THE RELATIONSHIP BETWEEN OBSERVED TASK CHARACTERISTICS AND THE PATTERN OF SEVENTH GRADE STUDENTS' SITUATIONAL ENGAGEMENT DURING A SCIENCE UNIT

by

Sarah J. Glassman
A Dissertation
Submitted to the
Graduate Faculty
of
George Mason University
in Partial Fulfillment of
The Requirements for the Degree
Doctor of Philosophy
Education

Committee:

_________________________________ Chair

____

____

_________________________________ Program Director

_________________________________ Dean, College of Education and Human Development

Date: ____________________________ Fall Semester 2016
George Mason University
Fairfax, VA

The Relationship between Observed Task Characteristics and the Pattern of Seventh Grade Students' Situational Engagement during a Science Unit

A Dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at George Mason University

by

Sarah J. Glassman
Master of Arts in Teaching
Union Graduate College, 2004
Bachelor of Arts
Brown University, 2001

Director: Seth Parsons, Professor
College of Education and Human Development

Fall Semester 2016
George Mason University
Fairfax, VA

Dedication

This is dedicated to my husband and best friend, Matt. Thank you for your support, patience, and help with this project.

I'm pretty sure you were my first social science research partner. We did after all, collect survey data from everyone we knew to plot friends and families' political philosophies on a two dimensional spectrum. Twenty years later, I am certain this project would not be completed without you.

Thank you for doing this first. The experience of living with someone completing a dissertation provided unmeasurable insight into what it took to complete a dissertation. Thank you for your support and patience. Many times you reminded me of advice given to you: while working on a dissertation, sometimes a productive day means that you did a load of laundry. Thank you for believing in me and continually encouraging me to complete this degree through all the challenges.

Thank you helping me with my project, both intellectually and practically. Thank you for critiquing many practice presentations, getting LOTS of books for me, and photocopying LOTS of surveys for me.

I also dedicate this dissertation to my three daughters, Anna, Abigail, and Elizabeth. My hope for all of you is that you know what makes you tick and you have the confidence to pursue it.

Acknowledgements

I would like to thank:

Seth Parsons: After taking some time away from the Ph.D. program, I gained an interest in the study of student engagement. I found a research study that excited me and I couldn't believe it when I realized that the author was a professor at George Mason. From the time we first met you have continually encouraged me, supported my growth as a scholar, and gave me good advice. And even when I didn't take all to your advice, you still supported me. I am especially grateful that you encouraged me to pursue a research project that I was passionate about. Because of this, I finished. And after all the work, I still like the project and believe the work is important and that it contributes to the understanding of student engagement in middle school science. I really can't thank you enough.

Erin Peters-Burton: I appreciate all the detailed advice you have given me to improve my dissertation. I am also grateful for your inspiration. Multiple times throughout my long journey as a doctoral student I was inspired to continue my studies because I was excited by your work. I remember when we talked over Skype while I was home full time caring for my two year old daughter and newborn baby. At the time I was questioning my continuation in the Ph.D. program. After hearing about the myriad of fascinating projects you were working on, I was sure I wanted to continue my doctoral studies.

Nancy Holincheck: Thank you for being part of my dissertation committee. Thank you also for being a role model for me. When I learned that like me you worked on your Ph.D. while you were home taking care of kids, I was inspired. I also remember your advice when I was struggling over a decision. You said there was not one way that I had to do it. I can't remember the specific decision, but I remember the advice and it has been useful to me again and again during this project.

Donna Sterling: Thank you for sharing your passion for science education with me. Thank you for pushing me to try new things and encouraging me to continue pursuing my interests.

David Brazer: Thank you for serving on my portfolio committee. Thank you for being a fantastic teacher of graduate students. And thank you for continually asking me to articulate my goals.

Gary Galluzo: Thank you for helping me navigate this process. Many times you advised me through difficult situations. I appreciate your patience and guidance.

Thank you to the two seventh grade science teachers who participated in this study and the sixth and seventh grade science teachers who participated in the pilot study. Thank you for opening your classroom and thank you for your time.

Thank you to the students who participated in this study as well as the pilot study that preceded it. By participating in this study you helped further the understanding of student engagement in seventh grade science.

George DeBoer: Thank you for your continued support throughout this process. Thank you for talking through various aspects of the project with me. And you may not know it, but thank you for providing my first scholarly reading material in science education before I started the Ph.D. program: *A History of Ideas in Science Education*.

John Banbury: Thank you for sharing your experiences finishing your own dissertation and advising dissertations. Your own reflections were helpful to me many times over.

Linda Peterson: Thank you for talking through aspects of this project with me. I'm thankful for your enthusiasm and support from the first to the last day of this degree.

Bernard Koch: Thank you for listening and for talking through various aspects of this project with me. I hope helping me work though some of my challenges will be useful to you on your own graduate school journey.

Laura Tokarczyk and Sara Birkhead: Thank you for your time helping with this project. I wish you all the best as you navigate your own research projects.

David and Sally Courtright: Thank you for the long list of specific things you did to help me finish this degree. And thank you for everything else.

Table of Contents

List of Tables

List of Figures

List of Equations

List of Abbreviations

Self-Determination Theory .... SDT

Intra-class Correlation ICC

Abstract

THE RELATIONSHIP BETWEEN OBSERVED TASK CHARACTERISTICS AND THE PATTERN OF SEVENTH GRADE STUDENTS' SITUATIONAL ENGAGEMENT DURING A SCIENCE UNIT

Sarah J. Glassman, Ph.D.

George Mason University, 2016

Dissertation Director: Dr. Seth Parsons

Student engagement is an important aspect of teaching and learning. Traditionally, engagement has been measured as a static trait. This study measured engagement as a fluid trait in order to explore the relationship between seventh grade students' situational engagement over a science unit and five specific task characteristics. Further, this study investigated how the changing pattern of instruction is related to a changing pattern of student engagement. Informed by Self-Determination Theory, the five specific task characteristics investigated were: the use of tasks that give students opportunities to act autonomously (choice), the use of tasks that challenge students (challenge), constructive feedback from the teacher or peers that guides students work on the current task (feedback), the inclusion of tasks that require student collaboration (collaboration), and tasks in which the importance or relevance is explained to students or the task includes a real-world problem or scenario (real-life significance). Student engagement was

measured as a multidimensional trait consisting of behavioral, emotional, and cognitive dimensions. Participants included two teachers and 37 students. Two classrooms were observed and video-recorded for 10 consecutive 1.5 hour blocks during a unit investigating cells. At the end of each block students completed a three item survey for each task. For all tasks in both classrooms, the cumulative presence of task characteristics correlated with student engagement. However, students' behavioral engagement negatively correlated with the use of choice. Students' engagement increased from low to high during four related tasks exhibiting the highest cumulative presence of task characteristics. Nine out of 10 tasks with the highest student engagement involved hands-on learning. However, students' engagement was lower during tasks elaborating on those hands-on tasks.

Chapter One: Introduction

Disengagement with school and school dropout are persistent problems in the United States. According to the 2009 High School Survey of Student Engagement (Yazzie-Mintz, 2010), 66% of students reported being bored at least every day in a high school class and 17% of students are bored in every class. The public high school class of 2008 included only 75% of the students who began high school four years earlier as ninth graders (Stillwell, 2010). The study of student engagement has attracted growing attention in the past 25 years as a means to improve student achievement and decrease student boredom and school dropout (Fredricks, Blumenfeld, & Paris, 2004; National Research Council & Institute of Medicine, 2004). Low student engagement is predictive of school drop-out even after controlling for academic achievement and student background (Rumberger, 2004). In addition, student engagement positively predicts students' grades, conduct, long-term motivation, and college performance (Finn & Rock, 1997; Lam et al., 2014; Lam, Wong, Yang, & Liu, 2012; Shernoff, 2010).

This chapter describes the purpose and justification of the present study. The theoretical background informing the study, Self-Determination Theory (SDT) is introduced and the specific research questions are stated. The end of the chapter presents a brief over-view of the study procedures as well as operational definitions of constructs important to the study. Chapter Two describes the theoretical framework guiding the study and reviews literature related to the study. Chapter Three describes the methods used to conduct the study. Chapter Four describe the results of the study and Chapter Five describes conclusions and implications of the study.

Unlike other factors that influence engagement, teachers have much control over the academic tasks given to students. The purpose of this research was to study the relationship between task characteristics and the pattern of seventh grade students' engagement over an instructional unit. The five specific task characteristics investigated in this study were chosen because previous research findings suggested they positively influence engagement. These five task characteristics include: the use of tasks that give students opportunities to act autonomously (choice), the use of tasks that challenge students (challenge), constructive feedback from the teacher or peers that guides students work on the current task (feedback), the inclusion of tasks that require student collaboration (collaboration), and the importance or relevance of the task is explained to students or the task includes a real-world problem or scenario (real-life significance).

The conceptualization of student engagement in this study is based on the multidimensional conceptualization of engagement consisting of behavioral, emotional, and cognitive dimensions (Fredricks et al., 2004; Reeve, 2012; Reschley & Christenson, 2012). Behavioral engagement includes on-task involvement and effort in the classroom (Reeve & Tseng, 2011). Emotional engagement is students' positive feelings in the classroom. Specifically in this study, it was measured as students' interest in the current task (Fredricks et al., 2004; Hampden-Thompson & Bennett, 2013; Lam et al., 2014; Reeve & Tseng, 2011; Shernoff et al., 2016; Skinner & Belmont, 1993). Cognitive engagement is the use of sophisticated learning strategies. Specifically, in this study, it was measured as the strategy of connecting new learning to previous learning (Greene, 2015; Reeve & Tseng, 2011). Further, the conceptualization of engagement in this study was as a fluid rather than static trait (Parsons, Malloy, Parsons, & Burrowbridge, 2015; Rotgans & Schmidt, 2011; Shernoff et al., 2016). Students' engagement was measured multiple times in connection to individual tasks in order to capture how students' engagement ebbs and flows throughout an instructional unit.

Why Middle School Science?

Science organizations and researchers have highlighted the importance of student engagement in science. The *Framework for K-12 Science Education* (National Research Council, 2012), which describes the vision of the recently published *Next Generation Science Standards* (NGSS Lead States, 2013), advocates for instructional approaches that increase student engagement in science both as a means to improve students' science understanding and as a means for motivating students to pursue science in college and as a career. The number of students choosing to pursue science and engineering careers is declining (National Science Board, 1999) and not high enough to meet the nation's needs (National Research Council, 2012). Student engagement in science may be a key factor in students' choice to pursue further study in science. Findings from previous research found that 15-year olds' emotional engagement in science is a stronger predictor of future intended interest in learning more about science compared to science efficacy, self-concept, or science achievement (Lin, Lawrenz, Lin, & Hong, 2012).

Scientific literacy is important for all citizens in order to understand the basis of policy issues, such as global climate change, and personal issues, such as human health and medicine. Students are more likely to learn new science knowledge when they are emotionally engaged (Sinatra, Heddy, & Lombardi, 2015).

Simultaneously, inquiry-based science teaching, which is a commonly advocated instructional approach to teach science (National Research Council, 1996, 2000; NGSS Lead States, 2013), may not be inherently engaging. Hampden-Thompson and Bennett (2013) found that students' perception of inquiry-based instruction in their science classes was negatively associated with students' engagement in science. Therefore, it is important to understand what does engage students in science.

Researchers have found that students' interest in science begins to decline as early as age 11 (Osborne, Simon, & Collins, 2003), which corresponds with the start of middle school. Therefore, enhancing student engagement in middle school science is particularly important. Student engagement in general declines during the transition to middle school (Eccles et al., 1993; Eccles, Lord, & Midgley, 1991; Eccles & Midgely, 1990). Simultaneously, the first year of middle school is often the first year that students take a designated science class. The first years of middle school also marks the beginning of adolescents, when students experience developmental milestones, such as increased responsibility and autonomy, that influence their behavioral, emotional, and cognitive engagement (Mahtmya, Lohman, Matjasko, & Farb, 2012). Therefore, it is important to understand what specifically engages students during this critical transition to middle school, which typically takes place in sixth or seventh grade.

Justification for the Problem

There are numerous factors that influence students' engagement. Previous research has shown that student engagement is related to student background, such as socio-economic status and mother's level of education, family and peer support, and school factors (Newmann, Wehlage, & Lamborn, 1992; Wylie & Hodgen, 2012). Teachers, schools, and districts have little ability to alter many factors related to student engagement such as socio-economic status, parents' level of education, and family and peer support. However, teachers and schools have much control over the learning environment provided to students. Academic tasks, which are the specific activities students complete while in class, are a foundational feature of the learning environment (Blumenfeld, Mergendoller, & Swarthout, 1987; Doyle, 1983; Parsons et al., 2015). Task, in this study, is defined as a classroom activity that requires students to generate a product. The product can be a written response, presentation, or object. This study specifically investigates the relationship between task characteristics and middle school students' engagement in science class.

The specific task characteristics investigated in this study were informed by SDT as well as an extensive literature review of previous research studying instruction and student engagement. SDT describes what motivates individuals (Deci & Ryan, 1987; Reeve, 2012). Motivation, which is any force that directs or energizes behavior, is closely linked to engagement, and often viewed as an antecedent of engagement (Reeve, 2012). Therefore, factors influencing student motivation are likely to also influence students' engagement. Specifically, SDT contends that individuals are motivated by their need to feel autonomy, competence, and relatedness (Deci & Ryan, 1987). Autonomy is the need to participate in behavior that is personally endorsed (Reeve, 2012). Competence is the need to be effective in exercising one's capacities in order to master challenges (Reeve, 2012; Skinner & Pitzer, 2012). Relatedness is the need to feel belonging and emotionally connected to other people (Parsons et al., 2015; Reeve, 2012; Skinner & Pitzer, 2012).

SDT, as well as previous research studying instruction and students' engagement, supports the relationship between five specific task characteristics and engagement. These five task characteristics include: the use of tasks that give students opportunities to act autonomously (choice), the use of tasks that challenge students (challenge), constructive feedback from the teacher or peers that guides students work on the current task (feedback), the inclusion of tasks that require student collaboration (collaboration), and the importance or relevance of the task (or learning in the task) is explained to students or the task includes a real-world problem or scenario (real-life significance). (Guthrie & Klauda, 2014; Hampden-Thompson & Bennett, 2013; Hipkins, 2012; Lam et al., 2014; Liu, Toprac, & Yuen, 2009; National Research Council & Institute of Medicine, 2004; Newmann et al., 1992; Parsons et al., 2015; Shernoff et al., 2016; Skinner & Belmont, 1993).

These five task characteristics are likely to promote students feelings of autonomy, competence, and relatedness (Figure 1).

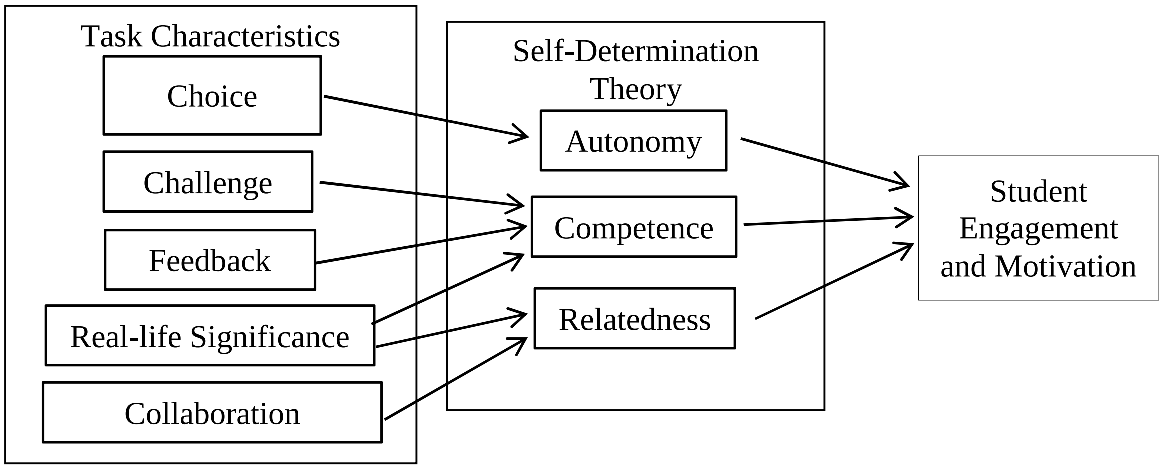


Figure 1. Self-Determination Theory as a Framework for the Influence of Task Characteristics on Students' Engagement

The use of choice for students is likely to increase students' feelings of autonomy. Challenging tasks as well as feedback to help students understand expectations are likely to increase students' feelings of competence. The use of collaboration is likely to increase students' feelings of relatedness. The use of real-life significance is likely to increase students' feelings of competence in and relatedness to the social world. Therefore, SDT suggests that students are likely to be motivated and therefore engaged by tasks exhibiting these characteristics.

There is substantial evidence from previous research that these five task characteristics influence middle and high school students' engagement across many subjects. Specific research has found that student engagement is linked to some of these five task characteristics at the high school level (Hipkins, 2012; Lam, Pak, & Ma, 2007), at the middle school level (Lam et al., 2014), and in high school science (Hampden-

Thompson & Bennett, 2013). However, only one identified study investigated the influence of task characteristics on middle school students' engagement in science (Liu et al., 2009), and that study only considered what engaged students during one particular online learning module. Therefore, the general purpose of this study is to investigate the extent that these five task characteristics are related to seventh grade students' engagement in science class.

Evidence supporting the influence of the use of these five task characteristics on middle and high school students' engagement is primarily based on large scale correlational analyses of students' perceptions of instructional characteristics and students self-reported engagement where both students' perceptions of instruction and engagement are measured through self-report. These findings are limited because the fluid nature of instruction and student engagement is not captured.

Static Verse Situational Measures of Engagement

Self-report surveys asking students to characterize their general engagement are the most commonly used measurement of engagement as a multidimensional construct (Fredricks & McColskey, 2012). This measurement of engagement provides a summative measurement of engagement over a particular period of time. On the other hand, some researchers have conceptualized engagement as a fluid construct and measured in-the-moment engagement multiple times through student interviews, classroom observations, or short self-report surveys (Parsons et al., 2015; Rotgans & Schmidt, 2011; Shernoff, Cavanaugh, Abdi, & Tonks, 2014). This in-the-moment conception of engagement is sometimes referred to as situational (Rotgans & Schmidt, 2011) or moment-by-moment

(Shernoff et al., 2014) engagement. A situational measure of engagement captures the fluid nature of engagement over the course of days and weeks.

Similar to the measure of engagement, the measure of instruction as it relates to engagement has also been primarily measured statically. Previous studies often used self-report surveys asking students to report their perceptions of instruction over the course of a semester or school year (Hampden-Thompson & Bennett, 2013; Hipkins, 2012; Lam et al., 2014, 2012). Also similar to the measure of engagement, some previous researchers have conceptualized instruction as a fluid construct and measured it through daily observations or interviews (Parsons et al., 2015; Shernoff et al., 2014). A situational measure of instruction captures the fluid nature of instruction over the course of days or weeks.

Although often measured as static traits, measuring engagement and instruction as fluid traits allows for a more nuanced study of the relationship between the variables and the opportunity to see how the changing pattern of instruction and engagement are related to each other. Findings from previous research, which measured both engagement and instruction as static traits, provide the majority of support for the positive relationship between these five task characteristics and engagement. However, it is important to understand if the relationship exists when both constructs are measured as fluid in nature. This study used both a situational measure of engagement as well as situational measure of instruction in order to investigate how a changing pattern of instruction influences a changing pattern of student engagement over time. Therefore, the more specific purpose of this study was to investigate the relationship between the pattern of observed task characteristics over a multi-day science instructional unit and the pattern of seventh grade students' situational engagement over the course of the unit.

Purpose Statement

Findings from previous research suggest that choice, challenge, feedback, collaboration, and real life significance are related to middle and high school students' engagement across all subjects. Students' engagement in science is important both as means to improve understanding and as a means for motivating students to pursue science in college and as a career (National Research Council, 2012; NGSS Lead States, 2013). Students' engagement in seventh grade science is particularly important because it is often the first designated science class taken by students. Only one previously identified study specifically considered the influence of instruction on middle school students' engagement in science. Therefore, one purpose of this research was to study the relationship between challenge, feedback, real-life significance, choice, and collaboration and seventh grade students' engagement in science. More specifically, the purpose of this research was to study the relationship between these five task characteristics and students' situational rather than static engagement.

As mentioned before, large scale quantitative studies using surveys to measure students' perceptions of instructional characteristics and students' self-reported engagement provide the most evidence for the relationship between choice, challenge, feedback, real-life significance, and collaboration and middle and high school students' engagement (Hipkins, 2012; Lam et al., 2014). This evidence provides strong support that these five task characteristics are likely to have a positive effect on student engagement.

However, because both engagement and instruction are fluid, it is important to investigate the relationship between a fluid measurement of task characteristics and a fluid measurement of students' engagement. Therefore, the purpose of this research was to answer the following research question:

1. Is there a relationship between the observed level of task characteristics in a seventh grade science classroom and students' engagement in the task?
2. What is the relationship between the pattern of observed task characteristics during a multi-day science instructional unit and the pattern of seventh grade students' situational engagement over the same multi-day instructional unit?

To answer this research question this study investigated the use of task characteristics and students' engagement for an instructional unit in two different seventh grade science classrooms. Table 1 describes the data to measure each construct in the study.

Table 1

Data to Measure Study Constructs

Construct	Dimension	Proposed data to measure construct
Engagement	Behavioral	Classroom observation
	Emotional	Student survey item
	Cognitive	Student survey item
Task Characteristics	Choice	Analysis of video-recording and contextual information using Task Characteristic Rating Scale
	Challenge	Student survey item
	Feedback	Analysis of video-recording and contextual information using Task Characteristic Rating Scale
	Collaboration	Analysis of video-recording and contextual information using Task Characteristic Rating Scale
	Real-life significance	Analysis of video-recording and contextual information using Task Characteristic Rating Scale

For each task students complete in the instructional unit, students answered three short survey items: one to measure students' emotional engagement, one to measure students' cognitive engagement, and one to measure students' perceived challenge. Students' behavioral engagement was measured by observation. Each day of the instructional unit was video-recorded. Contextual information, including hand-outs given to students and notes based on information conversations with teachers about instruction, were collected.

