component leading to increased student inquiry engagement. I offer a few thoughts on the lack of evidence supporting this hypothesis.

Online environments are naturally autonomous because of the transaction distance involved between participants (Moore, 1993). Perhaps autonomy-supportive statements by scientist-mentors made little difference to students as students already felt in control of the process. Students could ultimately decide whether to respond to scientists' comments and, if so, when. Also, it is conceivable that autonomy support is not as important in online mentoring relationships such as PS. Students, knowing that online mentors are not in a position to enforce demands and/or change grades, may feel autonomous regardless of how an online mentor expresses autonomy support through text. Or, once scientists expressed autonomy support and students felt comfortable and in control, maybe future autonomy-supporting expressions had little additive effect. The role of autonomy support in online text-based contexts definitely needs more investigation to determine how or if autonomy support differs in online versus face-to-face contexts.

While a relationship between autonomy support and inquiry engagement was not discovered in this study, both competence and relatedness support showed some associations with student inquiry engagement, particularly during the *Research Question* phase of inquiry (see Table 4.13). The *Research Question* phase is the first opportunity in an inquiry cycle for students to think about their own independent projects, and it makes sense that support, either intellectually (i.e., competence) or relationally (i.e., relatedness) from scientist-mentors could influence students to engage in this initial process at a deeper level. We must remember these students were inquiry novices. Perhaps getting motivationally supportive feedback from scientist-mentors at this stage was particularly encouraging and influenced engagement. Relatedness support also showed a strong association with the *Observations* phase of inquiry. We will discuss the relationship between these elements in the following section.

Importance of Relatedness Support in Online Mentoring

With the aid of online technology, students and scientists involved in programs like PS develop relationships that could play a significant role in the future success of online/blended science education initiatives. Although SDT posits autonomy and competence as the two most important factors in promoting self-determined motivation (Deci & Ryan, 2000), relatedness can play a special role in school environments. Since students rarely feel autonomous at school and are often either overwhelmed or unchallenged by the curriculum, school-related activities are typically not intrinsically motivating (Ratelle et al., 2007). Under these conditions, a strong relationship (i.e., established relatedness) with a significant other has been shown to stimulate student motivation (Koestner & Losier, 2002). Referred to as Organismic Integration Theory (OIT), this applicable SDT sub-theory states, “Whereas relatedness is less central than the other two needs for maintaining intrinsic motivation, it is very much central for promoting internalization” (Ryan & Deci, 2002, p. 19).

Internalization occurs when individuals begin to personally endorse behaviors or activities that were once extrinsically motivated (Deci & Ryan, 2000). In PS, scientists may serve as the significant other for students. Maybe the motivational support they provided is the critical factor explaining why PS engages students. Other research in SDT supports this conclusion (Ryan & Deci, 2000a). Also, research showing students develop stronger identities as science learners through forged relationships with scientists seems relevant to this line of thinking (Bryan et al., 2011).

Although not explicitly part of this study, I could not help but notice how many student-teams responded to their scientist-mentors in ways indicative of relatedness. In many of the dialogues, students began by self-disclosing in friendly and conversant manners. Statements such as “I love rock and roll and country music” (case 2), “I love baseball” (case 4), and “I love horses and rodeo” (case 10) were fairly common among student-teams. Other disclosures were more personal, such as this revelation by case 1, “I also have a very good lab partner. Her name is [student’s name]. I didn’t think that we would get along but we do very well.” Other students talked about botany preferences, such as, “My [favorite tree] is the pecan tree because I love eating the pecans!” (case 10).

In other instances, student-teams expressed desires to know more about the scientists. “We are curious to know what you look like. Could you please post a picture?” (case 2). After the scientist-mentor posted the picture, the student-team responded, “Thank you. :D Now we know who we are talking to.” In another case, students asked about the scientist’s work environment: “Do you work with other people? About how many?” (case 1). These comments indicated students had a desire to connect with scientists on a level beyond simply partnering together to complete a school project.

Once projects got into full swing, I also noted comments indicating student-teams wanted feedback from their scientist-mentors. A case 1 student, in the midst of a week-long online discussion with classmates and the scientist-mentor about a potential research question, wrote to the scientist-mentor, “What I really want to know is what you think, and why? I can’t wait to hear back from you.” Another student in the same case commented to the scientist-mentor, “Hey, it’s nice to hear back from you. How are you doing?” These types of comments characterized student-teams eager for support from scientists and equally eager for conversation beyond simple project dialogue.

As projects came to a close, several student-teams expressed appreciation to the scientist-mentors and indicated the experience was worthwhile. “Thank you so much for all of your hard work and time!! It means so much to us! I’m so glad that we got the chance to do this exciting experiment!!” (case 8). “Thank you for all of your help. If it wasn’t for you, we wouldn’t know what to do” (case 4). In one instance, a student from case 1 expressed how much he/she related to the scientist-mentor’s personality. “You are a good guide. You like to get into things and ask a lot of things. I am a person who likes to ask questions myself.” These comments, along with the associations of relatedness-supportive comments with student inquiry engagement, provide evidence that students valued the relationships they forged with scientists.

As mentioned previously, a high association was found between relatedness support and student engagement during the *Observations* phase of inquiry (Table 4.13). Based on the OEIC (Table 4.5), *Observations* include students sharing their data and research on the online platform. The dialogues indicated this was a particularly important part of the process as students and scientists exchanged information back and forth regarding observations. Scientist-mentors used open communication strategies (see Table 4.4) most often to get students to share observations. For example, sometimes scientist-mentors asked questions and invited participation from student-teams: “Looking forward to hearing more about your observations!” (case 2 scientist-mentor). “Any cool observations?” (case 10 scientist-mentor). Scientist-mentors also expressed appreciation for student-teams when they shared observations, with comments such as, “Thanks for all your updates and posting the pictures of your measurements and observations” (case 8 scientist-mentor), “Thanks for posting the pictures” (case 3 scientist-mentor), “Thanks for the photos – they look great!” (case 6 scientist-mentor), and “I see that you’ve added a new picture! Thanks!” (case 2 scientist-mentor). Student-teams were also eager to share observations, often telling scientist-mentors they were about to post updated pictures, data charts, or other observational data. “Look at our pictures sometimes and hopefully today I will be able to post new pictures” (case 9 student-team).

Relatedness between scientists and students may be a key factor in the success of PS. We need more research investigating educative online relationships. Simply communicating with students over the Internet is not enough. Social presence is a delicate dynamic, and while many scientist-mentors successfully engaged students, others struggled to create a strong social presence. For example, the student-team in case 3 (an LE case) became frustrated with what they perceived as lagging responses and asked their scientist-mentor, “Will you put up a picture of you and reply?”

Evidence Against Behaviorism

Adopting a behavioral view of motivation is tempting. As educators, we may think providing the proper environmental conditions guarantees motivated behavior. On the contrary, SDT postulates that internalized motivation is fully autonomous and self-directed (Ryan & Deci, 2002). The results of this study provided unexpected evidence that motivational support should not be viewed as a "reward" or "necessary factor" assuring students' engagement in inquiry.

As mentioned in the *Methods* section of this chapter, by chance the BSA assigned the same scientist-mentor to two different cases in our study (cases 5 and 9). The amount of motivational support provided by this mentor was similar in both cases. Each case was part of the LMS grouping, indicating this scientist-mentor provided motivational support in the lower tertile for this study. However, the student outcomes for these two cases were very different. Case 5 was part of the *Unsatisfactory* cases, while case 9 was the *Atypical* case. In other words, case 5 students did not engage in inquiry at high levels, while case 9 scored in the upper tertile of the OEIC, indicative of high student inquiry engagement.

These two cases provide evidence that, in education, students ultimately make the decision to participate and engage. As educators and mentors, we are obliged to provide the most supportive environments possible, and we should be willing and equipped to provide autonomy, competence, and motivational support. However, what students choose to do under these conditions is ultimately their decision. After all, the ultimate expression of autonomy (i.e., self-determination) is the decision of whether to engage in a given activity or walk away. We should provide all students with motivational support while realizing that an amotivated response is still possible. This realization makes research on internalization (i.e., increased motivation in previously amotivating situations) through increased relatedness that much more critical to the future of education in general, and online educational initiatives in particular.

Alternative Explanations and Limitations

In case study research, considering alternative explanations for the observed phenomena is critical for establishing validity (Yin, 2009). While the associations found in this study were evident, the aforementioned differences in cases 5 and 9 reiterate the fact that scientist-mentor motivational support is not the only possible factor contributing to differences in student-team inquiry engagement. Research diligence demands alternative explorations.

Typically in a study such as this one, differences in teacher quality would be explored as teachers have a great impact on learning. Without a doubt, teachers influence the depth at which students engage in an inquiry project. However, all 10 student-teams in this study had the same teacher, thereby eliminating teacher quality as a primary reason for observed differences in student inquiry engagement.

Another alternative explanation I explored was dialogue quantity. Perhaps specific motivationally supportive statements by scientist-mentors did not have as much impact on students as general voluminous online conversation. While scientist-mentors in the HMS cases did post more often than LMS cases (10 posts versus 5 posts per case), concurrent research on the social discourse patterns in the student-scientist dialogues in these same 10 cases did not find any association between student inquiry engagement levels and dialogue quantity (Stuessy et al., 2013). Additionally, the calculation of Spearman's *rho* (p = .147) showed no significant correlation between number of scientists' posts and student OEIC scores.

Yet another potential alternative explanation deals with the members within each of the student-groups. The teacher determined group membership. She acknowledged students' choices with whom to work as a major determinant of group membership while also making some efforts to populate groups with students of diverse abilities. She made no efforts to randomly select members for groups. Inequalities in group membership could be a viable limitation to the study. This alternative hypothesis warrants consideration when designing future online motivational support studies.