The video-recordings and contextual information was analyzed using a rubric to measure the use of choice, feedback, collaboration, and real-life significance for each task students complete in the instructional unit. Therefore, students' engagement was studied in accordance to the level of task characteristics.

Definitions

- Engagement – a multidimensional construct consisting of behavioral, emotional, and cognitive dimensions (Fredricks et al., 2004; Reeve, 2012; Reschley & Christenson, 2012)
    - Behavioral engagement – on-task involvement and effort in the classroom (Reeve & Tseng, 2011)
    - Emotional engagement – interest in the current task (Fredricks et al., 2004; Hampden-Thompson & Bennett, 2013; Lam et al., 2014; Reeve & Tseng, 2011; Shernoff et al., 2016; Skinner & Belmont, 1993)
    - Cognitive engagement – connecting new learning to previous learning (Greene, 2015; Reeve & Tseng, 2011)
- Situational student engagement – students' in-the-moment engagement (Shernoff, 2013)
- Academic task – classroom activity that requires students to generate a product (Doyle, 1983; Parsons et al., 2015)
- Choice - tasks that give students opportunities to act autonomously
- Challenge - the use of tasks that challenge students

- Feedback – constructive feedback from the teacher or peers that guides students' work on the current task
- Collaboration - the inclusion of tasks that require student collaboration
- Real-life significance – importance or relevance of the task (or learning in the task) is explained to students or the task includes a real-world problem or scenario

This chapter described the purpose and justification of the present study. The theoretical background informing the study, Self-Determination Theory (SDT) was introduced and the specific research questions were stated. A brief over-view of the study procedures as well as operational definitions of constructs important to the study were presented.

The following chapter will summarize research about effective science instruction, present a more detailed description of SDT, summarize history of the study of student engagement, and give an analysis of previous research studying the relationship between instruction and engagement. A detailed analysis of previous research studying the relationship between each the five task characteristics in this study and students' engagement will be explained. Previous research studying the influence of instruction on engagement when both traits are measured statically will be compared to previous research where both traits are measured dynamically.

Chapter Two: Literature Review

The purpose of this research is to study the relationship between five specific task characteristics and seventh grade students' engagement over a science instructional unit. This study uses a conceptualization of engagement as a dynamic and multidimensional construct (Fredricks et al., 2004; Parsons et al., 2015; Rotgans & Schmidt, 2011; Shernoff et al., 2016). The specific task characteristics investigated in this study include: the use of tasks that give students opportunities to act autonomously (choice), the use of tasks that challenge students (challenge), constructive feedback from the teacher or peers that guides students work on the current task (feedback), the inclusion of tasks that require student collaboration (collaboration), and the importance or relevance of the task is explained to students or the task includes a real-world problem or scenario (real-life significance).

This chapter briefly describes literature on effective science instruction. Next, the theoretical framework guiding this study, Self-Determination Theory (SDT) is described and the literature related to the construct of engagement is reviewed. Then the literature on tasks and previous research studying the relationship between each task characteristic and engagement is reviewed. The strengths and limitations of previous research measuring engagement and instruction as a static trait are summarized. Finally, findings from previous research measuring instruction and engagement fluidly exemplify how studying instruction and engagement over time provides new insights into the relationship between the variables.

Effective Science Instruction

There is no single agreed-upon approach for effectively teaching science. *A Framework for K-12 Science Education* describes that, "several previous NRC committees….have independently concluded that there is not sufficient evidence to make prescriptive recommendations about which approaches to science instruction are most effective for achieving particular learning goals" (National Research Council, 2012, p. 250). Nevertheless, many prominent science education resources advocate for an inquiry-based approach to teaching science (National Research Council, 2000, 2010, 2012; NGSS Lead States, 2013) as well as the inclusion of demonstrations, explanations, questioning, and scientific reasoning (Treagust & Tsui, 2014). Further, a meta-analysis of 61 experimental or quasi-experimental studies found that the following teaching strategies had a positive effect on student achievement (effect sizes in parentheses): real-life significance (1.48), collaboration (.95), questioning strategies (.74), inquiry-based learning (.65), hands-on learning (.57), assessment strategies (.51), the use of instructional technology (.48), and teacher modification of instructional materials (.29) (Schroeder, Scott, Tolson, Huang, & Lee, 2007).

Inquiry-based instruction is often used as an umbrella term to describe teaching approaches that are generally more student-centered than teacher-centered (Treagust & Tsui, 2014). More specifically, students use inquiry when they learn science by engaging in the process of doing science (National Research Council, 2000). This means that students ask scientifically-oriented questions, design and carry out investigations, interpret data, and draw conclusions about the evidence collected (Crawford, 2014). Inquiry-based instruction aligns with the practices of asking questions, planning and carrying out investigations, and analyzing and interpreting data outlined in *The Next Generation Science Standards* (NGSS Lead States, 2013). In the meta-analysis that found a positive effect of inquiry-based learning, inquiry-based learning was defined as student-centered instruction in which students may analyze data to answer a scientific research question (Schroeder et al., 2007).

In their review of research on science instructional methods, Treagust and Tsui (2014) describe the value of demonstrations, explanations, questioning, and scientific reasoning. The dramatic or surprising effects of a demonstration may increase students' engagement and motivation to learn (Treagust & Tsui, 2014). Beyond descriptions of information, an explanation is a claim that links cause to outcome or that relates variables to each other (NGSS Lead States, 2013; Treagust & Tsui, 2014). Students can have difficulties learning causal explanations that involve cause and effect relationships in phenomena (Treagust & Tsui, 2014). Therefore, the inclusion of teacher explanations and scaffolding for students to develop their own explanations is important.

The effective use of questioning in the science classroom includes appropriate wait time, various patterns of teacher-student dialogue, and the use of higher level and student-generated questions (Chin & Osborne, 2008; Lemke, 1990; Treagust & Tsui, 2014; Zoller & Nahum, 2012). The meta-analysis that found a positive effect of questioning on student achievement defined questioning strategies as varying timing positioning or cognitive levels of questioning (Schroeder et al., 2007). The dominant dialogue pattern of most science classrooms follows an initiation-response-evaluation or initiation-response-feedback pattern with the teacher providing the initiation, evaluation, and feedback (Treagust & Tsui, 2014). Other more student-centered dialogue patterns, such as debate, student-student discussion, and dialogue beginning with student-generated questions provides opportunities for more meaningful learning (Treagust & Tsui, 2014).

Scientific reasoning includes deductive reasoning, or drawing logically valid conclusions from the general to the specific, and inductive reasoning, or drawing logically valid conclusions from the specific to the general (Treagust & Tsui, 2014). Scientific reasoning is cornerstone of science education (American Association for the Advancement of Science, 1993) and an essential component of the practice of engaging in argument from evidence set forth in the *Next Generation Science Standards* (NGSS Lead States, 2013).

Hands-on science actively involves students in manipulating objects (Lumpe & Oliver, 1991; Vrtacnik & Gros, 2013). In the meta-analysis that found a positive relationship between hands-on learning and student achievement, the hands-on category was defined as the teacher providing opportunities for students to work or practice with physical objects (Schroeder et al., 2007).

Although there is not a single agreed-upon approach to teaching science, most prominent science education resources advocate for an inquiry-based approach to teaching science (National Research Council, 2000, 2010, 2012; NGSS Lead States, 2013). Effective science instruction also includes the use of demonstrations, explanations, scientific reasoning, various patterns of student-teacher dialog and other innovative questioning strategies, hands-on learning, teacher modification of assessments and instructional materials, and the use of instructional technology (Schroeder et al., 2007; Treagust & Tsui, 2014).

Theoretical Framework

The theoretical framework that guides the present study is SDT. SDT is an expansive theory that explains what motivates individuals (Deci & Ryan, 1987, 2000; Reeve, 2012; Ryan & Deci, 2000). The present study was informed by a theory of motivation because student motivation and student engagement are inherently linked. Motivation is any force that directs or energizes behavior (Reeve, 2012; Ryan & Deci, 2000) and engagement is students' active involvement in a learning activity (Reeve, 2012). Although motivation and engagement continuously influence each other, engagement is often viewed as an outcome of motivation (Reeve, 2012). Motivation is private, unobservable, and an antecedent to the more publically observable behavior of engagement (Reeve, 2012). Therefore, the theoretical underpinnings of motivation are likely to result in student engagement.

Most contemporary theories of motivation explain that individuals begin and continue with certain behaviors based on their goals and values (Deci & Ryan, 2000). SDT investigates both the content of these values and goals as well as the regulatory processes experienced to attain these goals (Deci & Ryan, 2000). Based on investigations of the social-contextual conditions that facilitate versus thwart individuals' motivation, SDT contends that individuals are motivated by innate needs for autonomy, competence, and relatedness (Deci & Ryan, 1987, 2000; Ryan & Deci, 2000). The task characteristics in the present study are likely to promote students' feelings of autonomy, competence, and relatedness. Therefore, based on SDT, the task characteristics in this present study are likely to promote students' motivation and engagement. The specific definitions of autonomy, competence, and relatedness are described below.

Autonomy. The need for autonomy is the psychological need to participate in behavior that is personally endorsed (Reeve, 2012). Deci and Ryan (1987) describe that people construe their environment as autonomy supportive or controlling. In an autonomy-supportive environment, a person feels encouraged to make his/her own choices. In a controlling environment, a person feels pressured toward particular outcomes (Deci & Ryan, 1987). Students experience autonomy satisfaction when they feel an internal locus of causality, a sense of psychological freedom, and perceived choice (Reeve, Nix, & Hamm, 2003). Previous research has found that teacher's use of autonomy-supportive versus controlling styles affect students' motivation (Deci & Ryan, 1987; Reeve, 2012). The choice task characteristic, or use of tasks that give students opportunities to act autonomously, are likely to promote students' feelings of autonomy and therefore promote students' motivation and engagement.

Competence. The psychological need for competence is the need to be effective in exercising one's capacities in order to master environmental challenges (Reeve, 2012). It includes understanding what needs to be done to reach desired outcomes and being effective in reaching those outcomes (Deci & Ryan, 1991). Reeve and Tseng (2011) found that students' self-reported feelings of competence in the classroom correlated with students' self-reported engagement. Completing challenging tasks are likely to increase students' feelings of competence and therefore promote students' motivation and engagement.

Reeve (2012) describes that competence-enhancing and competence-undermining external events affect intrinsic motivation. Competence-enhancing external events increase intrinsic motivation and competence-undermining external events decrease intrinsic motivation. Reeve (2012) describes that positive feedback is an example of competence support. The feedback task characteristic, or feedback from teachers or peers that guide students' work on the current task, is competence-enhancing, and therefore likely to promote students' motivation and engagement.

Relatedness. The psychological need for relatedness is the need to feel a satisfying involvement with the social world. It includes relating to and caring for others and feeling that others authentically relate to oneself (Deci & Ryan, 1991). The collaboration task characteristic, or the use of collaboration, provides an opportunity for students to feel a satisfying involvement with the social world through relating and caring for other group members.

Research guided by SDT has examined how factors influence individual's intrinsic as well as extrinsic motivation (Ryan & Deci, 2000). Student engagement in a school setting is likely to be influenced by intrinsic as well as extrinsic motivation. The difference between these two types of motivation as well as research studying the influence of autonomy, competence, and relatedness on both types of motivation, are described below.

Intrinsic vs. extrinsic motivation. An intrinsically motivated behavior is done for the inherent satisfaction of the activity itself whereas an extrinsically motivated behavior is done to attain a separate outcome (Deci, 1975; Ryan & Deci, 2000). Early motivational theory was dominated by externally motivated explanations for behavior. Behavior X occurred in order to achieve goal Y. Koch (1961) described the idea of intrinsic motivation when he argued that behavior is not always goal directed. He argued that many regular daily human behaviors, such as doodling, tapping out rhythms, fondly noticing a familiar object, or gazing out the window, cannot be categorized with an "in-order-to" explanation (Koch, 1956). Instead many human behaviors are motivated by enjoyment of the behavior itself (Koch, 1956, 1961). For instance, a person engaged in intrinsically motivated behavior can be so absorbed that he/she can suppress physical needs such as fatigue and hunger (Koch, 1956).

Students' behavior in school can be intrinsically motivated, but often it is to some extent extrinsically motivated (Reeve, 2012). Extrinsic motivation can vary from passive compliance to behaviors in which an individual actively commits to the goals and values of the behavior (Ryan & Deci, 2000). For example a student can do his/her homework to avoid punishment or because he/she believes it will help him/her achieve his/her own academic or careers goals. In the first case the behavior is externally regulated to avoid a punishment. In the second case the behavior is regulated based on a personally endorsed goal.

Organismic Integration Theory, a sub-theory of SDT, describes various levels of extrinsic motivation based on the extent that the value of the behavior is personally endorsed and autonomously regulated (Reeve, 2012; Ryan & Deci, 2000). The extent that the behavior is autonomously regulated is based on the extent that the behavior is internalized and integrated. Internalization is the “taking in” of the value of the behavior. Integration refers to making the value and regulation of the behavior one’s own (Ryan & Deci, 2000). Previous research has shown that more autonomous extrinsic motivation is associated with student engagement (Connell & Wellborn, 1991).

The extent to which an individual’s innate psychological needs of autonomy, competence, and relatedness are met determines a students’ intrinsic motivation (Deci & Ryan, 1987; Reeve, 2012). Further, research has shown that the extent to which these needs are met determines the extent to which students’ extrinsic motivation becomes personally endorsed and autonomously regulated (Ryan & Deci, 2000). Both intrinsic motivation and autonomously regulated extrinsic motivation are likely to promote students’ engagement (Connell & Wellborn, 1991; Reeve & Tseng, 2011). Therefore, students’ feelings of autonomy, competence, and relatedness are likely to promote students’ engagement.

Figure 2 summarizes the relationships between extrinsic and intrinsic motivation, engagement, and feelings of autonomy, competence, and relatedness.

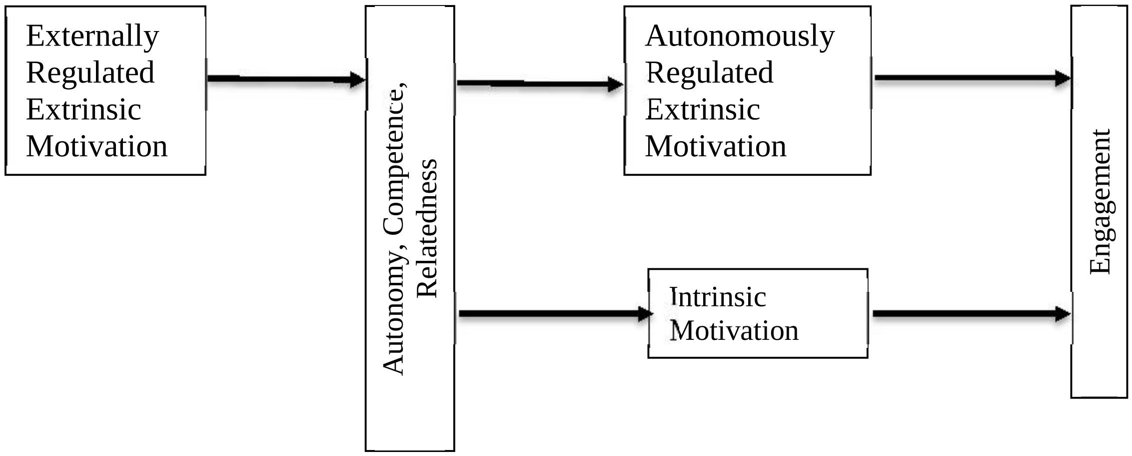


Figure 2. Influence of Autonomy, Competence, and Relatedness on Extrinsic and Intrinsic Motivation and Engagement

As described above, feelings of autonomy, competence, and relatedness are likely both to promote intrinsic motivation (Deci & Ryan, 1987; Reeve, 2012) and to promote extrinsic motivation to become autonomously regulated (Deci & Ryan, 2000). Both autonomously regulated extrinsic motivation and intrinsic motivation are likely to promote engagement (Connell & Wellborn, 1991; Reeve & Tseng, 2011). Therefore, increasing students' feelings of autonomy, competence, and relatedness are likely to promote students' engagement.

The direct relationship between students' feelings of autonomy, competence, and relatedness and students' engagement was proposed by Connell and Wellborn (1991) in their description of a process model of motivation. The model describes that context influences personal feelings and those personal feelings influence action and behavior.

Context that promotes feelings of autonomy, competence, and relatedness will result in the action of engagement. Alternatively, when the psychological needs of autonomy, competence, and relatedness are not met, a person will exhibit disaffection (Connell & Wellborn, 1991). The influence of feelings of autonomy, competence, and relatedness on motivation and engagement has been described by multiple theorists (Blumenfeld, Kemplar, & Krajcik, 2006; Parsons et al., 2015; Reeve, 2012).

The way in which the real-life significance task characteristic theoretically influences students' feelings of competence and relatedness is best understood as it relates to the model presented in Figure 2. Organismic Integration Theory explains how an individuals' extrinsic motivation moves from being externally regulated to autonomously regulated. In this process individuals are naturally inclined to internalize and integrate values of the social world into their own value system (Reeve, 2012). Students proactively seek out opportunities to do this because they want to understand how to increase their competence in the social world and to feel belonging in the social world (Reeve, 2012). When the importance or relevance of a task is explained or when students engage in a real-world problem they are likely to feel increased competence to contribute to the real world and increased belonging in the social world. Therefore, the real-life significance task characteristic, or when the importance or relevance of the task is explained to students or the task includes a real-world problem or scenario, is likely to promote students feelings of competence and relatedness.

Figure 1 summarizes how the use of the five task characteristics in this study are likely to promote students' feelings of autonomy, competence, and relatedness. The use of choice for students is likely to increase students' feelings of autonomy. Challenging tasks, feedback from teachers and peers to guide students on the current task, and tasks exhibiting real-life significance are likely to increase students' feelings of competence. The use of collaboration and real-life significance are likely to increase students' feelings of relatedness. Before the literature studying the relationship between each of these five task characteristics and engagement is reviewed, a history of the construct of engagement is described.

What is Engagement?

In the book *Student Engagement and Achievement in American Secondary Schools*, Newmann et al. (1992) defined engagement as "student's psychological investment in and effort directed toward learning, understanding, mastering the knowledge, skills or crafts that the academic work is intended to promote" (Newmann et al., 1992, p. 12). More recently, engagement has been conceptualized as a multidimensional construct including behavioral, emotional, and cognitive dimensions (Christenson, Reschley, & Wylie, 2012; Fredricks et al., 2004). Engagement was first organized into these specific dimensions by Fredricks, Blumenfeld, and Paris (2004) in a seminal paper analyzing previous research studying engagement and related constructs in order to clarify the conceptualization of engagement. The definitions of the three dimensions of engagement vary depending on the context and outcome being studied (Christenson et al., 2012; Reschley & Christenson, 2012). Much of the research defining school engagement is rooted in dropout prevention theory or general school reform (Reschley & Christenson, 2012). These schools of thought are interested in measuring general engagement with school in order to understand how school-wide policies affect student engagement. Consequently, many engagement instruments developed from these lines of research measure general engagement with school rather than engagement with classroom learning. Because the purpose of this research is to study the relationship between classroom instruction and student engagement, engagement refers to engagement in classroom learning rather than engagement with school in general.

Behavioral engagement. For the purpose of this study, behavioral engagement is defined as on-task involvement and effort in the classroom (Fredricks et al., 2004; Reeve & Tseng, 2011; Skinner & Belmont, 1993). In other research the definition of behavioral engagement sometimes includes positive conduct, such as adhering to classroom rules (Finn & Voelkl, 1993), adhering to school-wide rules and the absence of disruptive behavior (Finn & Voelkl, 1993) and attendance (Willms, 2003). It can also include participation in school-related activities (Fredricks et al., 2004; Lam et al., 2014). The definition used here is consistent with Reeve and Tseng's (2011) description of behavioral engagement as "students' on-task attention, lesson involvement, and effort" (Reeve & Tseng, 2011). The reason for limiting the definition of behavioral engagement to students' on-task attention is because the purpose of this research is to study the relationship between classroom instruction and student engagement. Although engaging classroom instruction can conceivably lead to increased general school engagement, limiting the definition of behavior engagement to students' on-task attention in class limits the measurement of engagement to characteristics that are most likely impacted by classroom instruction. Further, some researchers regard positive conduct and attendance as outcomes of engagement rather than indicators of engagement (Lam et al., 2014).

Emotional engagement. Emotional engagement broadly refers to students' feelings in the classroom. This can include interest, boredom, happiness, sadness, and anxiety (Fredricks et al., 2004). Emotional engagement has also been defined as students' feelings about school and/or their teacher or as students' identification with school (Fredricks et al., 2004) or a sense of belonging (Willms, 2003). For the purpose of this study, emotional engagement is broadly defined as students' positive feelings with learning. The definition is consistent with Reeve and Tseng (2011)'s definition of emotional engagement as "energized emotional states," such as, "enjoyment, interest, curiosity, and fun" (Reeve & Tseng, 2011). The reason for limiting the definition of emotional engagement to students' feelings about learning rather than students feelings about their teacher and/or school is that the purpose of this research is to study the effect of classroom instructional context on student engagement. Students' feelings about their learning are more useful than students' feeling about school generally to understanding the effect of the instructional context of one specific classroom on student engagement.

Within the broader definition of emotional engagement as students' positive feelings in the classroom, emotional engagement is more specifically defined as students' feelings of interest. The two emotions included most often in previous surveys measuring emotional engagement are interest (Hampden-Thompson & Bennett, 2013; Lam et al., 2014; Reeve & Tseng, 2011; Shernoff et al., 2016; Skinner & Belmont, 1993) and enjoyment (Hampden-Thompson & Bennett, 2013; Hipkins, 2012; Lam et al., 2014;

Reeve & Tseng, 2011; Taboada Barber & Buehl, 2013). Reeve and Tseng (2011) measured the emotional engagement of 365 high school students with four items. Based on an exploratory factor analysis of the 22 items measuring all dimensions of engagement, the item taping the emotion of interest had a higher factor loading to the emotional engagement factor compared to the item measuring enjoyment (Reeve & Tseng, 2011). Therefore, the present study measures students' interest as the specific indicator of students' positive emotions in the classroom.