An additional alternative explanation relates to the importance of immersion in the inquiry process. HMS cases provided more evidence of engagement in the *Immersion* phase of inquiry (see Table 4.15). Perhaps these teams were better grounded in the inquiry. Grounding may have sustained teams' interests in their inquiry projects over the course of the project, without regard to the amount of motivational support they received. Findings in the Peterson (2012) study support this alternative explanation. In that study, "exemplary" student-teams in PS engaged at higher levels in immersion than "average" student-teams. Although all student-teams in this study were provided with the same opportunities for immersion in the classroom (e.g., they had the same teacher and resources), online evidence of students' engagement varied considerably. The current study design and small number of cases precludes differentiating between the effects of high immersion engagement and online scientist-mentor motivational support.

One additional limitation of this study concerns the material posted on the website by the student-teams. The teacher noted in her personal reflections that students often struggled in their attempts to elaborate their ideas online (PS Teacher, 2012). Also, students sometimes failed to remember their online audience and assumed their activities and conversations in class, even if not posted, were somehow accessible to their online scientist-mentors (and ultimately to the researchers). Ensuring students participate fully in the online component represents another orchestration challenge for teachers inherent in complex blended learning environments. In the context of this research, students' failures to post certain products could have led to underestimations of student-team inquiry engagement, particularly as OEIC scores were dependent on student-team products/dialogues uploaded and archived on the PS website.

Implications and Future Direction

As online/blended learning grows in popularity and practice, research leading to the development of engaging learning environments under online conditions becomes more critical. The challenges faced by educators and learners, especially in text-only environments, are fundamentally different than in face-to-face formats. Establishing relationships and motivating learners is not as intuitive in text-only dialogues. The research in this study provides a first step in establishing a connection between motivational aspects of online scientist-mentoring and student inquiry engagement. While association does not imply causality, this study at least confirms a typical co-occurrence between two fundamental components of the PS blended learning environment: mentor motivational support and student inquiry engagement.

SDT provides a time-tested theoretical framework for evaluating motivation in learning environments. Techniques to support learner autonomy, competence, and relatedness (through the establishment of social presence) can be important to the future success or failure of online learning. For many nontraditional and/or rural students, online or blended learning environments provide access to high quality educational experiences without the constraints of accessibility and time. As new online programs are developed, the results of this investigation provide theory-driven information on ways to promote student motivation and engagement through online technology.

The findings in this study represent the “tip of the iceberg” when it comes to investigating motivationally supportive online mentoring environments. Future experimental studies in which groups of online mentors receiving training in motivational support are compared to control groups with no training would provide critical follow-up research. Furthermore, determining how student-teams’ needs change over the inquiry cycle and how scientist-mentors’ motivational support best meets these changing needs would be a fruitful next step for online mentoring research.

Conclusion

The current study provides evidence of a general positive association between online motivational support and student inquiry engagement. As scientist-mentors’ support of student-teams’ motivational support increased (especially relatedness support), a general pattern of greater student-team inquiry engagement occurred. However, scientist-mentors differed in the amounts of motivational support they provided and in the ways they provided support. This finding reinforces the notion that online mentors need training in motivational support and establishing social presence.

Moreover, this study demonstrates how students' engagement in scientific inquiry can be enhanced through participation in innovative programs such as PS. Seeing student comments such as "I love this experiment," "We are excited!," and "I'm glad that we got the chance to do this experiment!" are encouraging, particularly in science, a subject that has been associated with student apathy and disinterest in recent years. As existing online learning programs are modified and new online opportunities are created, effective curriculum developers will consider and integrate motivationally supportive principles into their designs of innovative learning environments. This study supports employment of concerted efforts to support student autonomy, competence, and relatedness through social presence to provide nurturing online environments leading to higher engagement. Finally, but no less important, this study provides evidence that scientists have the potential to make greater impacts on society through direct involvement in educational endeavors.

CHAPTER V

CONCLUSIONS

How often does the account of Johnny and Janice play out in reality across the U.S. and internationally? It's impossible to know for sure, but we can be sure students deserve science instruction far superior to dry PowerPoint lectures and canned dissection labs. Similarly, scientists should have avenues available for sharing their passions with others and communicating their understanding of science to students in relevant and practical ways. School-based science education can deliver so much more than detached lists of vocabulary terms void of context and real-life meaning. With the plethora of technology and research-based pedagogy at our disposal, we no longer have excuses to formally educate in the same, lifeless ways and relegate Johnny to monotonous classroom experiences and Janice to a life of isolation in her laboratory. How do we stem the tide?

The purpose of this dissertation was to investigate PS in order to: (1) explain its success in terms of factors contributing to student motivation, and (2) present specific evidence regarding the impact scientists have on student motivation when serving as online mentors.

Summary of Findings

In Chapter III, using Eisner's (1985) Connoisseurship/Critique model, I described two classrooms using PS, showing evidence of student motivation as they engaged in mentored inquiry projects. I systematically analyzed the data using grounded theory (Strauss & Corbin, 1990) and constructed a model explaining student motivation (Figure 3.1). The model elucidated how motivation was associated with student empowerment, online scientist-mentor communication, and authenticity of the PS experience. Furthermore, I identified intervening conditions and specific strategies used by teachers and scientists to foster student motivation. Finally, I evaluated the data with SWOT analysis (Table 3.4), linking principles of self-determination theory to the inductive discoveries in order to increase the explanatory power of the model. PS was supportive of students' autonomy, competence, and relatedness in tangible ways, thus contributing to student motivation. These results were consistent with other research indicating independent student thinking leads to higher motivation (Moos & Honkomp, 2011), building relationships with significant others promotes motivation (Reeve et al., 2004), and authenticity of experience increases positive attitudes toward science (Koballa & Glynn, 2007).

A specifically important outcome of Chapter III was the realization that scientist-mentors are vital contributors to students' inner motivational resources. This discovery was consistent with other research showing professional mentors can increase students' self-efficacy (Mullen, 2011). In order to further investigate the link between scientists and student motivation, I purposely investigated the contributions of scientist-mentors to student motivation in a follow-up study presented in Chapter IV.

Chapter IV included results from a multiple-case study of junior high student-teams from a remote, rural school district who, for the first time, partnered with scientists in an inquiry experiment through PS. Using self-determination theory as a framework, I developed a rubric to assess scientist-mentors' motivational support through their textual comments in asynchronous dialogues with students. I measured student-team engagement levels using the OEIC (Peterson & Stuessy, 2011). Although scientist-mentors' support of student motivation varied widely (both quantitatively and qualitatively), evidence linked higher scientist motivational support with higher student-team inquiry engagement. In particular, relatedness support by scientist-mentors, as measured by social presence theory, was identified as an important component contributing to student engagement.

Overall, these findings substantiated the claims made in the *Science* 2011 SPORE award article (Hemingway et al., 2011) that PS has a positive influence on the motivation of students as they engage in self-developed inquiry projects. Furthermore, these studies identified several conditions and factors contributing to increased student motivation and engagement. These conditions and factors included but were not limited to increased student empowerment/autonomy, relational support provided by scientist-mentors, and authentic plant-based inquiry investigations.

Implications and Future Research

The greatest consequence that could come from the findings of this dissertation study is successfully increasing student motivation in science classrooms. Self-determined motivation has been associated with better academic performance (Lepper et al., 2005; Pintrich & De Groot, 1990), increased conceptual learning and enhanced memory (Grolnick & Ryan, 1987), greater enjoyment of school (Ryan & Connell, 1989), and reduced anxiety (Deci et al, 1994; Deci et al., 1991). Consequently, motivation is one of the most significant factors determining students' success or failure in the classroom (Welch & Huffman, 2011). If motivation can be cultivated, our efforts to promote deeper learning are much more likely to be met with success (NRC, 2012a). The findings of this study contribute to the ongoing conversation about motivation, and they inform greater understanding of this complex construct in both practical and theoretical ways.

Practical Considerations

I considered practical implications from the perspectives of three actors who have the incredible challenge of nurturing motivation in students: teachers, scientist-mentors, and curriculum developers.

Teachers. Teachers set the stage for learning in school settings. Even when supplementing their own instruction with online discussions, research findings indicate teachers must place value on involvement in the online activity or students will neither value the experience nor persist in their participation (Xie et al., 2006). This dissertation study confirms the importance of teachers in motivating students. I concur with the insight of Hartnett et al. (2011) whose research led them to conclude that, "Practitioners need to be cognizant of the important role they play in influencing learner motivation…" (p. 33).

Teachers start the ball rolling when they sign their students up to participate in PS. This is no small task, in part because PS is not officially listed as part of any state curriculum. "The biggest withhold most teachers have [in starting PS] is making it fit the curriculum. Teachers think they need to have a spot in their curriculum that says, 'Now do *PlantingScience*!' The reality is, that will never happen," Dan admitted. Even after signing up, teachers often meet resistance as they begin to implement PS. Ironically, teachers report the resistance usually comes from co-teachers. I appreciated Dan's response to this challenge when he said, "I don't recognize barriers." After witnessing Dan's and Kelly's classrooms, I believe this "no barriers" attitude is necessary for any teacher who wishes to successfully implement PS in today's educational climate.

Once teachers take the plunge and sign up, they face the challenges of orchestrating a complex learning environment blending the use of computers, hands-on laboratory, and scientist-mentors. However, this dissertation bears witness that teachers can successfully orchestrate the complexities of PS in ways fostering student motivation. The teachers in this study provided their students with collaborative opportunities unlike many others in classroom science learning. By letting go, these teachers empowered their students. The teachers also challenged their students to dig deeper, encouraged through the use of positive reinforcement, and provided appropriate scaffolding. In turn, their students engaged in amazing participatory projects with professional scientists, all within the familiarity of their own classrooms. While the road to success is extremely challenging, the evidence presented in this dissertation implies PS is working, and now we know a little more about the reasons why.