Cognitive engagement. The definition of cognitive engagement can include investment in learning (Fredricks et al., 2004), preference for challenge, and positively coping with failure (Connell & Wellborn, 1991). More commonly, cognitive engagement is limited to sophisticated learning strategies, metacognition, and self-regulation (Greene, 2015; Reeve & Tseng, 2011). Within this more narrow definition of cognitive engagement, it is disputed whether self-regulating behavior should be included in the conceptualization of cognitive engagement or not. Lam et at. (2014) did not include self-regulated learning within the conceptualization of cognitive engagement based on the argument that self-regulation is behavioral in nature (Lam et al., 2014). On the other hand, Cleary and Zimmerman (2012) define cognitive engagement solely as self-regulation as they use the terms self-regulated learning (SRL) engagement and cognitive engagement interchangeably (Cleary & Zimmerman, 2012). Reeve and Tseng (2011) found evidence that self-regulation and metacognitive strategies should not be measured as part of cognitive engagement. Reeve and Tseng (2011) measured behavioral, emotional, and cognitive engagement of high school students using a self-report survey.

When they analyzed the survey items, they found that the metacognitive self-regulating strategies they had grouped as cognitive engagement cross-loaded with cognitive engagement and behavioral engagement. They suggested that cognitive engagement only be defined to include sophisticated learning strategies (Reeve & Tseng, 2011). Therefore, in the present study the definition of cognitive engagement is limited to sophisticated learning strategies.

Within the broader definition of cognitive engagement as the use of sophisticated learning strategies, the present study specifically measures students' connecting new learning to previous learning as the indicator of cognitive engagement. Reeve and Tseng (2011) measured the cognitive engagement of 365 high school students with eight items. Based on an exploratory factor analysis of the twenty-two items measuring all dimensions of engagement, the item asking students if they try to relate what they are learning to what they already know had the highest factor loading to the cognitive engagement factor (Reeve & Tseng, 2011). Therefore, this study measures students' connection of new learning to previous learning as the indicator for students' cognitive engagement.

Why Study the Influence of Task Characteristics on Student Engagement?

There are numerous factors that influence students' engagement. Previous research has shown that student engagement is related to student background, such as socio-economic status and mother's level of education, family and peer support, and school factors (Newmann et al., 1992; Wylie & Hodgen, 2012). Teachers, schools, and districts have little ability to alter many factors related to student engagement such as socio-economic status, parents' level of education, and family and peer support. However, teachers and schools have much control over the instructional tasks given to students and learning environment provided to students. Further, instruction may have a stronger influence on students' engagement compared to student characteristics. Findings from previous research found that only 25% of the variation in student engagement exists between individuals, whereas 75% of the variation in student engagement fluctuated based on changes in the learning environment (Shernoff, 2010).

Task Characteristics: What are They? How are They Related to Engagement?

What are tasks? Academic tasks, which are the specific activities students complete while in class, are a foundational feature of the learning environment (Blumenfeld et al., 1987; Doyle, 1983; Parsons et al., 2015). In Walter Doyle's seminal article, "Academic Work," he defined *academic task* as (a) the products students generate, (b) the operations used to generate the product, and (c) the resources available to students while generating a product (Doyle, 1983). Blumenfeld and colleagues (1987) extended this definition to include the form of the task, or the types of procedures, social organization, and type of products required by the task (Blumenfeld et al., 1987). Blumenfeld and colleagues (1987) argued that, "different task forms…have identifiable effects on teachers and on student behavior and learning" (Blumenfeld et al., 1987, p. 136). Parsons and colleagues (2015) defined task as a classroom activity that required a student response. Similar to both Parsons (2015) and Doyle (1983), the present study defines task as a classroom activity that requires students' to generate a product. The product can be an object (model), written response, or presentation.

What are the task characteristics in this study? Based on SDT as well as an extensive literature review of previous research studying instruction and student engagement, I identified five task characteristics that are likely to positively influence middle and high school students' engagement. These task characteristics include: the use of tasks that give students opportunities to act autonomously (choice), the use of tasks that challenge students (challenge), constructive feedback from the teacher or peers that guides students work on the current task (feedback), the inclusion of tasks that require student collaboration (collaboration), and the importance or relevance of the task is explained to students or the task includes a real-world problem or scenario (real-life significance). Specific findings describing the relationship between each of these task characteristics and student engagement are described in this section.

Student Choice. The relationship between student engagement and students' feelings of autonomy in the classroom is supported both theoretically and empirically. Theoretically, SDT predicts that students who feel an internal locus of causality will feel greater motivation and therefore, exhibit increased motivation. Ryan and Grolnick (1986) found that students' perceptions of their teachers' autonomy-support versus controlling behavior is related to students' mastery motivation (Ryan & Grolnick, 1986). Further, previous research has found that students in classrooms where teachers support student autonomy are more likely to experience intrinsic motivation compared to students in classrooms where teachers control student behavior (Deci & Ryan, 1987). Reeve and Tseng (2011) found that students' self-reported engagement correlated with students' feelings of autonomy in the classroom.

Theoretically, student autonomy occurs when students make decisions and choices to direct their own learning. The National Research Council and Institute of Medicine describe, in their review of high school student engagement, “Students are more likely to want to do school work when they have some choice in the courses they take, in the material they study, and in the strategies they use to complete tasks” (National Research Council & Institute of Medicine, 2004). Significant evidence suggests that providing choice to students is related to student engagement (Hipkins, 2012; Lam et al., 2012; Liu et al., 2009).

Liu, Toprac, and Yuen (2009) interviewed sixth grade students about the sources of their engagement while using a multimedia problem-based learning environment. Thirty-four out of 288 responses attributed choice and control while using the learning environment as sources of their engagement. This was the third most commonly cited source of engagement (Liu et al., 2009).

Previous research also suggests that simply giving students choices based on a set of teacher pre-selected options does not result in increased motivation on its own. Students need to perceive an internal locus of causality and a sense of psychological freedom in addition to a perceived sense of choice in order to feel increased motivation (Reeve et al., 2003). In other words, students need to feel that the choices among which they are choosing are choices that they endorse.

A number of findings from research studying student choice and student engagement support the idea that choice beyond teacher pre-selected options is important. Lam et al. (2012) found that students who perceive that their teachers give them choices about how and what they learn were more likely to be engaged in that particular class. Hipkins (2012) found that students were more likely to report choosing topics to learn and having the ability to try out new ideas in their most enjoyed class compared to their least enjoyed class. British students who were exposed to different types of mathematics instructions said they liked “activities” best. A prominent reason for this was because they could work autonomously (National Research Council & Institute of Medicine, 2004). In each of these findings student engagement is correlated with more than just a choice between teacher pre-selected options.

A majority of research studying choice and engagement found positive relationships between student choice and student engagement. However, Assor et. al (2002) found that middle school students’ perception of choice was only related to students’ emotional engagement and not related to combined measure of students’ behavioral and cognitive engagement. Further, Mozgalina (2015) investigated choice and task motivation in six different treatment conditions of 120 university level students in Germany. The students were preparing and giving a presentation about a famous person. The six treatment conditions had different amounts of autonomy in choosing a person to study as well as choosing the structure of the presentation. The group that had the most choice, both in choosing the content of the presentation as well as the structure of the presentation, reported the lowest perception of choice. This finding suggests that students’ perception of choice may not accurately reflect the amount of choice in the classroom. Mozgalina (2015) also found that the groups with greater choice about the structure of the presentation had lower perceived task motivation compared to the other groups.

Findings from a majority of research studying the relationship between choice and engagement suggest a positive relationship between student choice and student engagement (Guthrie & Klauda, 2014; Hampden-Thompson & Bennett, 2013; Hipkins, 2012; Lam et al., 2014; Liu et al., 2009; Skinner & Belmont, 1993). However some evidence suggests that choice may engage students emotionally, but not behaviorally or cognitively (Assor, Kaplan, & Roth, 2002). Further, some research suggests that students' perceived choice may not accurately reflect the amount of choice in the classroom (Mozgalina, 2015).

Challenge. Classroom tasks that exhibit challenge inspire students to master goals beyond what they can easily accomplish. The relationship between challenge and student engagement is supported both theoretically and empirically by previous research.

Theoretical support for the relationship between challenging activities and motivation are described by SDT. The psychological need for competence is the need to be effective in exercising one's capacities in order to master environmental challenges (Reeve, 2012). Based on the psychological need for competence, people seek challenges that are just beyond their capacities (Deci & Ryan, 1985). In one study, elementary-aged children, who were allowed to choose how to spend their time in different learning centers, spent the most time in centers that were slightly above their initial ability level. The children rated these centers as most interesting and moderately difficult (Danner &

Lonky, 1981). Completing challenging tasks are likely to increase students' feelings of competence and therefore promote students' motivation and engagement.

Previous research has found evidence that challenging tasks are related to engagement (Hipkins, 2012; Liu et al., 2009; Newmann, 1992; Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003; Turner et al., 1998). One study found that 16 year old students were more likely to report learning things that were challenging in their most enjoyed class compared to their least enjoyed class (Hipkins, 2012). Another study found a correlation between high school students reported level of engagement and perception of challenge in their social studies classes (Newmann, 1992). Shernoff et al. (2003) found that both students' perception of high challenge and students' perception of using high skills were associated with increased engagement. Further, the highest level of engagement was reported when students felt both that they were challenged and using high skills. Similarly, Turner et at. (1998) found that students' perception of high challenge and students' perception of using high skills were associated with feelings of involvement and intrinsic motivation. Liu et al. (2009) interviewed sixth grade students about a problem-based learning unit. The fifth most common instructional characteristic that students attributed to their engagement was the challenge of the activity. For instance one student described, "I thought it was hard, but it was fun at the same time because it was a challenge and I personally like challenges" (Liu et al., 2009).

Previous research has also found evidence that optimal challenge is related to students' engagement in the classroom (Lam et al., 2007, 2012; National Research Council & Institute of Medicine, 2004; Turner et al., 1998; Yazzie-Mintz, 2010). Lam et al. (2012) found that students' perception of a particular classes' assignments having the correct amount of challenge was associated with student engagement in that class. Evidence that the incorrect amount of challenge is unengaging is evidence from the reasons that students cite for considering dropping out of school. According to the 2009 High School Survey of Student Engagement, 35% of students considered dropping out of school because of the difficulty of the work and 13% considered dropping out of school because "The work was too easy" (Yazzie-Mintz, 2010).

Feedback. In this study feedback is defined as constructive feedback that students receive to guide their work on the current task. It includes feedback from the teacher and feedback from peers. The relationship between feedback and students' engagement is supported theoretically by SDT and empirically by previous research.

SDT describes that students have a need to feel competence, which includes understanding what needs to be done to reach desired outcomes and being effective in reaching those outcomes (Deci & Ryan, 1991). Students need clear and consistent feedback in order to understand what needs to be done and understand how to be effective in accomplishing what needs to be done.

Findings from previous research suggest that the use of regular feedback is related to student engagement. Hipkins (2012) compared statements about how 16 year old students characterized their most enjoyed class and least enjoyed class. The statement, "The teacher gives me useful feedback on my work that helps me see what I need to do and how to do it" had one of the largest differences between how students characterized their most enjoyed class compared to their least enjoyed class (Hipkins, 2012). The statement, “We assess each others’ work and give feedback” also had a large difference between the most and least enjoyed class.

Further findings support the notion that the type of feedback that is likely to result in increased student engagement is not just feedback that grades student’s performance, but feedback that helps students gain mastery. Students who pursue mastery are interested in gaining competence and mastering the task at hand rather than simply being perceived as competent (Anderman & Patrick, 2012). Previous research found that classrooms that promote student mastery have a positive influence on students’ engagement (Anderman & Patrick, 2012). Lam (2014) specifically found that the construct of mastery-oriented evaluation correlated with student engagement. The construct of evaluation consisted of four items, two of which described the type of feedback that teachers gave to students consisted of comments, suggestions, and areas for improvement beyond or instead of grades (Lam et al., 2014).

Student collaboration. During student collaboration students communicate with other students to help each other with individual assignments or accomplish common assignments. The National Research Council and the Institute of Medicine (2004) describes that students enjoy collaboration because it enables them to have meaningful interactions, decreases alienation, and provides multiple minds to work on challenging problems.

The relationship between student engagement and the use of collaboration in the classroom is supported both theoretically and empirically. SDT describes that individuals have a psychological need for relatedness, which is a satisfying involvement with the social world (Deci & Ryan, 1991). The use of collaboration in the classroom provides the opportunity for students to feel a satisfying involvement with the social world and therefore increased student motivation and engagement. The psychological need for relatedness also includes the need to relate and care for others and to feel that others authentically relate to oneself (Deci & Ryan, 1991). The use of student collaboration in the classroom may provide opportunities for students to relate and care for others and feel that others authentically relate to oneself.

Findings from previous research suggest that the use of collaboration has a positive influence on students' engagement. Hipkins (2012) found that students were more likely to report collaborating with other students through group work in their most enjoyed class compared to their least enjoyed class. Hipkins also found a greater difference between students who reported "help and support" from each other (34% difference) and assessing each other's work and giving feedback to other students (27% difference) in their most enjoyed class compared to their least enjoyed class, suggesting that it is not just group work that influences students' engagement, but help and support from peers and peer assessment that influences engagement. Hampden-Thompson and Bennett (2013) found that students' perceptions of the use of collaboration was a significant predictor of high school students' self-reported emotional engagement in science class.

Qualitative research at the middle school level found that students reported collaboration as the source of emotional engagement more often than other instructional characteristics. Parsons and colleagues (2013) interviewed sixth grade students to learn students' perceptions of emotional and cognitive engagement. Thirty-five out of 75 of student responses attributed their emotional engagement to the use of collaboration in the classroom, which was cited more than any other instructional characteristic (Parsons, Parsons, & Malloy, 2013). Liu et al. (2009) also interviewed sixth grade students to determine what aspects of a problem-based science unit emotionally engaged them. Similar to Parsons et al. (2013), Liu et al. (2009) found that students cited enjoyment of group interaction as a common source of student engagement.

Real-life significance. Tasks that exhibit real-life significance can fall into one of two categories. Tasks can have real-life significance if the task includes a real-world problem or scenario. Tasks can also have real-life significance if the importance or relevance of the task (or learning targeted by the task) is explained to students. The relationship between real-life significance and students' engagement is supported both theoretically and empirically.

SDT describes that individuals have a psychological need for competence, which is the need to be effective in mastering challenges (Deci & Ryan, 1991; Reeve, 2012). Further, SDT contends that individual have a need for relatedness or belonging in the social world (Deci & Ryan, 1991). Organismic Integration Theory, a sub-theory of SDT, describes that students are naturally inclined to internalize and integrate values of the social world into their own personally endorsed value system (Reeve, 2012). Students proactively seek out opportunities to do this because they want to understand how to increase their competence in the social world and to feel belonging in the social world (Reeve, 2012). When the importance or relevance of a task is explained or when students engage in a real-world problem they are likely to feel increased competence to contribute to the real world and increased belonging in the social world.

Previous research has shown that real-life significance is related to student engagement. Lam et al. (2012) found students who reported that a particular teacher made the real life significance of learning known to students were more likely to be engaged in that class. Among the six characteristics of instruction studied by Lam and colleagues (2012), real-life significance had the highest correlation with student engagement. Hipkins (2012) studied the relationship between classroom characteristics and students' engagement based on 417 sixteen year old students in New Zealand. She compared the percent of students who strongly agreed with statements about classroom characteristics in their most enjoyed class compared to their least enjoyed class. The statement that resulted in the greatest difference between students' most enjoyed class and least enjoyed class described the real-life significance of the class. 77% of students agreed or strongly agreed that the statement, "The teacher uses examples that are relevant to my experience," described their most enjoyed class and only 27% of students agreed or strongly agreed that the statement described their least enjoyed class. Further, 54% of students agreed or strongly agreed that the statement, "We do projects about real things/issues" described their most enjoyed class whereas only 25% agreed or strongly agreed that the statement described their least enjoyed class (Hipkins, 2012).

Hampden-Thompson and Bennett (2013) found that students' perceptions of their teachers' use of science to understand the world outside of school and the relevance of science to his/her life was significantly related to students' self-reported emotional engagement. This construct, which they labeled, “application in science,” was the strongest predictor of student engagement compared to students’ perceptions of collaboration as well as the use of both guided and inquiry-based laboratory investigations.

One of the ten dimensions that Shernoff and colleagues (2016) measured as part of a learning environment measurement that predicted high school students’ engagement was “relevance of the activity.” To measure this dimension observers considered whether students understood the relevance of the activity and whether the activity used problem-based learning or addressed a real world problem or scenario.

Previous research has also shown that when teachers connect learning to students’ experiences through the context of real-world examples and problems, student achievement increases. A meta-analysis of 61 experimental or quasi-experimental studies researching the effect of various teaching strategies on student science achievement found that the category of “enhanced context strategies” had the greatest effect (ES=1.48, N=7235) on student achievement. Enhanced context strategies were defined as relating learning to students’ previous experiences and/or the real world. The category specifically included problem-based learning, but also included field trips and reflection (Schroeder et al., 2007).

On the other hand, when students do not see the real-life significance of their work, they are less likely to be engaged. According to the High School Survey of Student Engagement, the second-most cited reason given by 42% of high school students who consider dropping out of school is, "I didn't see the value in the work I was being asked to do" (Yazzie-Mintz, 2010).

Summary of Previous Research Studying Instruction and Engagement

There is significant evidence from previous research that the five task characteristics in the present study influence student engagement for middle and high school students across many subjects. Table 3 summarizes the large scale quantitative studies investigating the relationship between students' perception of the use of the five task characteristics in this study and student engagement.

Table 2

Large Scale Quantitative Studies Supporting the Relationship Between Choice, Challenge, Feedback, Collaboration, and Real-life Significance and Students' Engagement

Grade/age	7th-11th grade	7th-9th grade	16 year-olds	15 year-olds	7th grade	3rd – 5th grade	6th-8th grade
Country	Hong Kong	International	New Zealand	United Kingdom	United States	United States	Israel
N	2,2,43	3,240	417	11,775	615	144	364
DV	IM	BE, EE, CE	EE	EE, M	BE, M	BE, EE	EE, BE/CE
Choice	X	X	X		X	X	EE only
Challenge	X	X	X				
Feedback	X	X	X				
Collaboration			X	X	X		
Real-life significance	X	X	X	X	X	X	X

Note. BE = behavioral engagement, EE = emotional engagement, CE = cognitive engagement, M = motivation, IM = intrinsic motivation

The "X" indicates which studies specifically found evidence for which task characteristics are related to engagement. Taken together, there is strong evidence for the relationship between the five task characteristics in this study and engagement. Specific research has found that student engagement is linked to some of the five task characteristics at the high school level (Hipkins, 2012; Lam et al., 2007), at the middle school level (Assor et al., 2002; Lam et al., 2014), and in high school science (Hampden-Thompson & Bennett, 2013). However, only one identified study investigated the influence of instructional characteristics on middle school students' engagement in science (Liu et al., 2009). Liu and colleagues (2009) found evidence that some task characteristics influence students' engagement, but they only considered what engaged students during one particular online learning module. Therefore, the general purpose of this study is to investigate the relationship between choice, challenge, feedback, collaboration, and real-life significance and seventh grade students' engagement in science class.

The research summarized in Table 2 is based on large scale correlational analyses of students' perceptions of instructional characteristics and students self-reported engagement where both students' perceptions of instruction and engagement are measured through self-report. These findings are limited because the fluid nature of instruction and student engagement are not captured. The following section describes the different between fluid and static measurements of engagement and instruction.

Static versus situational engagement. In his most recent book, *Optimal Learning Environments to Promote Student Engagement*, David Shernoff (2012) describes the difference between static engagement and situational engagement as "capital E" Engagement and "small e" engagement." While Engagement characterizes a static orientation a student generally has with school, a students' moment-by-moment engagement ebbs and flows throughout the day. He proposes that the positive emotions associated with "small e" engagement "may gradually accrue meaning, culminating in a strengthened, sustained, and persistent involvement in an area of interest" (Shernoff, 2013, p. 52). In other words, Engagement with a big E, or static engagement, may result from the summation of experiences of situational engagement. Similar to Shernoff, Sinatra and colleagues (2015), discuss the "grain size" of the context used to measure engagement. The grain size can range from an individual's engagement in a particular task to a group of learners' engagement in a course or school.

Self-report surveys asking students to characterize their general engagement are the most commonly used measurement of engagement as a multidimensional construct (Fredricks & McColskey, 2012). This measurement of engagement provides a static or summative measurement of engagement over a particular period of time. Other researchers have conceptualized engagement as a fluid construct and measured engagement through student interviews, classroom observations, or short self-report surveys (Parsons et al., 2015; Rotgans & Schmidt, 2011; Shernoff et al., 2014). This conception of engagement is sometimes referred to as situational (Rotgans & Schmidt, 2011) or moment-by-moment (Shernoff et al., 2014) engagement. A situational measure of engagement captures the fluid nature of engagement over the course of days and weeks. Using a situational measure of engagement is important in this study in order to study how engagement fluctuates based on the fluctuating instructional practices within a classroom.

Static vs. situational measure of instruction. Similar to the measure of engagement, the measure of instruction as it relates to engagement, has also been primarily measured statically. Previous studies often used self-report surveys asking students to report their perceptions of instruction over the course of a semester or school year (Hampden-Thompson & Bennett, 2013; Hipkins, 2012; Lam et al., 2014, 2012). Also similar to the measure of engagement, some previous researchers have conceptualized instruction as a fluid construct and measured it through daily observations or interviews (Parsons et al., 2015; Shernoff et al., 2014). A situational measure of instruction captures the fluid nature of instruction over the course of days or weeks.

Previous research measuring both engagement and instruction as static traits. The majority of previous research studying the relationship between instructional characteristics and student engagement consists of large scale quantitative studies using surveys to measure both students' perceptions of instructional characteristics and students' self-reported engagement. These measurements assume that engagement and instruction are static traits. In the following section, I will describe the strengths and limitations of each of these large-scale quantitative studies.

Seven previous studies considered the relationship between students' perceptions of the use of instructional characteristics and students' self-reported engagement. Considered together, these studies provide strong evidence that the five task characteristics in this study are related to engagement for middle and high school students in the United States. However, these studies are limited in some ways. Only one study considered all five of the task characteristics in this study. Further, two of the seven studies considered how instructional characteristics are related to emotional engagement, rather than viewing engagement as a multidimensional construct. Only two of the seven studies took place in the United States. Further, none of these studies specifically considered the relationship between task characteristics and middle school science.