Scientist-mentors. Perhaps the most important discovery in this study was evidence that scientists serving as online mentors can influence student motivation. The grounded theory developed in Chapter III indicated scientist-mentor interaction was one of the causal conditions leading to student motivation and engagement. When considered in tandem with the findings in Chapter IV that scientists' motivational support was associated with higher student engagement, we see evidence of a relationship between motivational support and engagement. The realization of scientists' impacts on student inquiry engagement is profound.

SDT provides a potential explanation for the relationship between scientist-mentors' motivational support and student engagement. According to SDT, people of high expertise or esteem (e.g., scientists) can motivate others of lesser expertise or esteem (e.g., students) by building relationships that foster internalization (Reeve et al., 2004). Remember from Chapter II that internalization is the process of taking a value or action that is not intrinsically motivating and personally endorsing it over time (Figure 2.1; Deci & Ryan, 2000; Ryan & Deci, 2000a). Internalization is catalyzed by relatedness (Deci & Moller, 2005; Ryan & Deci, 2002), which speaks volumes to the importance of online mentors establishing strong, interpersonal relationships with students. When students feel connected to people whom they respect (e.g., scientists), they often respond with increased motivation (Roca & Gagne, 2008).

Scientist-mentors used several strategies to promote positive student outcomes (Figure 3.1). Other mentors hoping to impact their protégés can likewise learn from these strategies. Of particular interest is how the scientist-mentors in this study navigated the unique asynchronous dialogues with their student-teams. The particular ways they spoke with students can provide insight for any educators interacting with students through a text-based medium.

As online dialogue uses only text-based communication, words are the only touch points between parties involved. Evidence from this study authenticates our knowledge that the ways in which educators respond to learners can have an impact on students' responses. If words are perceived as threatening or controlling, student motivation and engagement stands to suffer. To the contrary, if the words nurture the inner motivational resources of the learner, student motivation and engagement can be affected. The rubric developed in this study (see Chapter IV; Appendix A) provides concrete ways to support learner autonomy, competence, and relatedness (through the establishment of social presence) in online learning contexts. All online instructors and mentors could potentially enhance the online experiences of their students by familiarizing themselves with these specific techniques and implementing them in online conversations with learners.

Online curriculum developers. The BSA hit a home run with *PlantingScience*. From all indications, the program is engaging students and creating excitement for plant science and discovery. One of the loudest messages from this research is that curriculum developers need to provide learners with autonomy. PS modules culture student autonomy in most cases, particularly in *The Wonder of Seeds* unit I observed. Curriculum developers should consider the contributions of purposeful choice toward the motivation of learners when they design science curriculum and activities.

In addition, curriculum developers should note that authenticity was an additional causal condition identified through the grounded theory. The use of living plants was a huge factor in motivating students, and the power of being able to pursue questions without known answers was invigorating for most students in this study. However, remember that SDT predicts too much complexity can overwhelm students, a condition that occurred on occasion with certain modules of PS requiring complicated setups and analytical procedures. In order to nurture the need of competence in learners, tasks should be challenging, not overwhelming; novel, but not boring.

In addition to autonomy and competence, this dissertation provided evidence that relatedness can be established in online settings. Shen, Liu, and Wang (2013) also reported that all three psychological needs can increase through online interactions. Particularly in light of the boon of online education opportunities, curriculum developers should consider including components in their curricula that promote relatedness in online contexts. Overcoming geographical barriers to unite parties that otherwise would not be able to communicate seems like an effective use of technology that potentially benefits all involved parties.

Motivational training for teachers and mentors. If we intend to use the Internet to educate learners and unite them with professionals, we cannot assume striking up conversations online is enough. Establishing social presence can be difficult, and while many scientist-mentors in this study successfully engaged students, others struggled to create meaningful conversation. The struggles of online mentors are documented, with some studies noting how the facilitation of quality online discussions requires skill and training (Ensher et al., 2003; Rovai, 2007). Facilitators, whether teachers or mentors, set the tone for online inquiry and must be both sensitive and responsive to students' online needs (Garrison, 2011).

The success of an online intervention is directly related to the ability of the facilitator to get students to communicate online (Rovai & Jordan, 2004). Since online scientist-mentors played such a significant role in PS's success, it stands to reason that training for mentors could contribute to increased student motivation and engagement. Since professional development opportunities for teachers made a significant impact on how well students engaged in PS projects (Peterson, 2012), we need to initiate new research to develop training programs for mentors and other online educators in hopes of developing more conducive online learning environments.

Theoretical Considerations

While the practical implications of this study are numerous and important in advancing understanding of online learning and student motivation, this dissertation also contributes to our knowledge of SDT. The overall findings of this dissertation support the premise of SDT that autonomy, competence, and relatedness contribute to student motivation. My findings concur with Hartnett et al. (2011), who suggested situational conditions (specifically supports for autonomy, competence, and relatedness) positively influence student motivation in online contexts.