The first set of studies, completed by Lam and colleagues (Lam et al., 2014, 2007), is based on the creation and use of a Motivating Instructional Contexts Inventory (MICI) to measure students' perceptions of the use of six characteristics of instruction, which theoretically influence student motivation. The MICI includes four characteristics of instruction that correlate with task characteristics in this study: autonomy (choice in this study), challenge, evaluation (feedback in this study), and real-life significance, but does not include the use of collaboration. Based on 2,243 secondary school students in Hong Kong (equivalent to grades seven to eleven in the United States), the six instructional contexts measured by the MICI correlated with students' self-reported intrinsic motivation ($r = .22$, $p < .01$) (Lam et al., 2007). Although the MICI was designed with the intention of measuring students' perceptions of a motivating instructional context, the instructional characteristics measured with the inventory had a stronger correlation with students' self-reported engagement compared to students' self-reported motivation. Based on a sample of 3,240 seventh, eighth, and ninth grade students from 12 countries, Lam and colleagues (2014) found that students responses to the MICI correlated with students' self-reported engagement with a higher correlational coefficient than the previous study ($r = .50$, $p < .01$). These studies provide strong evidence that four of the five task characteristics (collaboration not measured) are related to student engagement at the middle and high school level.

The studies completed by Lam and colleagues (Lam et al., 2014, 2007) are limited in their ability to inform how instruction influences engagement in the United States because they took place in other countries. Although the second study is based on data collection in 12 countries, the first study only collected data from students in Hong Kong. The studies completed by Lam and colleagues (Lam et al., 2014, 2007) are further limited because the measurements of engagement and the use of instructional characteristics were self-reported by students. Lam and colleagues (Lam et al., 2014) identify this as a limitation of their research. They describe that student engagement was only measured by student self-report, which while valid, "using information from teachers, parents, peers, and third-party observers would add to the validity and robustness of the study" (Lam et al., 2014, p. 227). Finally, the measurement of engagement and the use of instructional characteristics were static measurements. The present study addresses these limitations by using both self-report and observational data and measures engagement and instruction as fluid traits.

Hipkins (2012) analyzed statements that 417 sixteen-year-old students from New Zealand attributed to their most enjoyed class compared to their least enjoyed class and found some evidence supporting the relationship between all five of the task characteristics in this study and engagement. Although, evidence supporting the relationship between some of the task characteristics in this study, such as real-life significance and feedback, was stronger than others. There was only weak evidence supporting the use of collaboration. Further, the measure of engagement in this study was based on a measure of emotional engagement alone. Hipkins recognized this limitation of her study, but argued that there is significant evidence that emotional engagement is predictive of cognitive and behavioral engagement and therefore, can serve as a proxy for a measure of general engagement. Although emotional engagement is related to cognitive and behavioral engagement, measuring all three dimensions of engagement provides a more robust conceptualization of the construct (Fredricks et al., 2004). Therefore, the present study measures behavioral, emotional, and cognitive engagement.

Similar to Hipkins (2012), a study completed by Hampden-Thompson and Bennett (2012) used a modified conceptualization of engagement in order to take advantage of data collected from 11,775 fifteen year-old students living in the United Kingdom as part of the 2006 Program for International Student Assessment (PISA). Hampden-Thompson and Bennett studied the relationship between students' perceptions of four instructional characteristics and a measure of student engagement consisting of what they described as an emotional dimension and a cognitive dimension. While the definition of emotional engagement in this study aligned with previous conceptualizations of emotional engagement, the definition of cognitive engagement was actually a measure of students' motivation in science and orientation towards a future in science. Only two of the four instructional characteristics in the Hampden-Thompson and Bennett study align with the task characteristics in this study. Further, as described above, the study was limited in that they did not measure behavioral and cognitive dimensions of engagement.

Two additional studies provide evidence that task characteristics from this study are related to students' engagement. When measured as static traits, three task characteristics from this study (real-life significance, choice, and collaboration) were related to students' engagement in middle school English Language Arts (Guthrie & Klauda, 2014) and two task characteristics (real-life significance and choice) were related to students' engagement in elementary school (Skinner & Belmont, 1993). Each of these studies measure engagement and instruction at static variables, but at multiple time points. I will discuss them in more detail in the following section detailing research measuring both variables dynamically or at multiple time points.

The six studies previously described provide strong evidence that the use of the five task characteristics in this study are likely to have a positive effect on student engagement. However, none of these studies specifically considered the relationship between the five task characteristics in this study and students' engagement in middle school science. Further, in the previous studies, both the measurements of engagement and instruction are static measurements based on self-report. Although often measured as static traits, both engagement and instruction are fluid traits. Studying the relationship between a fluid pattern of instruction and a situational measure of engagement over time will provide additional insight into the relationship between the two variables. The present study uses both a situational measure of engagement as well as a fluid measure of instruction in order to investigate the relationship between observed task characteristics and the changing pattern of student engagement over time. The following section describes previous research that measured engagement and instruction as fluid traits.

Summary of research measuring engagement and instruction as fluid traits. Each of the following studies investigated the relationship between engagement and instruction by measuring engagement and/or instruction dynamically in some way. Each of these studies exemplify how studying the relationship between instruction and engagement dynamically, or over time, provides additional insights into the relationship between the variables. Two studies, which took place at the middle school level, measured engagement and instruction at varying points in order to measure the effectiveness of professional development programs aimed at increasing teachers' use of motivating instruction (Guthrie & Klauda, 2014; Turner, Christensen, Kackar-Cam, Trucano, & Fulmer, 2014). Another study, which took place at the elementary school level, measured both teaching context and students' engagement in the fall and spring in order to study how student and teacher perceptions in the fall impact student and teacher perceptions in the spring (Skinner & Belmont, 1993). Another study measured instruction and the engagement of low-achieving and high-achieving students during one reading lesson in three different classrooms (Lutz, Guthrie, & Davis, 2006).

A final study, which took place in high school classrooms across many subjects, measured engagement and instruction similar to this study. Engagement was measured by surveying students about a short enough instructional periods that the instructional characteristics could be realistically measured through outside observation (Shernoff et al., 2016). Although Shernoff et al. (2016) measured engagement and instruction as dynamic traits, they analyzed the data points independently and did not consider how the changing pattern of instruction was related to the pattern of engagement.

In the first study measuring the effectiveness of middle school professional development, Guthrie and Klauda (2014) measured students' perceptions of the use of instructional support in control and treatment groups at three different times in order to study the effect of Concept-Oriented Reading Instruction (CORI). The four motivational instructional support practices align closely with four of the five task characteristics in this study: choice, collaboration, importance (real-life significance in this study), and competence (feedback in this study). By analyzing the use of motivational instructional support practices for both treatment and control groups at three different time points, they were able to conclude that CORI increased students' perceptions of the use of choice, collaboration, importance, and competence. They also found that students' perceptions of choice, collaboration, importance, and competence were more highly associated with increases in students' intrinsic motivation during CORI compared to the control group. These findings exemplify how measuring instruction and engagement over time can provide additional insights into the relationship between the variables.

In the second study measuring the effectiveness of middle school professional development, Turner et al. (2014) observed student engagement and the use of motivational support in six middle school classrooms over the course of three years in order to study change as a dynamic process following teaching professional development focusing on motivation and instruction. They observed classrooms four times a year and used observation protocols to measure both students' engagement and use of motivation support. By analyzing the twelve data points collected over time for each classroom, they were able to categorize the six teachers into two categories: those that had an upward trend in their use of motivational support and those that were stable in their use of motivational support. Further, they measured the variability in the data over time in order to help explain how the student-teacher interaction may have influenced the development of the two groups. Analyzing measurements of instruction and engagement over time enabled Turner and colleagues (2014) to draw implications about conceptualizing engagement and change as a dynamic process that would not have been possible if they only measured the variables statically.

Skinner and Belmont (1993) measured both teaching context and students' engagement in the fall and spring in order to study how students' and teachers' perceptions in the fall impact students' and teachers' perceptions in the spring. Specifically, teaching context included a measurement of involvement, structure, and autonomy support and engagement was conceptualized with two dimensions: behavioral engagement and emotional engagement. The autonomy dimension included items that tapped two task characteristics in this study: choice and real-life significance. Students' self-reported perception of teachers' autonomy support in the beginning of the year correlated with students' self-reported behavioral and emotional engagement in the spring. However, students' perceptions of autonomy support in the beginning of the year did not predict students' engagement in the spring as well as students' perceptions of teachers' involvement and structure in the beginning of the year. This finding, based on data collected over multiple time points, exemplifies how studying the influence of instruction on student engagement over time provides further insight into the relationship between the variables.

Lutz and colleagues (2006) measured the engagement of two low-achieving students and two high-achieving students in three different fourth grade classrooms during one 20-30 minute lesson as part of a larger study investigating reading instruction. Lutz and colleagues conceptualized engagement as a multidimensional construct and measured each of four dimensions, behavioral, emotional, cognitive, and social engagement for each of the 12 students every thirty seconds. By measuring both the fluctuation of engagement and instruction throughout the class period, they found that teacher directed individual attention to students was related to increased student engagement. Further, from their analysis of just one of the classrooms, they also found that engagement for the two high-achieving students increased when the teacher posed a cognitively challenging question. On the other hand, engagement for the two low-achieving students increased when the teacher ask students to share questions that they wrote and prompted them to continue reading. Compared to the present study, the study conducted by Lutz and colleagues is limited in that it only took place during one class period and average-achieving students were not included.

Similar to the present study, Shernoff and colleagues (2014) measured students' engagement with short surveys associated with a short enough period of time that the instruction for that period of time could be measured by observation. Shernoff and colleagues (2014) measured situational student engagement of 140 high school students in seven different classrooms in the following subjects: English, Math, Science, Social Studies, and Spanish. Instruction was measured through a classroom observation protocol that measured ten different dimensions of the learning environment. They found that "environmental complexity," which was a summative measure of the ten dimensions of the learning environment, predicted students' self-reported situational engagement. Two of the ten dimensions measured as part of “environmental complexity” aligned closely with task characteristics from this study, “feedback” and “relevance of the activity.” Five more of the ten dimensions contain aspects of the other three task characteristics from this study. For instance, the dimension, “Authentic and Challenging Tasks” measured by Shernoff and colleagues (2014) contains the statement, “challenge a good match for skill level,” which aligns with the challenge task characteristic, and “solving problems or fashioning products,” which aligns with the real-life significance task characteristic. These findings suggest that the five task characteristics in this study are related to engagement even when engagement and instruction are measured as fluid traits. However, the study takes place at the high school level across many subjects. Further, the measurement of “environmental complexity” used by Shernoff and colleagues (2016) was a global measurement that contained other aspects of instruction besides the task characteristics measured in this study. It is difficult to tease out which of the many aspects of each of the ten dimensions measured as part of “environmental complexity” may have had the most influence on students’ engagement.

Although Shernoff and colleagues (2016) collected data at multiple points during the same class period, they did not collect data from the same class over multiple days. In their analysis, they considered each time point to be independent of each other and therefore, did not specifically consider how the pattern of instruction influenced the pattern of engagement.

Each of these five studies described above exemplify how measuring engagement and instruction dynamically provides additional insights into the relationship between the variables. None of these studies, however, are situated in middle school science. Further, none of these studies measure engagement and instruction over multiple days within one instructional unit. Findings from previous research suggest that engagement is related to the five task characteristics in this study. Measuring task characteristics and engagement during each task of a multi-day instructional unit will provide additional insights about the relationship between these variables throughout the flow of instruction.

Conclusion

SDT as well as previous research suggests that task characteristics of choice, challenge, feedback, collaboration, and real-life significance are related to middle and high school students' engagement generally across all subjects. This study provides specific insight into the relationship between these five task characteristics and seventh grade students' engagement in science class. Previous research studying the influence of instruction on students' engagement primarily measures both instruction and engagement as static traits, which does not capture the fluid nature of instruction or engagement. At the same time, previous research that analyzed engagement and instruction at multiple points over time, provided additional insight into the relationship between instruction and engagement. Therefore, the purpose of this research is to study the relationship between the pattern of task characteristics and the pattern of seventh grade students' situational engagement in science class over multiple instructional units.

Chapter Three describes the procedures, participants, setting, and instrumentation used in this study, along with the proposed data analysis to address the following research questions:

1. Is there a relationship between the observed level of task characteristics in a seventh grade science classroom and students' engagement in the task?
2. What is the relationship between the pattern of observed task characteristics during a multi-day science instructional unit and the pattern of seventh grade students' situational engagement over the same multi-day instructional unit?

Chapter Three: Methods

The purpose of this research was to study the relationship between five specific task characteristics and seventh grade students' engagement over an instructional unit. The specific task characteristics investigated in this study included: the use of tasks that give students opportunities to act autonomously (choice), the use of tasks that challenge students (challenge), constructive feedback from the teacher or peers that guides students work on the current task (feedback), the inclusion of tasks that require student collaboration (collaboration), and the importance or relevance of the task is explained to students or the task includes a real-world problem or scenario (real-life significance).

In this study student engagement was conceptualized as a fluid trait (Parsons et al., 2015; Rotgans & Schmidt, 2011; Shernoff et al., 2016) having behavioral, emotional, and cognitive dimensions (Fredricks et al., 2004; Reeve, 2012; Reschley & Christenson, 2012). Behavioral engagement included on-task involvement and effort in the classroom (Reeve & Tseng, 2011). Emotional engagement was measured as students' interest in the current task (Fredricks et al., 2004; Hampden-Thompson & Bennett, 2013; Lam et al., 2014; Reeve & Tseng, 2011; Shernoff et al., 2016; Skinner & Belmont, 1993). Cognitive engagement was measured as the strategy of connecting new learning to previous learning (Greene, 2015; Reeve & Tseng, 2011).

This chapter describes the methods used to conduct this study. The participants, procedures and measures are described. Then the methods to analyze the data are explained and the significance of the study is reviewed.

Participants

Participants included two seventh grade science teachers from the same school and all the students they teach in one their classes. The school was recommended by a school district middle school science curriculum coordinator based on the criteria that seventh grade science teachers in the school use a variety of instructional approaches to teach science. The school offered three levels of seventh grade science: an advanced class offered to students who are selected based on test scores and academic performance, an honors class, and a general education class. Students who are not offered the advanced class could choose between taking the honors class and the general class.

The school where this study took place is a middle school with seventh and eighth grade students located in the metropolitan region of a Mid-Atlantic city. In the year before the study took place there were 989 students enrolled in the school and 47.42% of students were female. Also in the year before the study took place, students' ethnicity at the school was 11.02% Asian, 15.37% Black (not of Hispanic origin), 27.30% Hispanic, 40.55% White (not of Hispanic origin), and 5.76% another ethnicity. In that same year before the study took place 16.08% of students were identified as Limited English Proficient and 39.64% of students qualified for free or reduced lunch.

The specific teachers and class periods used in the study were chosen based on the criteria of being a general education class, not meeting during the first period of the day (due to a scheduling conflict of the primary researcher), and not meeting at the same time as each other. The teacher of the first class, Mr. Oliver, was a 60 year old male who was in his sixth year of teaching science. Teaching was his second career. The teacher of the second class, Ms. Jay, was a 32 year old female who was in her tenth year of teaching. The first class had 20 students in the class (11 males and 9 females). Two students' parents did not sign the consent form for the study. Therefore, 18 students (10 male and 8 female) participated in the study from the first class. The second class had 19 students in the class (10 males and 9 females). Four students' parents did not sign the consent form for the study. Therefore, 15 students (6 males and 9 females) participated in the study from the first class.

Before the study began, the project was explained to students. An assent form (Appendix C) was given to students to sign. A brief letter was sent home to parents (Appendix D) with a consent form (Appendix E). Students only participated in the study if they agreed to the assent form and their parents signed the consent form. The teachers signed consent forms (Appendix F). The methods for this project were reviewed by George Mason University IRB and the project was exempt from IRB review (Appendix A and Appendix B).

Certain topics throughout the science curriculum are likely to ignite specific emotions in students (Sinatra, Broughton, & Lombardi, 2014). For instance, students reported experiencing high levels of curiosity and interest when thinking about climate change (Broughton, Pekrun, & Sinatra, 2012). In order to control for the role of topic emotions, both classrooms were observed during instructional units addressing the same topic. In this school district teachers often teach the same topic during the same time of year. Therefore, in order to observe two teachers each day, both teachers were chosen from the same school.

Both classrooms were observed starting at the beginning of a unit primarily investigating cells. In both classrooms the unit also included experimental design, functions of living things, and organization of living things.

Procedures

The classes in this study met every other day for 1.5 hour blocks. Students in each class in the study were observed and video-recorded starting at the beginning of the cell instructional unit. Both classes were observed and video-recorded for the next ten consecutive blocks in the instructional unit. One of the classes went on a field trip un-related to the cell unit during the study. Since the purpose of the study was to investigate task characteristics and engagement over the course of an instructional unit, this block was not included in the study.

Tasks, or classroom activities that require students to generate a product, were the unit of analysis for the study. The product could be a written response, presentation, or object. At the end of each class period, students completed three Likert-type item survey for each of the tasks they completed in the block.

Prior to the class observations, the researcher determined what tasks the teacher expected students to complete during the class period being observed. Prior to each class observation, the teacher to emailed or explained to the primary researcher a description of the expected task(s) that students would complete during the block. At the beginning of the study the researcher explained to the teacher that each time students are given a new set of directions to develop a new type of product, they are completing a new task. The teacher was given the following directions to determine what constitutes a task:

Imagine a scenario where students first work with a partner to brainstorm ideas to prepare to write an essay. Then students took turns sharing their ideas with the class while the teacher recorded ideas in the front of the room and students recorded new ideas on their paper. Finally, students are given time to begin writing an essay on their own. The following day students are given more individual time to complete their essay. In this scenario, students have completed three separate tasks: working with a partner to brainstorm ideas for an essay, sharing ideas with the class while recording new ideas, and individually writing an essay. In this scenario, students would complete three surveys on the first day about the three tasks students worked on the first day and one survey on the second day to once again report about writing the essay. Imagine a different scenario where students brainstorm ideas for an essay and then write the essay. If the teacher does not specifically separate the time that students brainstorm for the essay and write the essay, the students have only completed one task.

Measures

In order to study the relationship between observed task characteristics and the pattern of students' situational engagement, both observed task characteristics and students' situational engagement were measured in conjunction with each task in the instructional unit. As described in Table 1, the task characteristics of choice, feedback, collaboration, and real-life significance were measured using the Task Characteristics

Rating Scale (Appendix H) while watching the classroom video-recordings and viewing contextual information. Behavioral engagement was measured by observation using the Behavioral Engagement Rating Scale (Appendix H). Emotional engagement, cognitive engagement, and challenge was measured by a student survey (Appendix G).

Student engagement. In this study student engagement was conceptualized as a multidimensional construct consisting of behavioral, emotional, and cognitive dimensions (Christenson et al., 2012; Fredricks et al., 2004). Behavioral engagement was students' on-task involvement and effort in the classroom (Fredricks et al., 2004; Reeve & Tseng, 2011; Skinner & Belmont, 1993). Emotional engagement was students' interest in the current task (Fredricks et al., 2004; Hampden-Thompson & Bennett, 2013; Lam et al., 2014; Reeve & Tseng, 2011; Shernoff et al., 2016; Skinner & Belmont, 1993). Cognitive engagement was students' connecting new learning to previous learning (Greene, 2015; Reeve & Tseng, 2011). In this conceptualization of engagement, behavioral engagement is often considered to be an observable, action-oriented dimension whereas emotional and cognitive engagement are internal (Reschley & Christenson, 2012). Therefore, in this study, students' behavioral engagement was measured by observation and students' emotional and cognitive engagement were measured by survey.

Behavioral engagement. In this study behavioral engagement was students' on-task involvement and effort in the classroom (Fredricks et al., 2004; Reeve & Tseng, 2011; Skinner & Belmont, 1993). Similar to previous researchers, on-task involvement was conceptualized as an observable trait in this study and measured by observation (Lutz et al., 2006; Parsons et al., 2015). Appleton and Lawrenz (2011) measured student engagement through observation by measuring whether 0-20% of the class, 20-80% of the class, or 80-100% of the class appeared engaged every five minutes. This observational measure of engagement did not predict students' self-reported engagement (Appleton & Lawrenz, 2011). In their conclusions, Appleton and Lawrenz suggest that more frequent samples with finer scales may produce observational data more predictive of students' perceptions of their own engagement. Based on this suggestion, behavioral engagement will be measured more frequently (every minute) with a finer scale. The scale consisted of the percent of students who appear on-task every minute.

In the observation protocol used by Appleton and Lawrenz (2011) they judged the percent of students who were "displaying on-task and involved actions relevant to the academic tasks of classroom instruction" (Appleton & Lawrenz, 2011, p. 147). This language is the broad indicator of behavioral engagement on the Behavioral Engagement Rating Scale (Appendix G). More specific indicators to judge students' engagement with the Behavioral Engagement Rating Scale are from the behavioral engagement observation protocol used by Lutz and colleagues (2006). Lutz and colleagues (2006) scored individual students' behavioral engagement on a four point scale with the least engaged rating for behaviors completely unrelated to the current task and the most engaged rating for behaviors suggesting enthusiasm and eagerness to participate. Using the behavioral engagement rating scale combined with emotional and cognitive engagement rating scales, Lutz and colleagues (2006) achieved at 92.5% exact agreement between two judges. Lutz et al.'s description of the third highest level of behavioral engagement, "clearly on-task, as suggested by eye movement and posture toward the speaker; raising hand; writing; speaking; clearly listening," (Lutz et al., 2006, p. 17) comprises the next set of indicators on the Behavioral Engagement Rating Scale.

As described in the Behavioral Engagement Rating Scale, the number of students on-task was counted every minute. Students were counted starting at the beginning of each minute. To the best extent possible, students were counted in the same order every time. At the beginning of the study students were numbered on a seating chart in a sweeping pattern around the room so that students would be counted in the same order every minute. When students moved throughout the classroom for certain activities, students were counted in the same pattern around the room as usual, but students were then counted in a different order.

In order to determine the reliability of the Behavioral Engagement Rating Scale, two observers measured students' behavioral engagement during some class periods. Lacy and Riffe (1996) describe that the number of randomly selected samples required for a reliability test is based on the total sample size, the desired confidence interval, and desired p-value. Equation 1 (Lacy & Riffe, 1996) estimates the random sample size for reliability tests where *n* is the number of test units, *N* is the total sample size, *CI* is the desired confidence interval subtracted from 100%, *Z* is the Z-score associated with the desired p-value, and *P* is the desired level of agreement for the whole set of scores.

Equation 1 Sample Size for Reliability Test

$$n = \frac{(N-1)(CI/Z)^2 + P(1-P)N}{(N-1)(CI/Z)^2 + P(1-P)}$$

The amount of behavioral engagement data scored by two raters for the reliability study was calculated using Equation 1. During the study 861 behavioral engagement scores were recorded. Using Equation 1 with 861 as the total sample size, a 95% confidence interval, a desired p-value of .05, and a 80% desired level of agreement for the whole set of scores, the number of behavioral engagement scores required to estimate reliability was 144. During four blocks in the study a second researcher measured students' behavioral engagement. This resulted in 208 behavioral engagement scores for the reliability study.

The primary observer using the Behavioral Engagement Rating Scale had five years of experience teaching middle and high school science and math and was the lead researcher in this study. The criteria for selecting observers for the reliability study was experience teaching or leading students between ages eight and 18 and some familiarity with social science research. Two additional researcher participated in the Behavioral Engagement Rating Scale reliability study. One of the observers in the reliability study was a graduate student in an Education Ph.D. program. She had eight years of experience teaching Spanish in elementary, middle, and high school. The second observer in the reliability study was also a graduate student in an Education Ph.D. program. She had 13 years of combined experience teaching elementary school and math at the middle school level. Both researchers in the reliability study were trained by using the Behavioral Engagement Rating Scale during a class block that was not included in the reliability study. The four blocks used in the reliability study were randomly selected from the ten total blocks that at least one researcher was available to collect data.

The intra-class correlation (ICC) statistic was calculated between the first and second raters' engagement scores in the reliability study to determine the reliability of the

Behavioral Engagement Rating Scale. The ICC statistic is appropriate for ratio variables and suitable for studies where a subset of units are rated by two coders and the other units are rated by one coder (Hallgren, 2012). Unlike Cohen's kappa, which is calculated based on all-or-nothing agreement, calculation of an ICC statistic includes the magnitude of disagreement (Hallgren, 2012). When counting the number of students who are on-task in a minute, scores that differ by one or two have greater reliability compared to scores that differ by many students. Therefore, the ICC statistic was a useful measure of reliability for the Behavioral Engagement Rating Scale.

The specific ICC statistic used was a one-way random model. Because more than two raters scored the all paired data, a one-way model was used instead of a two-way model (McGraw & Wong, 1996). The data analyses for the rest of study used the scores generated by the primary rater alone. Therefore, the reliability based on single measures was used rather than the reliability based on average measures (McGraw & Wong, 1996).

Emotional engagement. Emotional engagement is broadly defined as students' positive feelings about learning (Fredricks et al., 2004). This can include interest, enjoyment, happiness, and curiosity. Students were asked to report their emotional engagement in association with each task throughout two instructional units. Students will most likely report their emotional engagement 20 to 35 times throughout the study. Therefore, emotional engagement will be measured with a single item in order to reduce the burden on instructional time.

The two emotions included most often in previous surveys measuring emotional engagement are interest (Hampden-Thompson & Bennett, 2013; Lam et al., 2014; Reeve

& Tseng, 2011; Shernoff et al., 2016; Skinner & Belmont, 1993) and enjoyment (Hampden-Thompson & Bennett, 2013; Hipkins, 2012; Lam et al., 2014; Reeve & Tseng, 2011; Taboada Barber & Buehl, 2013). Reeve and Tseng (2011) measured the emotional engagement of 365 high school students with four items, which tapped students' feelings of enjoyment, interest, curiosity, and fun. Table 3 shows the factor loadings of each item to the emotional engagement factor based on an exploratory factor analysis of the twenty-two items measuring all dimensions of engagement.

Table 3

Factor Loadings of Emotional Engagement Items to the Emotional Engagement Factor from Engagement Survey Conducted by Reeve and Tseng (2011)

Item	Factor Loading
When I am in class, I feel curious about what we are learning	.88
When we work on something in class, I feel interested	.84
I enjoy learning new things in class	.78
Class is fun	.45

The items measuring curiosity, interest, and enjoyment all had high (>.8) factor loadings to the emotional engagement factor (Reeve & Tseng, 2011). Although curiosity had the highest factor loading, interest is used in this study because it is a more common measure of emotional engagement across the field (Hampden-Thompson & Bennett, 2013; Lam et al., 2014; Shernoff, 2013; Skinner & Belmont, 1993). Therefore, students' interest in the task is used to measure students' emotional engagement (Appendix G).

Cognitive engagement. The definition of cognitive engagement can include investment in learning (Fredricks et al., 2004), preference for challenge, and positively coping with failure (Connell & Wellborn, 1991). More commonly, cognitive engagement is defined as sophisticated learning strategies, metacognition, and self-regulation (Greene, 2015; Reeve & Tseng, 2011). Some researchers argue that self-regulation and metacognition should not be included in cognitive engagement (Lam et al., 2014; Reeve & Tseng, 2011). Therefore, the definition of cognitive engagement in this study is limited to students' use of sophisticated learning strategies (Reeve & Tseng, 2011).

Students were asked to report their cognitive engagement in association with each task throughout two instructional units. Students will most likely report their cognitive engagement 20 to 35 times throughout the study. Therefore, cognitive engagement will be measured with a single item in order to reduce the burden on instructional time.

Reeve and Tseng (2011) measured the cognitive engagement of 365 high school students with eight items. Table 4 shows the factor loadings of each item to the cognitive engagement factor based on an exploratory factor analysis of the twenty-two items measuring all dimensions of engagement (Reeve & Tseng, 2011).

Table 4

Factor Loadings of Cognitive Engagement Items to the Cognitive Engagement Factor from Engagement Survey Conducted by Reeve and Tseng (2011)

Item	Factor loading
1. When doing schoolwork, I try to relate what I'm learning to what I already know	.85
2. When I study, I try to connect what I am learning with my own experiences	.83
3. I try to make all the different ideas fit together and make sense when I study	.83
4. I make up my own examples to help me understand the important concepts when I study	.71
5. When what I am working on is difficult to understand, I change the way I learn the material	.68
6. When I'm working on my schoolwork, I stop once in a while and go over what I have been doing	.47
7. As I study, I keep track of how much I understand not just if I am getting the right answers	.45
8. Before I begin to study, I think about what I want to get done	---

Not surprisingly, items 4-8, which tap self-regulation and metacognition, have low or no (item 8) factor loadings to the emotional engagement factor. Items 1-3 have the highest factor loadings and are all quite similar. Because item 1 has the highest factor loading and is similar to the other two items with the highest factor loadings, the item measuring cognitive engagement in this study is adapted from item 1. Therefore, the extent that students connected what they learn in the task to what they already know is the single item measuring cognitive engagement in the student survey (Appendix G).

Validity. As three dimensions of the multidimensional construct of engagement, behavioral, emotional, and cognitive engagement are related to each other (Christenson et al., 2012; Fredricks et al., 2004). Therefore, in order to test the validity of the measures, the Pearson correlation coefficient will be determined between the behavioral, emotional, and cognitive engagement scores for each task.

The validity of the behavioral engagement rating will be further tested with the inter-rater reliability calculation used to test the reliability of the behavioral engagement scores. If two independent raters score behavioral engagement similarly, it contributes to the validity of the measure.

The survey items used to measure students' emotional and cognitive engagement were taken from the engagement survey used by Reeve and Tseng (2011). Reeve and Tseng (2011) tested the validity of the emotional and cognitive survey items by calculating the Pearson correlation coefficient between emotional and cognitive engagement and students' perceived autonomy, competence, relatedness, and achievement. As expected, emotional engagement was significantly correlated with perceived autonomy ($r = .43$, $p < .01$), perceived competence ($r = .49$, $p < .01$), perceived relatedness ($r = .57$, $p < .01$), and achievement ($r = .47$, $p < .01$). Cognitive engagement was also significantly correlated with perceived autonomy ($r = .32$, $p < .01$), perceived competence ($r = .49$, $p < .01$), perceived relatedness ($r = .32$, $p < .01$), and achievement ($r = .50$, $p < .01$). The correlation between students' emotional and cognitive engagement and students' achievement and perceived autonomy, competence, and relatedness contributes to the validity of the emotional and cognitive engagement survey items.

Task characteristics. Choice, feedback, collaboration, and real-life significance will be scored using the Task Characteristics Rating scale (Appendix I) while watching the classroom video-recordings and reviewing contextual information. Each separate task completed by students will be the unit of analysis. Because the amount of challenge perceived by each student is unique to each student and difficult to determine by observation, the challenge task characteristic will be measured by a survey item, which is described below.

Choice, feedback, collaboration, and real-life significance. Choice, feedback, collaboration, and real-life significance will be measured using the Task Characteristics Rating Scale. The overall format of the Task Characteristics Rating scale is the same as the format of the observation protocol used by Shernoff and colleagues (Shernoff, 2013; Shernoff et al., 2016) to measure dimensions of the learning environment. However, Shernoff and colleagues measured 10 dimensions of the learning environment and the Task Characteristics Rating Scale measures four task characteristics. Like Shernoff and colleagues, each task characteristic (dimension of the learning environment), is described by a set of indicators. Also, each task characteristic (dimensions of the learning environment) is given a rating between zero and six based on the amount of time that different percentages of the indicators were present. For instance, a score of zero is given when none of the indicators were present, a score of three is given when "half of the indicators were present or some of the indicators were present half the time," and score of six is given when “all of the indicators were present or most of the indicators were present in an exemplary way.” After several iterations of coding and discussion, Shernoff and colleagues achieved a Cohen’s Kappa of .80 or above for all coding categories in their observation protocol.

Chapter Two described the previous research and theory informing the definition of each task characteristic. Like the observation protocol used by Shernoff and colleagues (2013, 2016), multiple specific indicators were chosen to define each indicator. The specific wordings of most indicators were adapted from the observation protocol used by Shernoff and colleagues or from previously used surveys measuring students’ perceptions of instruction. The surveys include the Motivating Instructional Contexts Inventory (Lam et al., 2007), a survey created for the Competent Children, Competent Learners project (Hipkins, 2012), and survey items administered as part of the Programme for International Student Assessment 2006 study (Hampden-Thompson & Bennett, 2013). Table 5 shows which observation protocol or survey informed the wording of each indicator. Four indicators were not adapted from previous observation protocols or surveys. The reasons for including these indicators are described below.

Within the choice task characteristic, the indicators, “students have flexibility within the task” and “opportunities for choice beyond teacher pre-selected options are provided” were not adapted from a previous observation protocol or survey. These indicators were written based on previous research that found that perceived choice better predicts motivation when coupled with a perceived locus of causality and a sense of psychological freedom (Reeve et al., 2003). This finding as well as findings that students enjoy having the ability to try out new ideas (Hipkins, 2012) and work autonomously (National Research Council & Institute of Medicine, 2004) informed the wording of these indicators.

Within the feedback task characteristic the indicators, “students are told they will receive verbal or written teacher feedback on the task at a later time” and “students are told they will received verbal or written peer feedback at a later time” were added after the pilot study. These particular indicators were observed during the pilot study, and it was determined that these comments would impact students perception of feedback.

Table 5

Previous Literature Informing the Wording of Task Characteristic Indicators

Task Characteristics and Indicators	Literature Informing Wording of Indicator
Choice	
- Teacher provides more than one format of task for students to choose from	(Lam et al., 2007)
- Students have flexibility within the task	
- Student choice over what they learn (specific topics within more general required topic)	(Hipkins, 2012; Lam et al., 2007)
- Opportunities for choice beyond teacher pre-selected options are provided	
Feedback	
- Students receive verbal or written teacher feedback while working on the task	(Shernoff et al., 2016)

- Students are told they will receive verbal or written teacher feedback on the task at a later time	
- Students receive verbal or written feedback from peers	(Hipkins, 2012; Shernoff et al., 2016)
- Students are told they will receive verbal or written peer feedback at a later time	
- Feedback consists of comments, suggestions, and areas of improvement beyond or instead of grades	(Hipkins, 2012; Lam et al., 2007)
- Feedback gives students clear direction about what they need to do	(Hipkins, 2012; Shernoff et al., 2016)
Collaboration	
- Students work in pairs or groups to accomplish a common task	(Shernoff et al., 2016)
- Students get help and support from each	(Hipkins, 2012)
- Students participate in peer assessment / peer feedback	(Hipkins, 2012)
Real-life significance	
- Importance or relevance of the task is clarified	(Lam et al., 2007; Shernoff et al., 2016)
- Importance or relevance of the science learning targeted the task is clarified	(Hampden-Thompson & Bennett, 2013)
- Examples are relevant to students' experiences	(Hipkins, 2012)
- Task incorporates a real world problem or scenario	(Hipkins, 2012; Shernoff et al., 2016)

In order to determine the reliability of the Task Characteristic Rating Scale, two raters scored the task characteristics for some tasks. Once again, Equation 1 (Lacy & Riffe, 1996) was used to determine the sample size for the reliability test.

Before the study began Equation 1 was used to estimate the number of tasks needed for the reliability study based on an estimate of the total number of tasks that would be in the study. It was determined that about half the tasks in the study would need to be part of the reliability test. Therefore, the second rater scored three randomly selected tasks out of every six tasks completed for the reliability study.

In the end, the total number of tasks in the study was 64. Each of the four dimensions of each task was a separate score and therefore the total sample size of scores was 256. Using Equation 1 with 256 as the total sample size, a 95% confidence interval, a desired *p*-value of .05, and a .6 desired level of agreement for the whole population, the number of test units required to estimate reliability was 129.3. Because there were four task characteristic scores in each task, 33 tasks were needed for the reliability test. The second scorer scored two out of the last three tasks in the study and that resulted in 34 total tasks scored by two raters for the Task Characteristics Rating Scale reliability study.

The primary rater using the Task Characteristics Rating Scale had five years of experience teaching middle and high school science and math and was lead researcher in this study. The second rater had 20 years of experience teaching middle and high school science and used the Task Characteristic Rating Scale during the pilot study.

The intra-class correlation (ICC) statistic was calculated between the first and second raters' task characteristic scores to determine the reliability of the Task Characteristic Rating Scale. The ICC statistic is appropriate for ordinal variables and suitable for studies where a subset of units are rated by two coders and the other units are rated by one coder (Hallgren, 2012). Unlike Cohen's kappa, which is calculated based on all-or-nothing agreement, the ICC statistic is calculated based on the magnitude of disagreement (Hallgren, 2012). Task characteristic scores are rated on a zero to six scale. Scores that differ by one or two have greater reliability compared to scores that differ by three or four. Therefore, the ICC statistic is a useful measure of reliability for the Task Characteristic Rating Scale.

Specifically, the two-way random ICC model with the consistency definition will be used. Because the same two raters scored the all data, a two-way model was used instead of a one-way model (McGraw & Wong, 1996). The two raters were assumed to be randomly selected from the population of people who meet the criteria for using the rating scale and therefore, a two-way random model was used rather than a two-way mixed model (McGraw & Wong, 1996). Systematic differences between the raters were not relevant because the data analyses used the scores generated by one rater. Therefore, a consistency model rather than an absolute model was appropriate and the reliability based on single measures was used rather than the reliability based on average measures (McGraw & Wong, 1996).

Both the first and second rater using the Task Characteristics Rating Scale had significant middle and high school teaching experience. This experience contributed to the validity of the scores produced using the scale. Although primarily a measure of reliability, the ICC statistic between the first and second raters' scores also served as a measure of validity. Two raters, both with significant teaching experience, independently scored the task characteristics similarly. This contributed to the validity of the scale.

Challenge. The perceived challenge is different for each student. Further, students' perception of challenge is difficult to measure by observation. Therefore, a self-report survey item was used to measure this task characteristic. The survey item used in the present study was taken from Shernoff and colleagues' (2014) engagement study. Like Shernoff and colleagues (2014), challenge was measured with a single five point Likert-type item asking students, "Was it challenging?" (Appendix G).

Student survey. The three-item student survey (Appendix G) consisted of one item to measure students' emotional engagement during the task, one item to measure students' cognitive engagement during the task, and one item to measure students' perception of challenge for the task. As mentioned previously, the teacher emailed the researcher a short description of each task that the teacher expected students to complete during each day of the study. For each instructional task students were expected to work on, a separate three-item survey was prepared. A short description of the task was written at the top of the survey. The survey for each separate task for each class period was photocopied on a different color paper to make it easier for students to distinguish which survey was associated with which task. At the end of each class period in the study, students completed a survey for the task(s) they completed during that class period. Because the class period did not always go as the teacher expected, some of the prepared surveys were not used. In order to protect students' anonymity, students wrote their first, middle, and last initial on top of the survey instead of their names.

Behavioral engagement rating scale. Students' behavioral engagement was measured by classroom observation using the Behavioral Engagement Rating Scale (Appendix H). Before beginning an observation, the observer recorded the total number of students in the class and the start and end time of the class. Then, based on the teacher's email or verbal description of the expected tasks for the day, the observer wrote a short description of each of the expected tasks on the observation protocol. While measuring students' behavioral engagement, the observer recorded the approximate start and end times for each task in order to provide guidance for later parsing the video-recording into tasks. The observer only measured behavioral engagement during the time periods where students were working on a specific task. Behavioral engagement was not measured while the teacher was giving directions or during transition time between tasks.

Video-recording. Each class period observed in the study was video-recorded. The video-recording was then used to measure the use of task characteristics during each task. Therefore, the purpose of the video-recording was to capture the classroom instruction. The video-camera was placed in the back of the room and aimed toward the front of the room. To the best extent possible, the video-recorder was aimed at the teacher. Some students were captured on the video-recording, but the camera was not focused on individual students. The camera was aimed so that any students who did not want to be in the study or whose parents did not want them to be in the study was not in the recording.

The classroom observer started a stopwatch at the same time as the video camera. The time on the stopwatch were recorded on the Behavioral Engagement Rating Scale in association with each engagement score. Then the behavioral engagement scores were later associated with specific tasks on the video-recording.

After data collection, the video-recordings were parsed in to specific tasks in preparation for use with the Task Characteristics Rating Scale. The approximate task start and task end times recorded by the classroom observer were used in conjunction with the videos to determine the exact start and end times for each task. The task started when students' time for working on a task began and ended when the students' time for working on the task ended. For most tasks, students were given time to work on the task and after that time the teacher reviewed the task. The time that the teacher reviewed the task was not included in the time of the task unless the majority of students were completing a majority of the task during the teacher directed time. Students' behavioral engagement during the time of the task was calculated as the average behavioral engagement from the start time of the task to the end time of the task.

Contextual information. Contextual information including handouts, teacher emails, and observer notes were collected in association with each task in the study. They were reviewed while using the Task Characteristics Rating Scale to measure task characteristics. All handouts given to students were collected. The teacher's emailed description of the task or verbal description of the task was included as notes in the contextual information. Further, the observer took notes based on informal conversations with teachers and classroom instruction.

Task Characteristics Rating Scale. Task characteristic scores for each task were determined using the Task Characteristics Rating Scale while watching the video-recordings and viewing the contextual information. Students' behavioral engagement during the time of the task was only based on the time that students were working on the task. However, the teachers' instructions and comments both before and during the task were considered when scoring the task characteristics. For instance, if the teacher told students that they would be given feedback on their writing before the task began, that comment contributed to the feedback characteristic score for the task. Therefore, when using the Task Characteristics Rating Scale, the rater watched the video-recording for the time that the teacher introduced the task as well as the time that students were working on the task.

Data Analyses

The following analyses were conducted in order to answer each of the following research questions:

1. Is there a relationship between the observed level of task characteristics in a seventh grade science classroom and students' engagement in the task?

In order to answer this research question the cumulative task characteristic score for each task was calculated, an engagement score for each task was calculated, and the Pearson correlation coefficient between was calculated between them. The cumulative task characteristic scores for each task was calculated by adding the scores for each of the five dimensions. Choice, feedback, collaboration, and real-life significance were scored between zero and six based on the task characteristic scoring rubric. The challenge score was calculated by averaging the challenge survey item for that task from each student in the class. Since the challenge survey item ranges from one to five, the resulting score, based on this calculation, ranged from one to five. The five sub-scores were added to result in a cumulative task characteristic score for each task that ranged from one to 29.

The engagement score for each task was calculated by adding the behavioral, cognitive, and emotional engagement scores for the task. Behavioral engagement scores for each task consisted of the percent of students on task during each minute that students worked on the task. An average behavioral engagement score for each task was calculated by averaging all the behavioral engagement scores during the time of the task. Only scores recorded during the time that students were supposed to be working on the task were included. Any scores recorded during the task directions or after the teacher told students to stop working on the task were not included in the average behavioral engagement score for the task. The average behavioral engagement score for the task was scaled by dividing the percent of students on task by 20%. The scaled average behavioral engagement score for the task could theoretically range from zero and five. Emotional and cognitive engagement scores were calculated by averaging the emotional and cognitive survey responses, which are scored on a one to five scale, from the class for each task. The engagement score for each task could theoretically range from two to 15.

Then the Pearson correlation coefficient between the task characteristic scores and engagement scores for all the tasks together and for each classroom separately was calculated. The Pearson correlation coefficient between cumulative engagement, each dimension of engagement (behavioral, emotional, and cognitive), and each task characteristic (choice, challenge, feedback, collaboration, and real-life significance) was calculated.

2. What is the relationship between the pattern of observed task characteristics during a multi-day science instructional unit and the pattern of seventh grade students' situational engagement over the same multi-day instructional unit?

In order to answer research question two, two types of graphs were created to depict the pattern of engagement and pattern of observed task characteristics over time for each classroom. The first graph showed students' continuous behavioral engagement over time in conjunction with a bar graph to show the use of task characteristics over time. In conjunction with the graph from each classroom, a table was created to describe the content covered and type of activity completed in each task.