However, my results also suggest a lack of understanding of how SDT specifically differs between online and face-to-face contexts. While SDT has predicted autonomy as the most important contributor to self-determined behavior (Deci & Ryan, 1985), the results I reported in Chapter IV reveal that autonomy support from scientist-mentors was not significantly correlated with student engagement. Perhaps transaction distance (Moore, 1993) provided so much autonomy for distance learners that autonomy support from mentors was not as important in the online context. Or, maybe students embraced having a choice in their experiments and did not need as much autonomy support from scientists as they might have in a face-to-face setting. Results from Chapter III lend credence to the latter explanation as student empowerment was identified as a causal condition for motivation and engagement. Nevertheless, I do not have a definitive answer explaining why autonomy support was not significant. However, this discrepancy and others raised in this study provide ripe grounds for future research initiatives.

A more interesting line of future research, in my opinion, is pursuing the question of how internalization works in online contexts. Once again, results from this study suggested possible internalization, but the design of this study prohibited making more definitive assertions on the matter. Some questions related to internalization specifically and SDT generally that could be pursued include: (1) How do the empirically derived conditions for internalization identified in face-to-face settings (Deci et al., 1994; Deci & Moller, 2005; Reeve, 2002) differ in online contexts? (2) In addition to the factors identified by social presence theory, what other factors promote relatedness in online environments? (3) Do learners' motivational needs change over the course of an inquiry project? In other words, do learners need more autonomy support in the beginning, competence support in the middle, etc.? (4) Are intrinsically motivated learners distracted or encouraged by numerous posts from online mentors?

In addition, I will continue to research and refine the motivational support rubric created in Chapter IV. Refinement may include adding or removing some of the indicators. Also, a major shortcoming of the current instrument is its reliance on quantities of motivationally supportive comments. Perhaps I can develop a subjective measure capable of detecting differences in the quality of motivationally supportive comments. Regardless, as text-based communication is a widespread phenomenon in education and in society, I believe the rubric promises to be a useful contribution to online learning efforts.

The results of this dissertation are both encouraging and humbling. On the encouraging side, the findings revealed new understandings about a program (i.e., PS) that is positively influencing student motivation and engagement in science education. In addition, this study uncovered concrete factors contributing to student motivation, specifically revealing how teachers and scientists play a role in the process. The potential impact scientists can have on science learners' motivation through online partnerships is exciting. Perhaps the partnerships facilitated by PS can help solve the aforementioned problems of declines in students' interests in STEM fields (Toplis, 2011) and scientists' struggles to find tangible ways to make broader impacts on society (Lok, 2010).

On the humbling side, we still have huge gaps in our understanding. How do we best utilize technology to create mentorships leading to increased student motivation and engagement? How do we use technology to effectively broaden impact opportunities for scientists? In many ways, our current standardized testing system continues to drive students toward poor attitudes about science (Koballa & Glynn, 2007). On the other hand, intense investigations of successful programs like PS provide relevant information on how to develop curriculum, use technology, and train practitioners to deliver motivating instruction that improves learners' attitudes about science.

In the introduction to this manuscript, I shared how motivation research has received renewed interest as a result of declines in STEM career aspirations (NRC, 2012b). I used the word *renewed* because some researchers, like Elliot Eisner, highlighted the importance of motivation and engagement for decades. What we emphasize in research might really be a question of what we value. What should we value? Eisner thought teachers should know – teachers like Dan and Kelly, who diligently labor to make differences in the lives of students, in part by integrating innovative programs like PS. Eisner asked, and I leave you with his answer:

> Engagement, I believe, is a fundamental criterion used by teachers to select learning activities and to appraise their consequences. The reason for using this criterion rather than instructional objectives is because, as I view the situation, teachers believe that engagement, intellectual and emotional immersion, is a better indicator of educational value than achievement test scores. (Eisner, 1985, p. 70)

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APPENDIX A

MOTIVATIONAL SUPPORT RUBRIC AND TRAINING GUIDE FOR SCIENTIST CONTRIBUTIONS TO DIALOGUES IN PLANTINGSCIENCE

Category: Autonomy Support
- Code: Providing or acknowledging choice
- Code: Providing or acknowledging ownership/interest
- Code: Autonomy supportive phraseology
- Code: Providing rationale
- Code: Acknowledging negatives

Category: Competence Support
- Code: Asking content or process questions
- Code: Offering explanations
- Code: Providing positive feedback

Category: Relatedness Support (based on Social Presence Theory)
- Subcategory: Interpersonal Communication
    - Code: Affective expression
    - Code: Humor
    - Code: Self-disclosure
- Subcategory: Cohesive Communication
    - Code: Inclusive language
    - Code: Salutations/greetings/phatics
    - Code: Use of names
- Subcategory: Open Communication
    - Code: Asking questions/inviting participation
    - Code: Complimenting and appreciation
    - Code: Expressing agreement
    - Code: Reference to previous posts

Category: Autonomy Support

<table>
<tr><td>Code:
Providing or acknowledging choice

Definition:
Statements implying students exercised choice; implying students have a future choice</td><td>Key things to look for in statement:
Asking questions acknowledging students can make a decision; “Have you decided”; “What are you going to do?”
“choice”;
“What are you thinking about?”</td></tr>
<tr><td colspan="2">Examples in context:
Lastly, I posted a question earlier, but no one in your group has given an answer yet. You don't have to answer, but I'll post it here again just in case you missed it...

Let me know when you've chosen one question to focus on, and I can help you with experimental design.

Is there anything you would do differently next time?</td></tr>
</table>

<table>
<tr><td>Code:
Providing or acknowledging ownership/interest

Definition:
Scientist makes reference that project is students’ and they are ultimately responsible for decisions about the project; Scientist makes refer to students’ interests</td><td>Key things to look for in statement:
“Your”
“working with you”</td></tr>
<tr><td colspan="2">Examples in context:
I have a few ideas and questions that may help in running your experiment.

Your change in your research question seems like a good idea.

I am excited about working with you on your project this term.</td></tr>
</table>

<table>
<tr><td>Code:
Autonomy supportive words/phrases

Definition:
Suggestive words/phrases that do not implicitly demand student action</td><td>Key things to look for in statement:
“might” or “may” “if you wish”
“could” or “can” “please consider”
“have you tried?” “option”
“probably” “you may want”</td></tr>
<tr><td colspan="2">Examples in context:
Below are some examples of the type of data you might want to collect: number of days required for seed germination, number of seeds that germinate, height of the seedlings, dry weight of seedlings.

If you wish to test how fast different seeds grow it might be useful to measure how much energy is packed into the seed before it is planted.</td></tr>
</table>

Autonomy support, cont.

Code: Providing rationale **Definition:** Providing a reason for doing a certain action; giving relevance to a certain task or practice	**Key things to look for in statement:** Explanations for why something is important
Examples in context: Centimeters do make your plant sound bigger, but I don't think that's why you use them! Just about all scientists (including me!) measure using the metric system with meters for lengths and liters for volumes. Once you get used to it, it's much easier to work with centimeters than inches. I know this may seem like a lot to think about, but a good scientist tries to think about all the crazy outcomes that may happen in his experiment, and then tries to adjust the experiment to handle those crazy outcomes fairly and without bias. Thinking ahead to consider how you will measure your plants and how you will use those measurements to evaluate which seed is fastest will be of great help in the long run! All scientists do this.	

Code: Acknowledging negatives **Definition:** Recognizing students' negative comments or disappointments as opposed to ignoring them or dismissing them as invalid	**Key things to look for in statement:** Empathy towards or validation of the way students are feeling as opposed to condemnation of their attitudes
Examples in context: Sometimes this does not even help, especially if there are other environmental factors involved. I'm sorry that your seeds grew mold. Unfortunately scientists deal with failed experiments all too often.	

Category: Competence Support

<table>
<tr><td>Code:
Asking content or process questions

Definition:
Questions sparking deeper thought about botanical content; questions requiring students to elaborate on their experimental process</td><td>Keys things to look for in statement:
“Why?”
“How?”
“What?”</td></tr>
<tr><td colspan="2">Examples in context:
Why might one type of seed need a helicopter wing (maple seed) while another seed need to really small (radish seed)?

How are you going to apply the liquids and how are you going to grow the plants?</td></tr>
</table>

<table>
<tr><td>Code:
Offering explanations

Definition:
Scientists explains a phenomenon, process, or answers a student question</td><td>Key things to look for in statement:
Explanatory prose</td></tr>
<tr><td colspan="2">Examples in context:
So long as there is sufficient light, water, and carbon dioxide, plants will carry out photosynthesis. However, if you are asking how long it takes to measure photosynthesis, that depends on the sensitivity of the method you use. If you are measuring the uptake of carbon dioxide by the leaf using a gas analyser, you can detect photosynthesis over a time span of seconds. On the other hand, if you are trying to measure photosynthesis by looking at the change in weight of the plant over time, this will take a number of days.

I am not surprised to hear about your results with the coke and vinegar. Let's think a bit about the properties of those two liquids. The Coke is something you like to drink because it tastes sweet. If you look on the label, you see that the sweetness comes from a type of sugar. Lots of things want to eat that sugar - including the mold and mildew that is growing on your seeds. The seeds don't need the sugar from the Coke, because they pack their own as starch in the seed to tide them over until they begin to photosynthesize to make more sugar on their own. Now that the fungus is established, it can start to kill the seeds by growing into them. This isn't a problem with the water, because it doesn't provide a good media for the fungus and it can't get established in the seeds</td></tr>
</table>

Competence support, cont.

<table>
<tr><td>Code:
Providing positive feedback</td><td>Key things to look for in statement:
Praise or positive statements tied to a specific action or statement.
Ex. Not just “good job!”, but “Good job on your experimental design!”</td></tr>
<tr><td colspan="2">Examples in context:
Wow! You guys have made so many good observations and have asked a ton of great questions!