The second graph showed the strength of each task characteristic in conjunction with strength of students' overall engagement for the task. Side-by-side bar graphs showed the strength of each task characteristic for each task. The color of each bar was used to represent students' overall engagement for the task.

Both these graphs were analyzed by first identifying rising or declining patterns in engagement over time. Then the pattern of observed task characteristics associated with these rising and/or declining patterns of engagement was described.

Pilot Study

During the spring of 2015 a pilot study was conducted in two classrooms: a sixth grade science class and a seventh grade science class. All data collection instruments were used to collect data during three consecutive days in both classrooms. During the pilot study I learned the importance of clearly explaining the definition of a single task to the teacher. During the pilot study, the teachers did not completely understand the definition of a task. Because the task descriptions used to make student surveys are based on the teacher's emailed description, data collected in the pilot study surveys were not well aligned with tasks. In one case, survey data was aligned to multiple tasks. In another case, two surveys were aligned to a single task.

During the pilot study student consent forms and parent assent forms included a check box which allowed students to participate in the study, but not be included in the video-recording. This created three groups of students: students not participating at all, students participating in the behavioral engagement count and completing surveys who could not be video-recorded, and students who were participating in all aspects of the project. Also, some students brought their consent forms in on the second day of data collection such that their participation status changed. Additionally, students changed seats (as part of the instruction) on most days of the pilot study in both classrooms. All these factors made it hard to keep track of which students were supposed to be participating or not participating in which aspects of the study.

Based on this experience I removed the checkbox from the student assent and parent consent forms which had allowed students to participate in the project without being part of the video-recording. During data collection for the present study, there was only two groups of students: those who were participating in all aspects of the project and those not participating in the project. Further, parent consent forms were be passed out and collected weeks before the start of the study such that students' status of participation did not change in the middle of the study. Both of these changes clarified which students were and were not participating in the project in each classroom.

Significance

The study of student engagement has attracted growing attention in the past 25 years as a means to improve student achievement and decrease student boredom and school dropout (Fredricks et al., 2004; National Research Council & Institute of Medicine, 2004). Student engagement positively predicts students' grades, conduct, long-term motivation, and college performance (Finn & Rock, 1997; Lam et al., 2014, 2012; Shernoff, 2010).

Findings from previous research suggest that choice, challenge, feedback, collaboration, and real life significance are related to middle and high school students' engagement across all subjects. Students' engagement in science is important both as means to improve understanding and as a means for motivating students to pursue science in college and as a career (National Research Council, 2012; NGSS Lead States, 2013). Students' engagement in seventh grade science is particularly important because it is often the first designated science class taken by students. Only one previously identified study specifically considered the influence of instruction on middle school students' engagement in science. Therefore, one purpose of this research was to study the relationship between challenge, feedback, real-life significance, choice, and collaboration and seventh grade students' engagement in science. More specifically, the purpose of this research was to study the relationship between these five task characteristics on students' situational rather than static engagement.

Large scale quantitative studies using surveys to measure students' perceptions of instructional characteristics and students' self-reported engagement provide the most evidence for the relationship between choice, challenge, feedback, real-life significance, and collaboration and middle and high school students' engagement (Hipkins, 2012; Lam et al., 2014). This evidence provides strong support that these five task characteristics are likely to have a positive effect on student engagement. Findings from previous research measuring engagement and instruction dynamically provide additional insights into the relationship between the variables. Measuring task characteristics and engagement during each day of a multi-day instructional provided additional insight into the relationship between these variables throughout the flow of instruction.

The method for measuring behavioral, emotional, and cognitive engagement in this study was unique. The majority of previous research studying the relationship between engagement and instruction measured engagement statically (Hampden-Thompson & Bennett, 2013; Hipkins, 2012; Lam et al., 2014, 2012). Of the studies that measured engagement dynamically, no previously identified study measured the behavioral, emotional, and cognitive engagement of an entire class in conjunction with identified tasks. Further, no previously identified study measured behavioral engagement continuously over multiple days. The methods developed for measuring behavioral, emotional, and cognitive engagement in this study provide a novel way for gaining insight into the relationship between engagement and instruction for future studies.

Chapter Four: Results

The purpose of this research was to study the relationship between five specific task characteristics and seventh grade students' engagement over an instructional unit. The specific task characteristics investigated in this study included: the use of tasks that give students opportunities to act autonomously (choice), the use of tasks that challenge students (challenge), constructive feedback from the teacher or peers that guide students work on the current task (feedback), the inclusion of tasks that require student collaboration (collaboration), and the importance or relevance of the task is explained to students or the task includes a real-world problem or scenario (real-life significance).

In this study student engagement was conceptualized as a fluid trait (Parsons et al., 2015; Rotgans & Schmidt, 2011; Shernoff et al., 2016) having behavioral, emotional, and cognitive dimensions (Fredricks et al., 2004; Reeve, 2012; Reschley & Christenson, 2012). Behavioral engagement included on-task involvement and effort in the classroom (Reeve & Tseng, 2011). Emotional engagement was measured as students' interest in the current task (Fredricks et al., 2004; Hampden-Thompson & Bennett, 2013; Lam et al., 2014; Reeve & Tseng, 2011; Shernoff et al., 2016; Skinner & Belmont, 1993). Cognitive engagement was measured as the strategy of connecting new learning to previous learning (Greene, 2015; Reeve & Tseng, 2011).

This chapter describes results of analyses conducted to answer the following research questions:

1. Is there a relationship between the observed level of task characteristics in a seventh grade science classroom and students' engagement in the task?
2. What is the relationship between the pattern of observed task characteristics during a multi-day science instructional unit and the pattern of seventh grade students' situational engagement over the same multi-day instructional unit?

In order to answer these research questions this study investigated the use of task characteristics and students' engagement for an instructional unit in two different seventh grade science classrooms. For each task students completed in the instructional unit, students answered three short survey items: one to measure students' emotional engagement, one to measure students' cognitive engagement, and one to measure students' perceived challenge. Students' behavioral engagement was measured by observation. Each day of the instructional unit was video-recorded. The video-recordings and contextual information were analyzed using a rubric to measure the use of choice, feedback, collaboration, and real-life significance for each task students complete in the instructional unit.

Reliability

The ICC statistic for the reliability of the Behavioral Engagement Rating Scale was .86. This statistic was based on a one-way model and assumes single measures are used for the scores in the study. An ICC statistic between .75 and 1.00 is considered excellent (Cicchetti, 1994). The ICC statistic for the reliability of the Task Characteristics Rating Scale was .71. This statistic was based on a two-way random model with consistency definition and was based on single measures. An ICC statistic between .60 and .74 is considered good (Cicchetti, 1994).

Is there a relationship between the observed level of task characteristics in a seventh grade science classroom and students' engagement in the task?

Table 6 displays the minimum, maximum, and average cumulative task characteristic scores and engagement scores for tasks in each classroom separately as well as both classrooms together.

Table 6

Minimum, Maximum, Mean, and Standard Deviations for Task Characteristic Scores and Engagement Scores

	Task Characteristic Score			Engagement Score		
	Oliver	Jay	Total	Oliver	Jay	Total
Min.	3.41	3.07	3.07	7.80	9.22	7.80
Max.	12.57	19.57	19.57	12.35	12.21	12.35
M	8.60	9.49	9.03	10.36	10.77	10.56
SD	2.66	4.10	3.44	1.21	.88	1.07
N	33	31	64	33	31	64

The possible cumulative task characteristic score ranged from one to 29. The cumulative task characteristic score in Mr. Oliver's class ranged from 3.41 to 12.57. The cumulative task characteristic scores for Ms. Jay's class ranged from 3.07 to 19.57. Based on the possible cumulative task characteristic score ranging from one to 29, the majority of tasks in both classrooms had task characteristic scores in the bottom half of all possible scores. Only four tasks in Ms. Jay's class had task characteristic scores in the second half of the overall range.

The possible task engagement score ranged from two to 15. The task engagement scores in Mr. Oliver's class ranged from 7.80 to 12.35. The task engagement scores in Ms. Jay's class ranged from 9.22 to 12.21.

The data comprising the total engagement scores, the engagement sub-scores, the cumulative task characteristic scores, and the individual task characteristic scores meet the assumptions of a correlation in that they are independent and linear. None of the pairs of variables had a curvilinear or exponential relationship. The Pearson correlation coefficient between the task characteristic scores and engagement scores for all the tasks observed was positive and statistically significant ($r = .27$, $p = .03$, $N = 64$). This correlation was lower than correlations between global measures of instruction and engagement in previous research. Shernoff (2016) found a Pearson correlation coefficient of .33 between a measure of Environmental Complexity and student engagement. Lam (2014) found a Pearson correlation coefficient of .50 between a measure of motivational context and students' engagement. The Pearson correlation coefficient between the task characteristic scores and engagement scores in Mr. Oliver's classroom was also positive and statistically significant ($r = .37$, $p = .03$, $N = 33$). The Pearson correlation coefficient between the task characteristic scores and engagement scores in Ms. Jay's classroom was positive, but not statistically significant ($r = .17$, $p = .35$, $N = 31$).

For all tasks observed, students' engagement significantly correlated with two task characteristics on their own, feedback ($r = .34$, $p = .01$, $N = 64$) and collaboration (r

= .36 p = .01, N = 64). The correlation between feedback and student engagement was higher than previous research (Shernoff, Tonks, Anderson, & Dortch, 2011) and the correlation between collaboration and student engagement was about the same as previous research (Guthrie & Klauda, 2014; Hampden-Thompson & Bennett, 2013). Students' engagement did not significantly correlate with choice (r = .04, p = .76, N = 64), challenge (r = .21, p = .10, N = 64), or real life significance (r = -.02, p = .85, N = 64). For all tasks observed, cumulative task characteristic scores significantly correlated with both emotional engagement (r = .42, p < .001, N = 64) and cognitive engagement (r = .33, p = .01, N = 64), but did not significantly correlated with behavioral engagement (r = -.16, p = .22, N = 64).

Table 7 shows the Pearson correlation coefficients between each dimension of engagement (behavioral, emotional, and cognitive), and each task characteristic (choice, challenge, feedback, collaboration, and real-life significance).

As expected emotional engagement is positively correlated with cognitive engagement (r = .43) at about the same strength as previous research (Lam et al., 2014; Reeve & Tseng, 2011). However, behavioral engagement did not correlate with either emotional engagement or cognitive engagement.

Students' behavioral engagement was negatively correlated with choice (r = -.29). Students' emotional engagement was positively correlated with feedback (r = .40) and collaboration (r = .60) The Pearson correlation coefficient between emotional engagement and collaboration was higher than previous research (Guthrie & Klauda, 2014; Hampden-Thompson & Bennett, 2013). Students' cognitive engagement was positively correlated with choice (r = .27) and feedback (r = .37).

Table 7

Correlations of Engagement and Task Characteristic Variables

	1	2	3	4	5	6	7	8
1. BE	-	-.04	.03	-.27*	.05	-.04	-.13	.06
2. EE	-	-	.43**	.19	.17	.40**	.60**	-.19
3. CE	-	-	-	.27*	.24	.37**	.09	.19
4. Choice	-	-	-	-	-.01	.49**	.36**	.32**
5. Challenge	-	-	-	-	-	.17	-.03	-.17
6. Feedback	-	-	-	-	-	-	.53**	.03
7. Collaboration	-	-	-	-	-	-	-	-.24
8. RLS	-	-	-	-	-	-	-	-

Note. BE = Behavioral Engagement; EE = Emotional Engagement; CE = Cognitive Engagement; RLS = Real-life Significance.
*p < .05. **p < .01.

What is the relationship between the pattern of observed task characteristics during a multi-day science instructional unit and the pattern of seventh grade students' situational engagement over the same multi-day instructional unit?

Tasks in Mr. Oliver's class. Table 8 displays the description, engagement score, and task characteristic score for tasks in Mr. Oliver's class. Table 9 displays the three engagement sub-scores and five task characteristic sub-scores for each task in Mr. Oliver's class.

Table 8

Task Descriptions from Mr. Oliver's Class

Day	Task	Task Name	Description of Task	TC Score	Eng. Score
1	1	Annotate cell reading	Students read an introduction to the microscope and cell lab they would soon begin working on. While reading the introduction, students circled words they did not know and important words. They also underlined the main idea.	7.13	11.53
	2	Label microscope	Students used their textbooks to label a diagram of a microscope.	9.44	11.37
	3	Observe the letter "e"	Students observed a printed letter "e" in the microscope and wrote observations in their science notebooks.	10.75	11.70
	4	Observe and sketch cork cells	Students observed cork cells in the microscope and made a sketch in their lab book.	10.19	11.60

2	5	Functions of living things warm-up	From a list of functions that living things perform, students chose which functions were performed by plant cells, animal cells, or both.	5.76	10.14
	6	Observe and sketch onion and cheek cells	Students observed and sketched onion and cheek cells in the microscope.	10.41	11.38
3	7	Starting cell notes	As a warm-up, students read about cells in their textbook and set up a page in their science notebook to take notes about cells.	3.41	11.16
	8	Cell Theory notes	Students watched a movie about cell theory and took notes on a chart in their lab books.	5	11.24
	9	Observe a living tree	Earlier in the year each student chose a tree to observe throughout the year. During this task the class went outside to observe the trees. Each student wrote observations in their science notebooks and took notes detailing evidence of life functions of his/her tree.	11.2	11.46
4	10	Is it Living? warm-up	Students chose which objects were living and non-living then wrote a rule to define "living"	8.92	10.34
	11	Cell notes	Students took notes about cells in their science notebooks.	10.42	10.36
	12	Annotate another cell reading	Students read an introduction to the next cell lab. While reading the introduction, students circled words they did not know and	7.36	9.52

			important words. They underlined the main idea.		
	13	Observe and sketch root tip and elodea cells	Students used the microscope to observe and sketch root tip and elodea cells.	11.75	12.35
5	14	Is it a Theory? warm-up	Students chose which statements, from a set of given statements, applied to scientific theories. Then students defined the word theory in their own words.	5.21	9.57
	15	More cell notes	Students continued to take notes about cells in their notebooks while watching a movie.	10	10.78
	16	Observe and sketch elodea, blood, nerve, and muscle cells	Students used the microscope to observe and sketch elodea, blood, nerve, and muscle cells.	12.57	12.25
6	17	Annotate water reading	Students read an article about groundwater deficit. While reading the article, students circled words they did not know and important words. They underlined the main idea.	8.00	10.28
	18	Lab summary and application	Students worked collaboratively to answer lab summary and application questions.	10.73	8.57
	19	Cell quiz	Student completed a multiple choice quiz about cells.	4.73	10.30
	20	Privet lab	Students read introductory material about cell and tissue organization. Then students viewed the cross-section of a	8.67	10.31

			privet leaf in the microscope and sketched in their lab books.		
7	21	What is a hypothesis? warm-up	Students chose which statements, from a list of statements, describe a hypothesis. Then students wrote a definition of “hypothesis” in their own words.	6.07	7.80
	22	Huff puff lab	Students worked in groups to complete an experiment to determine how the weight of a cup affects how far students can blow the cup across a table.	12.20	12.00
	23	Observe and sketch privet leaf and blood vessels.	Students viewed and sketched the privet leaf in the microscope if they did not already do so. Then students viewed and sketched blood vessels in the microscope.	7.13	9.88
8	24	Experimental design warm-up (plants)	Students read an experiment about plants, drew a diagram to represent the experiment, and identified components of the experiment.	9.56	9.00
	25	Experimental Design notes	Students took notes about experimental design	4.81	9.77
	26	Set-up radish seed experiment	Students set up an experiment to investigate the effect of radiation on radish seed germination.	11.88	11.63
9	27	Experimental design warm-up (bees)	Students read an experiment investigating the effect of flower color on bees’ attraction to the flower. Then students identified components of the experiment.	6.38	9.71

	28	Observe radish seeds	Students collected quantitative and qualitative data about their radish seeds.	11.06	11.23
	29	A cell is a city	Students watched a movie about cells while taking notes on a worksheet comparing a cell to a city.	3.56	8.99
10	30	Experimental design warm-up (dogs)	Students read an experiment investigating the effect of temperature on dogs' respiratory rate. Then students wrote how to improve the experiment.	11.53	9.11
	31	Experimental design diagram for radish seed lab	Students completed an experimental design diagram of the radish seed lab.	10.18	8.97
	32	Set up part 2 of the radish seed lab.	Students set up a second part of the radish seed lab to investigate the effect of gravity on radish seed growth.	9.00	8.63
	33	Graph radish seed lab part 1	Students made a graph to display data collected during part 1 of the radish seed lab.	8.88	8.95

Table 9

Engagement and Task Characteristic Sub-scores for Mr. Oliver's Class

Task	BE	EE	CE	Challenge	Choice	Feedback	Collaboration	RLS
1	4.31	3.53	3.69	2.13	2	1	0	2
2	4.36	3.82	3.19	2.44	0	4	2	1
3	3.62	4.71	3.38	2.75	1	3	4	0
4	3.95	4.53	3.13	2.19	1	3	4	0
5	3.91	3.00	3.24	2.76	1	2	0	0
6	3.56	4.53	3.29	2.41	1	3	4	0
7	3.33	4.53	3.29	2.41	0	1	0	0
8	4.44	3.47	3.33	2.00	0	1	1	1
9	3.53	4.13	3.80	2.20	2	4	1	2
10	3.26	3.42	3.67	2.92	2	3	0	1
11	4.028	2.75	3.58	2.42	1	3	0	4
12	3.57	2.58	3.36	2.36	2	3	0	0
13	3.94	4.25	4.17	2.75	1	4	4	0
14	3.21	3.00	3.36	2.21	2	1	0	0
15	4.13	3.21	3.43	2.00	3	1	0	4
16	4.04	4.36	3.86	2.57	2	4	4	0
17	4.44	2.69	3.15	2.00	2	2	0	2
18	3.37	2.33	2.87	1.73	1	3	3	2
19	4.83	2.40	3.07	2.73	0	1	0	1
20	3.65	3.67	3.00	1.67	1	3	3	0
21	2.13	2.47	3.20	2.07	2	2	0	0
22	4.46	4.27	3.27	2.20	2	3	4	1
23	2.48	4.07	3.33	2.13	1	1	3	0
24	3.19	2.94	2.88	2.56	1	2	2	2
25	3.71	2.75	3.31	1.81	0	1	0	2
26	4.08	4.13	3.44	1.88	2	2	4	2
27	4.33	2.44	2.94	2.38	1	2	0	1
28	4.36	3.63	3.25	2.06	2	3	4	0
29	3.24	2.94	2.82	2.56	0	1	0	0
30	3.34	2.71	3.06	2.53	3	3	2	1
31	2.62	3.35	3.00	2.18	2	2	4	0
32	2.34	3.35	2.94	2.00	1	2	4	0
33	3.06	2.94	2.94	1.88	1	3	3	0

Note. BE = Behavioral Engagement; EE = Emotional Engagement; CE = Cognitive Engagement; RLS = Real-life Significance.

During the 10 observed blocks in both classrooms, the first task that students completed each day was referred to as a warm-up. Students were usually instructed to complete their warm-up quietly and independently. During part of the time students completed this task, the teacher took attendance.

In Mr. Oliver's class, the five tasks with the highest engagement scores were observe and sketch root tip and elodea (task 13); observe and sketch elodea, blood, nerve, and muscle cells (task 16); huff puff lab (task 22); observe the letter "e" (task 3); and set up radish seed experiment (task 26). The engagement scores on those tasks along with the task characteristic scores in parentheses were 12.35 (11.75), 12.25 (12.57), 12.00 (12.20), 11.70 (10.75), and 11.63 (11.88), respectively. All of these tasks had higher than average task characteristic scores. All of these tasks also involved hands-on manipulation of a scientific tool or tools (microscope, petri dish, ruler, pipette) and/or a living thing (radish seeds).

The five tasks with the lowest engagement scores were What is a hypothesis? warm-up (task 21), lab summary and application (task 18), set up part 2 of the radish seed lab (task 32), graph radish seed lab part 1 (task 33), and experimental design diagram for radish seed lab (task 31). The engagement scores on those tasks along with the task characteristic scores in parentheses were 7.80 (6.07), 8.57 (10.73), 8.63 (9.00), 8.94 (8.88), and 8.97 (10.18) respectively. In three out of five of these tasks students analyzed or reflected on previous hands-on tasks, which were in the set of tasks with the five highest engagement scores. In task 18 (low engagement task) students answered questions related to task 16 (high engagement task). In task 31 and 33 (low engagement tasks) students analyzed the design and data from task 26 (high engagement task).

The five tasks with the highest task characteristic scores were observe and sketch elodea, blood, nerve, and muscle cells (task 16); huff puff lab (task 22); set up radish seed experiment (task 26); observe and sketch root tip and elodea cells (task 13); and the experimental design warm-up about dogs (task 30). These tasks had task characteristics scores of 12.57, 12.20, 11.88, 11.75, and 11.53. The first four of these tasks had engagement scores greater than one standard deviation above the average engagement score for all tasks in Mr. Oliver's class.

The five tasks with the lowest task characteristic scores were starting cell notes (task 7), a cell is a city (task 29), cell quiz (task 19), experimental design notes (task 25), and cell theory notes (task 8). These tasks had task characteristic scores of 3.41, 3.56, 4.73, 4.81, and 5.00 respectively. All of these tasks (except the quiz) were related to taking notes from a textbook, movie, or teacher lecture. Two of these tasks (starting cell notes and cell theory notes) had higher than average engagement scores, one of these tasks had an average engagement score (engagement quiz) and two of these tasks (cell is a city and experimental design notes) had lower than average engagement scores.

Pattern of Behavioral Engagement in Mr. Oliver's Class. Figure 3 shows students' behavioral engagement in Mr. Oliver's class and the cumulative task characteristic scores of each task in Mr. Oliver's class. The blue line displays students' behavioral engagement during each task in the instructional unit. The height of each bar corresponds to the value of the cumulative task characteristic score for the task. The width of each bar corresponds to the time that students worked on the task. The numbers below each bar correspond to the number of the task.

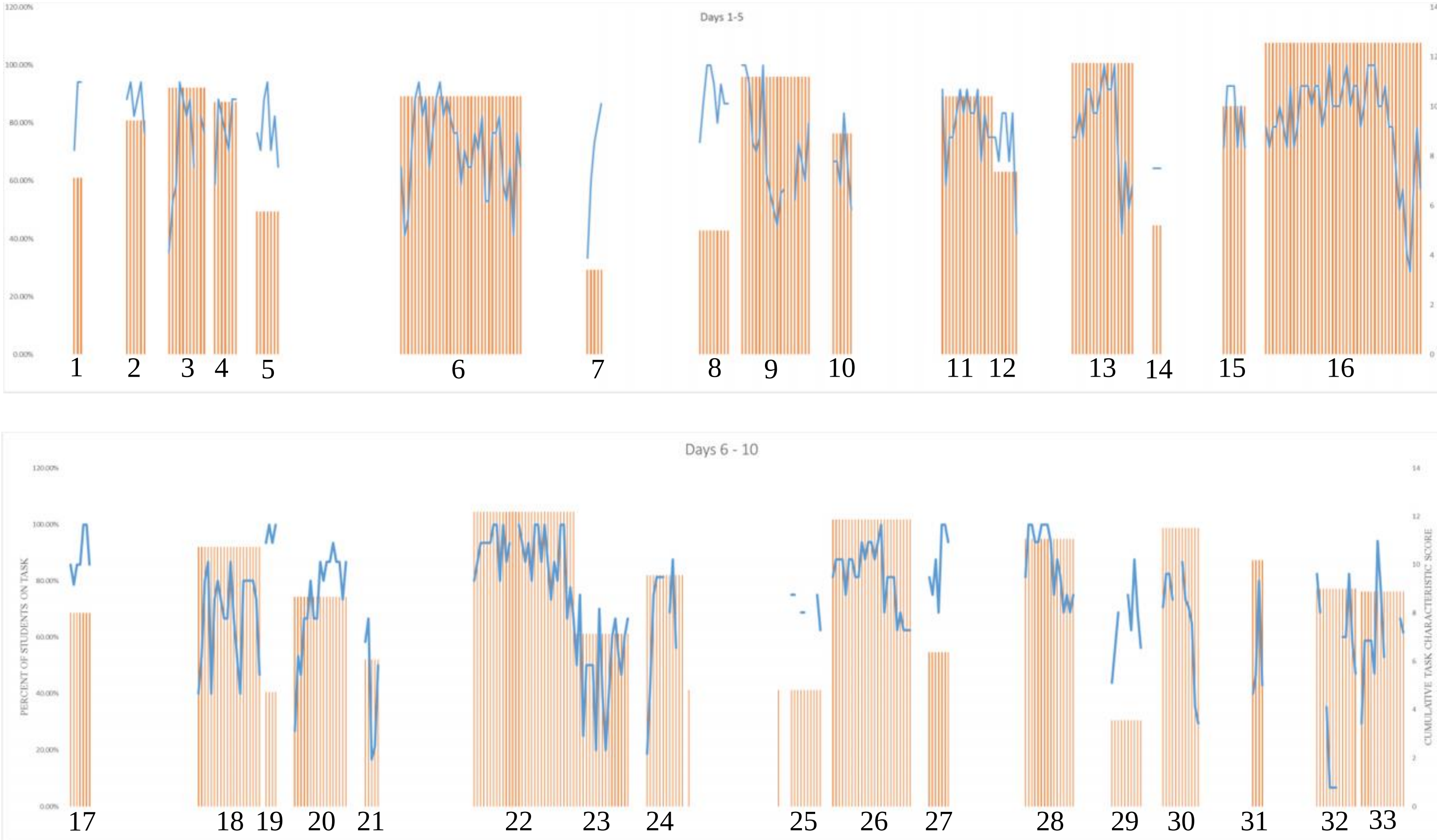


Figure 3. Students' Behavioral Engagement and Task Characteristic Scores in Mr. Oliver's Class

Figure 3 shows that students' behavioral engagement fluctuates over the course of a task. During numerous tasks students' engagement starts low and ends high (tasks 1, 3, 7, and 20); starts high and end low (tasks 9, 13, and 16); or fluctuates between high and low throughout the task (tasks 2, 5, 6, 9, 15, and 18).

Engagement measured as a multidimensional trait correlated with the cumulative presence of task characteristics. However, the average behavioral engagement during each task did not correlate with the use of task characteristic scores. Therefore, as expected, the rising and falling pattern of task characteristic scores depicted in Figure 3 does not correlate with the rising and falling pattern of behavioral engagement scores. Task 19 (cell quiz) in particular has a lower than average task characteristic score (4.73) and consistently high behavioral engagement score.

During the first five days of the cell unit, there is a pattern of rising task characteristics scores during the set of tasks each day. The first five days of the cell unit begin with tasks 1, 5, 7, 10, and 14, which are all the warms-ups for the day. Figure 3 shows that the task characteristic scores of each task increase following the warm-up task on each of the first five days

The five tasks with the highest task characteristic scores in Mr. Oliver's class have decreased engagement at the end of the task. These tasks include observe and sketch elodea, blood, nerve, and muscle cells (task 16); huff puff lab (task 22); set up radish seed experiment (task 26); observe and sketch root tip and elodea cells (task 13); and the experimental design warm-up about dogs (task 30).

Tasks in Ms. Jay's class. Table 10 displays the description, engagement score, and task characteristic score for tasks in Ms. Jay's class. Table 11 displays the engagement and task characteristic sub-scores for each task.

Table 10

Task Descriptions from Ms. Jay's Class

Day	Task	Task Name	Task Description	TC Score	Eng. Score
1	1	Cell notes foldable – day1	Students took notes from a Power Point presentation about the parts of the cell on a foldable handout with corresponding diagrams to color.	7.67	10.21
	2	Observe and sketch cork cells	Students observed cork cells in the microscope and made a sketch in their lab book.	10.08	12.07
	3	Observe and sketch onion and cheek cells	Students observed and sketched onion and cheek cells in the microscope.	10.17	12.03
2	4	Types of cell warm up	Students watched a video about the difference between prokaryotic and eukaryotic cells and took notes on a Frayer Model	9.57	10.66
	5	Cell lab analysis and application	Student completed analysis and application questions for the cork, onion, and cheek cell lab	5.14	10.41
	6	Cell Theory video and notes	Students watched a movie about the development of the Cell Theory and took notes	7.07	11.19

			about four prominent scientists		
	7	Four square Cell Theory	Students copied the 4 square Cell Theory diagram into their notebooks and make small pictures or illustrations for each part of the cell theory.	5.93	9.86
3	8	Microscope as an example of engineering	As a warm-up students read about the microscope as an example of engineering and answered questions related to the reading	11.71	10.47
	9	Nature of Science cube challenge	Students worked in groups to predict what was on the bottom of a cube based on the pattern of words and numbers on the visible sides of the cube	14.93	10.20
	10	Cell notes foldable – day 2	Students continued taking notes from a Power Point presentation about the parts of the cell on a foldable handout with corresponding diagrams to color.	7.50	10.71
	11	Microscope quiz	Students used notes they previously took in their lab books to complete a quiz labeling a microscope and identifying the purpose of microscope parts.	4.62	11.54
4	12	Is it Living? Warm up and functions of living things notes	Students chose which objects were living and non-living then wrote a rule to define “living”. Students took notes about the functions that living things have in common.	8.15	10.80

	13	Observe and sketch root tip and elodea cells	Students used the microscope to observe and sketch root tip and elodea cells.	9.69	11.94
5	14	Scientific theory warm-up	Students read about scientific theories and answered questions related to the reading	7.67	10.18
	15	Observe and sketch blood, nerve, and muscle cells	Students used the microscope to observe blood, nerve, and muscle cells.	9.33	12.21
	16	Cell notes foldable – day 3	Students continued taking notes from a Power Point presentation about the parts of the cell on a foldable handout with corresponding diagrams to color.	6.92	10.40
	17	Cell riddles exit ticket	Students identified which cell part was described in each riddle.	5.50	10.95
6	18	Lab application warm up	Students answered application questions for the elodea, blood, nerve, and muscle cell lab.	4.93	9.23
	19	Comparing a cell to a factory	Students determined which cell part best corresponded to 12 different parts of a factory	11.33	9.53
	20	Cell project brainstorm	Students work in groups to brainstorm what systems they would like to compare to a cell for their cell project	16.07	9.35
	21	Observe and sketch privet leaf and	Students viewed and sketched the privet leaf in the microscope if they did not already do so. Then students	9.00	11.49

		blood vessels.	viewed and sketched blood vessels in the microscope.		
7	22	Lab application warm up continued	Students continued answering application questions for the elodea, blood, nerve, and muscle cell lab	7.64	9.79
	23	Cell project – day 1	Students worked in groups to create a model of a system in which each part of the system is compared to a part of a cell	17.43	11.00
8	24	Correct levels of organization warm-up	Students corrected the mistakes they made on a worksheet identifying different levels of organization in living things	6.43	9.76
	25	Cell project – day 2	Students continued to work in groups to create a model of a system in which each part of the system is compared to a part of cell	19.57	10.92
9	26	Comparing plant and animal cells warm-up	Students completed a chart comparing various features between plant and animal cells	3.07	9.56
	27	Cell project – day 3	Students continued to work in groups to create a model of a system in which each part of the system is compared to a part of cell	19.31	11.82
	28	Set-up radish seed lab	Students set up an experiment to investigate the effect of radiation on radish seed germination.	9.43	10.83
10	29	Watch and rate classmates	While students watched each other's cell project presentations, they wrote	10.87	11.84

	cell project presentations	down the best cell part comparison of each presentation and rated each presentation		
30	Quiz-quiz trade	Each student carried a cell review question on a card while they circulated the room to find a partner. After finding a partner the pair quizzed each other using the cell review question in their hand. Then students traded cards and found a new partner.	13.13	11.01
31	Cell quiz	Students completed a cell quiz consisting of cell riddle fill in the blanks (like task 17) and multiple choice questions.	6.40	11.78

Table 11

Engagement and Task Characteristic Sub-scores for Ms. Jay's Class

Task	BE	EE	CE	Challenge	Choice	Feedback	Collaboration	RLS
1	3.37	3.67	3.18	2.67	1	2	1	1
2	4.29	4.36	3.42	3.08	1	3	3	0
3	3.61	4.75	3.67	3.17	1	3	3	0
4	3.45	3.64	3.57	2.57	1	2	1	3
5	3.63	3.43	3.36	2.14	0	3	0	0
6	3.62	4.00	3.57	2.07	0	3	0	2
7	2.86	4.00	3.00	1.93	2	2	0	0
8	3.25	3.57	3.64	2.71	3	3	0	3
9	2.63	4.00	3.57	2.93	4	4	4	0
10	3.21	3.79	3.71	2.50	1	2	0	2
11	3.93	4.00	3.62	2.62	0	2	0	0
12	3.80	3.77	3.23	2.15	1	2	0	3
13	3.40	4.69	3.85	2.69	1	3	3	0
14	3.43	3.42	3.33	2.67	1	2	0	2
15	4.05	4.67	3.50	2.33	1	3	3	0
16	3.23	3.50	3.67	1.91	1	2	0	2
17	3.87	3.58	3.50	2.50	1	2	0	0
18	2.42	3.13	3.67	2.93	0	1	0	1
19	2.79	3.47	3.27	2.33	2	3	2	2
20	2.08	3.87	3.40	2.07	4	4	3	3
21	3.49	4.33	3.67	2.00	1	3	3	0
22	3.51	2.93	3.36	2.64	2	2	0	1
23	2.71	4.43	3.86	2.43	5	4	4	2
24	3.13	3.14	3.50	2.43	0	3	0	1
25	2.64	4.36	3.93	2.57	6	5	4	2
26	2.35	3.50	3.71	2.07	0	1	0	0
27	3.58	4.23	4.00	2.31	6	5	4	2
28	3.19	4.14	3.50	2.43	0	3	4	0
29	3.57	4.40	3.87	1.87	3	2	2	2
30	2.94	3.93	4.13	2.13	2	3	4	2
31	4.78	2.73	4.27	2.40	0	3	0	1

Note. BE = Behavioral Engagement; EE = Emotional Engagement; CE = Cognitive Engagement; RLS = Real-life Significance.

Like Mr. Oliver's class, the first task that students completed each day was referred to as a warm-up. Students were instructed to complete their warm-up quietly and independently. During part of the time students completed this task, the teacher took attendance.

In Ms. Jay's class, the five tasks with the highest engagement scores were observe and sketch blood, nerve, and muscle cells (task 15); observe and sketch cork cells (task 2); observe and sketch onion and cheek cells (task 3); observe and sketch root tip and elodea cells (task 13); and watch and rate classmates cell project presentations (task 29). The engagement scores with the task characteristic scores in parentheses were 12.21 (9.33), 12.07 (10.08), 12.28 (10.17), 11.94 (9.69), and 11.84 (10.87) respectively. Four out of five of these tasks involved observing and sketching cells in the microscope. Two of these tasks, observe and sketch blood, nerve, and muscle cells (task 15) and observe and sketch root tip and elodea cells (task 13), were the same tasks as the two tasks with the highest engagement score in Mr. Oliver's class.

The five tasks with the lowest engagement scores were lab application warm-up (task 18), cell project brainstorm (task 20), comparing a cell to a factory (task 19), comparing plant and animal cells warm-up (task 26), and correct levels of organization warm-up (task 24). The engagement scores with the task characteristic scores in parentheses were 9.22 (4.93), 9.35 (16.07), 9.53 (11.33), 9.56 (3.07) and 9.77 (6.43) respectively. Three out of five of these tasks were warm-ups completed at the beginning of class while the teacher took attendance. Task 18 in Ms. Jay's class was the same as task 18 in Mr. Oliver's class. In Mr. Oliver's class, this task also had one of the five lowest engagement scores. During task 18 in both classrooms students answered questions analyzing and applying what they learned during their experience observing and sketching root tip, elodea, blood, and muscle cells. For some of the questions students were required to use their textbook as a resource to help explain why they observed what they did. In both classrooms the task of observing and sketching the cells (task 15 in Mr. Oliver's class and task 16 in Ms. Jay's class) was one of the tasks with the highest engagement scores.

The five tasks with the highest task characteristic scores were cell project – day 2 (task 25), cell project – day 3 (task 27), cell project – day 1 (task 23), cell project brainstorm (task 20), and nature of science cube challenge (task 9). The task characteristic scores for these tasks were 19.57, 19.31, 17.43, 16.07, and 14.93 respectively. All five of these task characteristic scores were higher than the highest task characteristic score in Mr. Oliver's class. The four tasks with the highest task characteristic scores were all associated with the cell project. Table 12 displays the task characteristic sub-scores for the four tasks associated with the cell project. The table shows that the tasks associated with the cell project had higher task characteristics scores because they had higher than average scores for choice, feedback, collaboration, and real-life significance.

Table 12

Task Characteristics Scores of the Cell Project Compared to Average Task Characteristic Scores

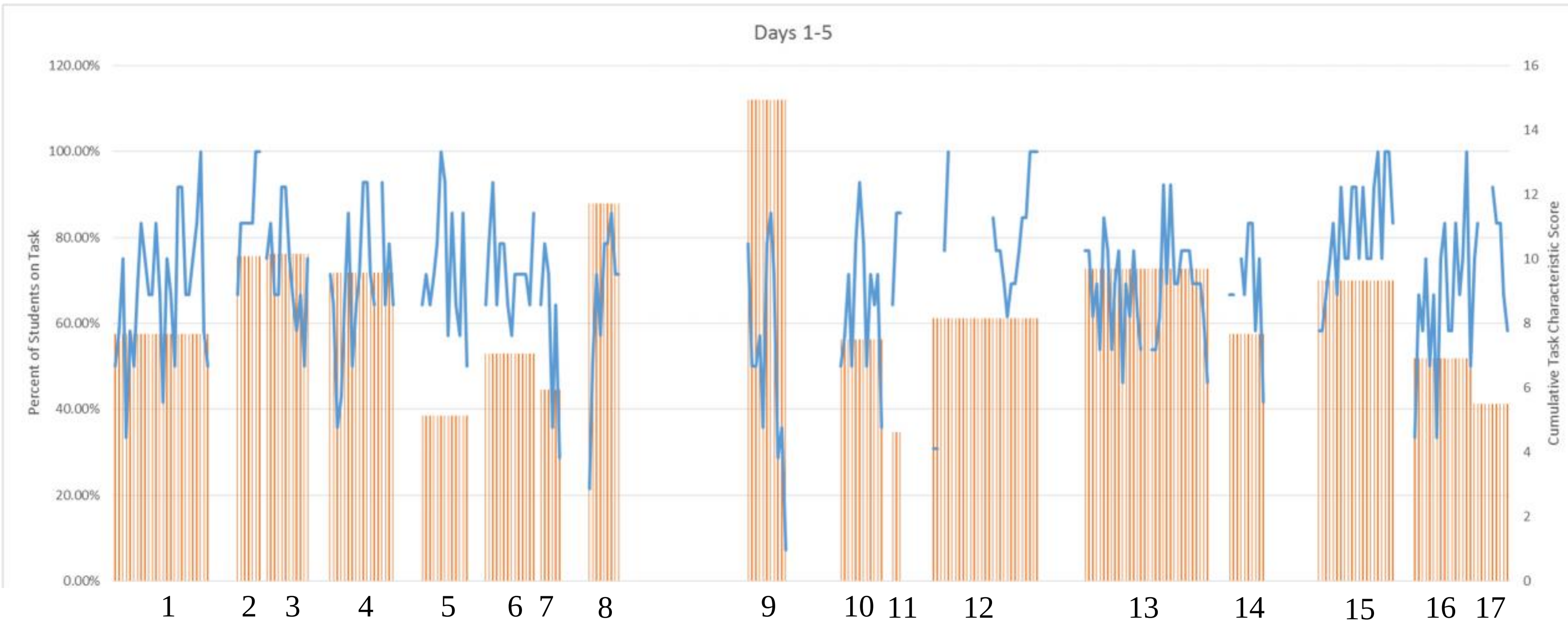
	M	Cell project brainstorm (task 20)	Cell project day 1 (task 23)	Cell project day 2 (task 25)	Cell project day 3 (task 27)
Cumulative TC Score	9.03	16.07	17.43	19.57	19.31
Choice	1.47	4	5	6	6
Challenge	2.35	2.07	2.43	2.57	2.31
Feedback	2.53	4	4	5	5
Collaboration	1.69	3	4	4	4
Real-life Significance	1.03	3	2	2	2

During the cell project students' were given a high amount of choice because they were able to choose both which system they were going to compare to a cell as well as how to make their model. While working on the project, the teacher continuously circulated the room to give students feedback on their work. Additionally, students knew that at the end of the project they would receive feedback from both the teacher and their peers. Students continuously collaborated with each other to accomplish a common group task. Finally, the project had some real-life significance because students could make the project relevant to their lives by choosing a system that was important to them. Examples of systems that students' chose were a basketball team, a computer, a national park, and a shopping mall.

From the beginning to the end of the cell project, students' engagement increased. Starting with cell project brainstorm (task 20) and going through each day that students worked on the cell project (tasks 23, 25, and 27) and ending with watch and rate classmates cell project presentation (task 29), students' engagement score increased each day. Students' engagement score during the first task in the project (cell project brainstorm) was 9.35, which was less than one standard deviation below the mean engagement score in Ms. Jay's class. Students' engagement score during the last task (watch and rate classmates cell project presentations) was 11.83, which was greater than one standard deviation above the mean engagement score in Ms. Jay's class.

The five tasks with the lowest task characteristic scores were comparing plant and animal cell warm-up (task 26), microscope quiz (task 11), lab application warm-up (task 18), cell lab analysis and application (task 5), and cell riddles exit ticket (task 17). These tasks had task characteristic scores of 3.07, 4.62, 4.93, 5.14, and 5.50 respectively.

Pattern of behavioral engagement in Ms. Jay's class. Figure 4 shows students' behavioral engagement in Ms. Jay's class and the cumulative task characteristic scores of each task in Ms. Jay's class. The blue line displays students' behavioral engagement over the time of the task. The height of each bar corresponds to the value of the cumulative task characteristic score for the task. The width of each bar corresponds to the amount of time that students were given to work on the task. Table 10 provides a description of each task completed in Ms. Jay's class


Days 1-5
Percent of Students on Task
Cumulative Task Characteristic Score
120.00%
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
16
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

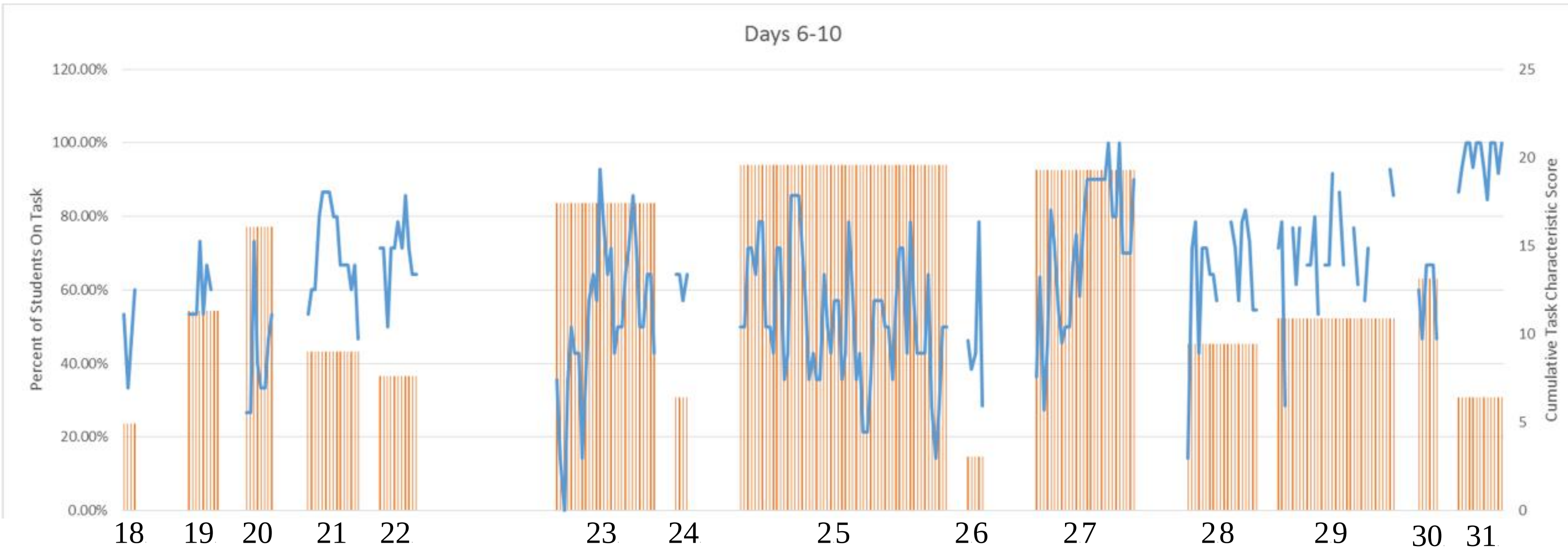


Figure 4. Students' Behavioral Engagement and Task Characteristic Scores in Ms. Jay's Class

Similar to Mr. Oliver's class, Figure 4 shows that students' behavioral engagement fluctuates over the course of a task. Once again, during numerous tasks students' engagement starts low and ends high (tasks 1, 4, 15, 16, 23, and 27); starts high and ends low (tasks 3, 5, and 9); or fluctuates between high and low throughout the task (tasks 10, 13, 21, 22, and 25).