I just noticed that you have now posted your research question and that you want to focus on the effect of vinegar on plant growth and that you are predicting that vinegar will decrease plant growth. That is a great start.</td></tr>
</table>

Category: Relatedness Support

<table>
<tr><td colspan="2" align="center">Subcategory:
Interpersonal Communication</td></tr>
<tr><td>Code:
Affective expression

Definition:
Indications of feelings or emotions</td><td>Keys to look for in statement:
Emoticons, exclamation points, etc.</td></tr>
<tr><td colspan="2">Examples in context:
I'm glad that you guys had fun working on your experiment! I hope you all learned a lot. Plants are really interesting systems to study. Good luck on your classes this year! :)

I love science too! There's always something new to discover :)</td></tr>
</table>

<table>
<tr><td>Code:
Humor

Definition:
Interjecting statements to lighten the mood.</td><td>Keys to look for in statement:
See below</td></tr>
<tr><td colspan="2">Examples in context:
"The most exciting phrase to hear in science, the one that heralds the new discoveries, is not 'Eureka!' (I found it) but 'That's funny...'" -Isaac Asimov

All scientists do this, even us old ones!</td></tr>
</table>

Relatedness support, cont.

<table>
<tr><td>Code:
Self-disclosure

Definition:
Discussion of personal information not directly related to project.</td><td>Keys to look for in statement:
See below</td></tr>
<tr><td colspan="2">Examples in context:
My lab is going great. I'm mainly doing work with DNA this semester. I will start my fieldwork in the spring. I'm doing a much different experiment than your group, but I do perform seed germinations fairly frequently.

Where do you live? I live in Nova Scotia which is on the east coast of Canada, just North east of Maine. Nova Scotia is like Maine in many respects. Fishing and forestry are important industries. In my area, the Annapolis Valley, agriculture is also important. We grow apples, grapes, blueberries, raspberries, strawberries, etc. Nova Scotia is in the Acadian Forest region. This is an area where the natural vegetation is a mixture of deciduous and evergreen trees. This time of year the leaves of the deciduous trees are turning color (red, orange, yellow) and the forest looks very pretty.2) What kind of music do you like? I like all kinds of music, but I especially like old rock and roll music from the 50's and 60's. I am afraid I don't know any rap music, but I do listen to it sometimes as my youngest daughter is a fan.</td></tr>
</table>

<table>
<tr><td colspan="2">Subcategory:
Cohesive Communication</td></tr>
<tr><td>Code:
Inclusive language

Definition:
Language referring to teamwork, working together, etc.</td><td>Keys to look for in statement:
“part of a team”
“work with you”</td></tr>
<tr><td colspan="2">Examples in context:
I'm glad that you're a part of the experiment as well! I can't wait to work with you more.

I am looking forward to working with you and am excited to hear your ideas on your experiment.</td></tr>
</table>

<table>
<tr><td>Code:
Salutations/Greetings/Phatics

Definition:
Phatics – social conversation not related to project or personal disclosure</td><td>Keys to look for in statement:
“Hello”
“The weather here is great!”</td></tr>
<tr><td colspan="2">Examples in context:
It's been cool and rainy here lately. How is the weather in Texas?

Hello team! Greetings! I can't wait to hear from you.</td></tr>
</table>

Relatedness support, cont.

<table>
<tr><td>Code:
Use of names

Definition:
Calling students by personal name or screen i.d. (does not refer to collective references using team name); scientists using their own names in posts</td><td>Keys to look for in statement:
Names (not team related)</td></tr>
<tr><td colspan="2">Examples in context:
<u>Summer Rose</u>, thanks for telling me which seeds you've looked at and how you sprouted the seeds last week.

<u>Robin</u>, I would love to hear about your pigment chromatography experiment when you have the time. Chromatography is a really neat scientific tool! Have a great week!</td></tr>
</table>

<table>
<tr><td colspan="2" align="center">Subcategory:
Open Communication</td></tr>
<tr><td>Code:
Asking questions/inviting participation

Definition:
Scientist asks questions to induce response or invites students to respond with other phrases</td><td>Keys to look for in statement:
Questions requiring a response;
“I can’t wait to hear back from you”
“Let me know what you think”</td></tr>
<tr><td colspan="2">Examples in context:
Looking forward to hearing more about your observations!

,Have you started your experiment yet? How is it going? Are all the seeds still alive? Have there been any surprises?</td></tr>
</table>

<table>
<tr><td>Code:
Complimenting and appreciation

Definition:
Scientist making statements to compliment students.</td><td>Keys to look for in statement:
“Thank you”
“Congratulations!”</td></tr>
<tr><td colspan="2">Examples in context:
I appreciate you giving your project some thought and coming up with a question that intrigues you.

Thanks for all your updates and posting the pictures of your measurements and observations.</td></tr>
</table>

Relatedness support, cont.

Code: Expressing agreement **Definition:** Scientist agrees with previous suggestion of students	**Keys to look for in statement:** “Sounds good” “That’s a good idea”
Examples in context: The numbering sounds like a good way to keep track of your seeds! Your change in your research question seems like a good idea.	

Code: Reference to previous posts **Definitions:** Explicit reference to previously posted material	**Keys to look for in statement:** “Your last statement” “I saw your post”
Examples in context: Last week, you told me that you were defining growth as "which plant gets farther along in limited time" I just noticed that you have now posted your research question and that you want to focus on the effect of vinegar on plant growth.	