Once again, the rising and falling pattern of task characteristic scores depicted in Figure 4 does not correlate with the rising and falling pattern of behavioral engagement scores. Also, similar to Mr. Oliver's class, the two assessments (task 11 and task 31) had lower than average task characteristics scores (4.62 and 6.40 respectively) and a pattern of high behavioral engagement throughout the task.

As previously described, student engagement increased throughout the five tasks associated with the cell project (tasks 20, 23, 25, 27, and 29). Students' behavioral engagement also has a similar pattern throughout the cell project. Figure 4 shows that students' behavioral engagement increases during task 20 and starts low at the beginning of task 23 and gradually rises across tasks 23, 25, and 27, ending with high behavioral engagement at the end of task 27. All four of these tasks as well as task 9 were the five tasks with the highest task characteristic scores in Ms. Jay's class. Figure 4 shows that Task 9, which was unrelated to the cell project, had decreased behavioral engagement at the end of the task. Task 9 in Ms. Jays' class had the same pattern of behavioral engagement that was observed in the five tasks with the highest task characteristic score in Mr. Oliver's class.

The tasks within the cell project were different from the other tasks (from both classes) with high task characteristic scores in that the four tasks were related to each other and part of a long-term project in which students prepared a product to present to the class. The tasks associated with the cell project were also unique in that students knew the final product was a major grade.

Pattern of engagement in Mr. Oliver's class. Figure 5 shows the pattern of task characteristics and overall engagement in Mr. Oliver's class. The length of each bar depicts the score for each task characteristics. The color of each bar depicts student's engagement during the task. Red is low engagement and blue is high engagement.

Figure 5. Pattern of Task Characteristics and Student Engagement in Mr. Oliver's Class. Bars represent the strength of challenge, choice, collaboration, feedback and real-life significance. Student engagement for each task is depicted by the color of the bars. Dark blue is the highest engagement and dark red is the lowest engagement.

Figure 5 shows an overall pattern of decreasing engagement in Mr. Oliver's class during the cell unit. Tasks in the beginning of the unit are predominantly blue, which represents high engagement relative to the rest of the unit, tasks in the middle of the unit vary between low and high engagement, and tasks at the end of the unit are predominantly red, which represents low engagement. However, the two tasks with the highest engagement, task 13 (12.35) and task 16 (12.25), occurred in the middle of the cell unit. During both those tasks students used the microscope to observe cells in the microscope. The next three tasks with the highest engagement score were the huff puff lab (task 22, engagement score was 11.99), observe the letter "e" in the microscope (task 3, engagement score was 11.69), and set up radish seed lab (task 26, engagement score was 11.63). All five of these tasks have relatively high task characteristic scores. All five of these tasks also involved some kind of hands-on manipulation.

Pattern of engagement in Ms. Jay's class. Figure 6 shows the pattern of task characteristics and engagement in Ms. Jay's class. The length of each bar depicts the score for each task characteristics. The color of each bar depicts student's engagement during the task. Red is low engagements and blue is high engagement.

Figure 6. Pattern of Task Characteristics and Student Engagement in Ms. Jay's Class. Bars represent the strength of challenge, choice, collaboration, feedback and real-life significance. Student engagement for each task is depicted by the color of the bars. Dark blue is the highest engagement and dark red is the lowest engagement.

Unlike Mr. Oliver's class, Ms. Jay's class does not show decreasing engagement throughout the cell unit. Figure 6 shows that during the first 26 tasks of the cell unit, students' overall engagement oscillates between low and high engagement. Then students' engagement was relatively high during the last five tasks of the cell unit.

The challenge column of Figure 6 portrays that two of the tasks with the highest perceived challenge were highly engaging (tasks two and three) and two of the tasks with the highest perceived challenge were not engaging (tasks nine and 18). Tasks 2 and 3 were the first two tasks that students used the microscope to observe and sketch cells. Task nine was the Nature of Science Cube Challenge. During this task students worked in groups to predict what was on the bottom of a cube based on the pattern of words and numbers on the visible sides of the cube. This task had one of the highest cumulative task characteristics scores not only because of the high perceived challenge, but also because students collaborated, students had flexibility about how to approach the problem, and students received feedback from the teacher during the task. During task 18 students answered application questions based on the blood, nerve, and muscle cell lab.

Figure 6 depicts that students' overall engagement increases throughout the cell project. Viewing tasks 20 (cell project brainstorm), 23, 25, and 27 (three days of cell project) in order in Figure 5, the color of the bars change from red to blue. The color of the bar for task 20 is dark red, which represents low engagement, the color of the bars for tasks 23 and 25 light blue, which represents medium to high engagement, and the color of the bar for task 27 is blue, which represents high engagement.

As described before, nine out of 10 of the tasks with the highest engagement scores (from both classrooms) included hands-on manipulation. Following four of those tasks, student completed tasks to analyze the work they did in the hands-on task. Three of those analysis tasks had some of the lowest engagement scores in the study. All of those analysis tasks had lower engagement scores compared to the hands-on task. In Mr. Oliver's class, students completed tasks 13 and 16, where they observed and sketched cell in the microscope. Those tasks had engagement scores of 12.35 and 12.25, respectively. Then students completed questions summarizing and applying what they learned in the lab during task 18, which had an engagement score of 8.57. Also in Mr. Oliver's class students completed tasks 26 and 28, where they set-up their radish seed lab and observed their radish seeds. Those tasks both included hands-on manipulation and had engagement scores of 11.63 and 11.23, respectively. Then students wrote down the experimental design of the experiment and graphed their results in tasks 31 and 33, which had engagement scores of 8.97 and 8.95, respectively. In Ms. Jay's class students observed and sketched cells in tasks 2 and 3, which had engagement scores of 12.07 and 12.03 respectively. Then in task 5 students completed analysis and application questions related to tasks 2 and 3. That task had an engagement scores of 10.41. Students observed and sketched more cells in tasks 13 and 15, which had engagement scores of 11.94 and 12.21, respectively. Then in tasks 18 and 22, students completed questions applying what they learned in the lab. Those tasks had scores of 9.23 and 9.79, respectively.

Summary

For all tasks in both classrooms, the cumulative presence of task characteristics was positively related to student engagement. However, it was students’ emotional and cognitive engagement that significantly correlated with engagement. Specifically, emotional engagement correlated with feedback and collaboration and cognitive feedback correlated with choice and feedback. Behavioral engagement had a negative relationship with student choice. Choice and real life significance was not significantly related to any aspect of engagement.

Students overall engagement as well as students’ behavioral engagement continuously increased during the tasks associated with the cell project. These four tasks associated with the cell project had the highest task characteristic scores in Ms. Jay’s class as well as overall. However, for the other six tasks with the highest task characteristic score, students’ engagement decreased at the end of the task.

Nine out of 10 of the tasks with the highest engagement scores involved hands-on learning. However, student engagement decreased during follow-up tasks that analyzed the tasks that included hands-on learning.

Chapter Five describes conclusions based on these results. Implications for research and teaching are described.

Chapter Five: Discussion

The purpose of this research was to study the relationship between choice, challenge, feedback, collaboration, real-life significance and seventh grade students' engagement over an instructional unit. Engagement was conceptualized as a fluid trait (Parsons et al., 2015; Rotgans & Schmidt, 2011; Shernoff et al., 2016) having behavioral, emotional, and cognitive dimensions (Fredricks et al., 2004; Reeve, 2012; Reschley & Christenson, 2012).

The present study included 38 students and two teachers in two classrooms. Each science class was observed every day for 10 blocks during an instructional unit about cells. For each task students completed, students answered three short survey items: one to measure students' emotional engagement, one to measure students' cognitive engagement, and one to measure students' perceived challenge. Students' behavioral engagement was measured by observation. Each day of the instructional unit was video-recorded. The video-recordings and contextual information were analyzed using a rubric to measure the use of choice, feedback, collaboration, and real-life significance for each task students complete in the instructional unit. For all tasks in both classrooms, the cumulative presence of task characteristics correlated with student engagement ($r = .27$, $p = .03$, $N = 64$).

Discussion of Findings

This chapter interprets the results presented in the previous chapter. Analyses investigated the following research questions:

1. Is there a relationship between the observed level of task characteristics in a seventh grade science classroom and students' engagement in the task?
2. What is the relationship between the pattern of observed task characteristics during a multi-day science instructional unit and the pattern of seventh grade students' situational engagement over the same multi-day instructional unit?

Relationships between behavioral, emotional, and cognitive engagement. In the present study engagement is conceptualized as a multi-dimensional construct consisting of behavioral, emotional, and cognitive dimensions (Fredricks et al., 2004; Reeve, 2012; Reschley & Christenson, 2012). As expected, emotional engagement correlated with cognitive engagement. However, behavioral engagement did not correlate with emotional engagement or cognitive engagement. In the present study both emotional and cognitive engagement were measured by student survey and behavioral engagement was measured by observation. Findings from many previous studies have found a positive relationships between students' self-reported behavioral engagement and students' self-reported emotional and cognitive engagement (Lam et al., 2014; Reeve & Tseng, 2011; Skinner & Belmont, 1993). However, like the present study, findings from previous research are mixed concerning the relationship between engagement measured through observation and engagement measured through student survey.

An observed measure of behavioral engagement did not correlate with self-reported cognitive engagement in the study conducted by Appleton and Lawrenz (2011), which took place in 159 middle and high school classrooms. In Appleton and Lawrenz's study, however, six out of eight of the items measuring self-reported cognitive engagement tapped students' perceptions of the use of instructional characteristics rather than students' perceived engagement. Although the survey included one item that tapped cognitive engagement, the survey as a whole was not a measure of cognitive engagement as it is often defined.

On the other hand, a study that took place in 84 high school classrooms found a positive relationship between observed engagement and students' self-reported engagement (Hyungshim, Reeve, & Deci, 2010). In this study, however, both the observed measure and the self-reported measure of engagement included multiple dimensions of engagement within the measure. The observed measure of engagement included six engagement-related aspects of students' collective engagement: attention, effort, verbal participation, persistence, positive emotion, and voice. Self-reported engagement was measured with four items, two that tapped behavioral engagement, one that tapped cognitive engagement, and one that tapped emotional engagement.

Findings from many previous studies have found a positive relationships between students' self-reported behavioral engagement and students' self-reported emotional and cognitive engagement (Lam et al., 2014; Reeve & Tseng, 2011; Skinner & Belmont, 1993). In those studies behavioral engagement was defined as students' perceived effort, attention, persistence, and participation (Lam et al., 2014; Reeve & Tseng, 2011; Skinner

& Belmont, 1993). In the present study students' observed behavioral engagement did not correlate with students' self-reported emotional or cognitive engagement. Possibly an observational measure of students' on-task engagement does not tap the same construct as students' perceived effort, attention, persistence, and participation. Another possibility is that observation is a poor measure of engagement, even behavioral engagement. Future research comparing the relationships between observed measures of engagement, self-reported measures of engagement and achievement growth, would shed light on the difference between and value of each type of measure. Further research is also needed to understand the relationship between students' on-task observable engagement and students' perceived effort, attention, persistence, and participation as well as students' on-task observable engagement and students' perceived emotional and cognitive engagement.

Relationships between task characteristics and student engagement. The cumulative use of choice, challenge, feedback, collaboration, and real-life significance correlated with student engagement measured as a multi-dimension trait consisting of behavioral, cognitive, and emotional dimensions. This finding is consistent with previous literature investigating the relationship between instruction and student engagement in middle and high school across many subject areas (Guthrie & Klauda, 2014; Hampden-Thompson & Bennett, 2013; Hipkins, 2012; Lam et al., 2007; Liu et al., 2009; National Research Council & Institute of Medicine, 2004; Parsons et al., 2015; Shernoff et al., 2014; Skinner & Belmont, 1993). The findings of this study suggest that the cumulative use of these task characteristics are related to seventh grade students' engagement in science class. Specifically, it was students' emotional and cognitive engagement that was related to the cumulative use of task characteristics. Further, the specific task characteristics that were individually related to some aspect of engagement were choice, feedback, and collaboration. Whereas, challenge and real-life significance did not individually relate to engagement in the present study.

Considering each dimension of engagement separately, emotional and cognitive engagement each correlated with the cumulative use of task characteristics, but behavioral engagement did not. Once again, findings based on the measure of behavioral engagement in this study differ from previous research. Previous researchers found a positive relationship between behavioral engagement and choice (Guthrie & Klauda, 2014; Lam et al., 2014; Skinner & Belmont, 1993), challenge (Lam et al., 2014), feedback (Lam et al., 2014), collaboration (Guthrie & Klauda, 2014), and real-life significance (Guthrie & Klauda, 2014; Lam et al., 2014; Skinner & Belmont, 1993). Once again, each of these studies measured behavioral engagement as students' perception of some combination of effort, attention, persistence, dedication, and participation, whereas the present study measured behavioral engagement by observing students' on-task involvement and effort. This finding provides further evidence that an observational measure of behavioral engagement may not measure the same construct as students' perceptions of their effort, attention, and persistence or observation may not be a good method for studying behavioral engagement.

The assessment tasks exemplified the negative relationship between students' behavioral engagement and the use of tasks characteristics. The task characteristic scores on these assessments were low because students had no choice, no collaboration, and little or no real-life significance. However students had a pattern of high behavioral engagement during the assessments. Further, students' total engagement was average or higher than average on the three assessments. Although students had no choice, collaboration, and little or no real-life significance, they did have a clear expectation of teacher feedback in the form of a grade. Possibly this aspect of feedback has a particularly strong relationship with student engagement on its own.

In the present study behavioral engagement had a negative relationship with student choice. Findings from previous research support a relationship between perceived autonomy and student engagement (Reeve & Tseng, 2011; Ryan & Grolnick, 1986). Further, a majority of previous research investigating the relationship between perceived choice and student engagement found a positive relationship between the two variables (Hipkins, 2012; Lam et al., 2014; Reeve et al., 2003). However, one study based on Israeli elementary and middle school students, found that student's perception of choice was related to perceived emotional engagement, but not related to a combined measure of perceived cognitive and behavioral engagement (Assor et al., 2002).

Mixed results concerning the relationship between student engagement and choice may depend on how choice is operationalized. For example, students' engagement in reading was positively related to choice when choice was defined as choice of reading material (Guthrie & Klauda, 2014). In the present study choice included flexibility within the task, choice of task format, and choice of learning within the task.

Although previous research found that students' perceived choice is related to student engagement, students' perceptions of choice may not accurately reflect the amount of choice in the classroom (Mozgalina, 2015). While studying six treatment conditions, Mozgalina (2015) found that the group that had the most choice reported the lowest perception of choice. If students' perception of choice does not accurately reflect the amount of choice in the classroom then students' perception of choice could be related to engagement (Hipkins, 2012; Lam et al., 2014; Reeve et al., 2003), whereas an observed measure of choice many not be related to student engagement.

Mozgalina (2015) also found that the groups with greater choice about the structure of the presentation had lower task motivation compared to the other groups. Engagement and motivation are inherently linked and engagement is often viewed as an outcome of motivation (Reeve, 2012). If greater choice leads to lower task motivation, it may also lead to lower engagement.

Findings from the present study, as well as findings from previous research suggest that the relationship between student choice and student engagement is complicated. Taking a closer look at the pattern of engagement during the highest choice tasks in this study may provide one possible explanation for the complicated relationship between student engagement and choice.

In the present study, the four tasks with the highest choice scores were all associated with students' work on the cell project in Ms. Jay's class. The pattern of engagement over those four tasks started low, increased throughout the tasks in the project, and ended high. During this project students first needed to choose a system to compare to a cell. Then students needed to choose which part of the system they would compare to each part of the cell and why. Finally students built a model of their system. Perhaps students were less engaged at the beginning of this high choice task because it took time to make choices about which system to choose and which parts of the system to compare to a cell. Mozgalina (2015) found evidence that high choice tasks require more time in general. Mozgalina found that the group with the most choices spent longer time preparing their presentations compared to all the other groups.

In the present study, once students made choices about which system to compare to a cell and which parts of the system to compare to each part of the cell, students had clear direction to work on a task that they had a lot of autonomy developing. Students likely experienced high feelings of autonomy during the latter part of the project. As described by SDT, autonomy is the need to participate in behavior that is personally endorsed (Reeve, 2012). Although students' in Ms. Jay's class were given a lot of choice during the whole project, they may not have felt that they were participating in behavior that was personally endorsed until they had already made some or most of the early choices that guided their later work on the project.

In the present study engagement had a positive relationship with feedback and collaboration. This supports findings from previous research studying the relationship between feedback and engagement (Hipkins, 2012; Lam et al., 2014) and collaboration and engagement (Guthrie & Klauda, 2014; Hampden-Thompson & Bennett, 2013; Hipkins, 2012; Liu et al., 2009; Parsons et al., 2013).

Findings from previous research suggest a positive relationship between engagement and challenge (Hipkins, 2012; Lam et al., 2014; Liu et al., 2009; Shernoff et al., 2003; Turner et al., 1998); the present study found no significant relationship between engagement and challenge. Based on the psychological need for competence, people seek challenges that are just beyond their capacities (Deci & Ryan, 1985). Possibly, some of the tasks that students rated as most challenging during this instructional unit were more than just beyond students' capacities and therefore too hard. Whereas previous research has found evidence that challenging tasks are related to engagement (Hipkins, 2012; Liu et al., 2009; Newmann, 1992; Shernoff et al., 2003; Turner et al., 1998), previous research has also found evidence that optimal challenge is related to students' engagement in the classroom (Lam et al., 2007, 2012; National Research Council & Institute of Medicine, 2004; Parsons et al., 2013; Turner et al., 1998; Yazzie-Mintz, 2010). The most challenging tasks in this instructional unit may have been beyond students' optimal challenge.

Task nine and task 18 in Ms. Jay's class may be examples of tasks that were too far beyond students' optimal challenge. Both these tasks had high perceived challenge, but low overall engagement. During task nine, the Nature of Science Cube Challenge, students collaborated in a group to predict what was on the bottom of a cube based on the pattern of words and numbers on the visible side of the cube. Students had high behavioral engagement at the beginning of this task, but students' behavioral engagement decreased throughout the task. Students may have been excited for the challenge in the beginning, but by the end of the task, few groups were able to correctly predict what was on the bottom of the cube. During task 18 students were supposed to answer application questions based on observing and sketching elodea, blood, nerve, and muscle cells. Many of the questions were not directly related to students' previous hands-on work. Instead, students needed to use their notes and textbook to connect their hands-on work to science concepts. Students may have found this to be too challenging and therefore, not engaging. The challenge in both these tasks may not have resulted in feelings of competence for students.

On the other hand, the two tasks with the highest perceived challenge in Ms. Jay's class were also the second and third most engaging tasks in Ms. Jay's class: the first two tasks that students used the microscope to observe and sketch cells. The task in which students first used the microscope in Mr. Oliver's class also had high perceived challenge and high engagement. Unlike the Nature of Science Cube Challenge, in which many students ultimately did not figure out the correct answer on their own, students successfully gained a new skill while using the microscope for the first time. Although students found their first experiences using a microscope challenging, they ultimately mastered a new skill, which likely resulted in feelings of competence.

Findings from previous research also suggest a positive relationship between engagement and real-life significance (Assor et al., 2002; Guthrie & Klauda, 2014; Hampden-Thompson & Bennett, 2013; Hipkins, 2012; Lam et al., 2014; Skinner & Belmont, 1993), the present study did not find a relationship between engagement and real-life significance. This may be due to the fact that there were few tasks that exhibited much real-life significance. The scale of possible real-life significance scores ranged from zero to six and the average score for all tasks was 1.03. Forty-five percent of tasks received a score of zero and 91% of tasks received a score of zero, one, or two. Because the sample of tasks in the present study primarily included tasks with little or no real-life significance, there may not have been enough variability to identify a relationship between engagement and real-life significance.

Hands-on tasks. Hands-on science actively involves students in manipulating objects (Lumpe & Oliver, 1991; Vrtacnik & Gros, 2013). In the present study, nine out of 10 of the tasks with the highest engagement scores from each classroom involved hands-on manipulation. Seven of those tasks involved using a microscope to observe and sketch cells. One task involved conducting an investigation studying the effect of weight of an object on how hard it is to blow the object (although unrelated to cells, this investigation was used to exemplify experimental design). Another task involved setting up an investigation to study the effect of radiation on radish seed germination.

Findings from previous research suggest that hands-on science has a positive effect on student achievement (Schroeder et al., 2007). However, previous research investigating the relationship between hands-on science and student engagement or motivation is limited. One study surveyed 533 middle school students and found that students reported higher interest in hypothetical instructional episodes involving investigations compared with hypothetical instructional episodes in which students receive information passively, participate in discussions, or participate in brainstorming (Swarat, Ortony, & Revelle, 2012). On the other hand, a study at a technical school in Slovenia found that student motivation was not related to hands-on laboratory work in spectrometry (Vrtacnik & Gros, 2013). Additional research is needed to investigate the relationship between hands-on science and students' engagement.

Four times during the study, students completed one or more hands-on task(s) followed by one or more task(s) to analyze the hands-on work. In all four of these instances students were highly engaged during the hands-on tasks and less engaged during the analysis tasks. This trend is concerning. If students are not engaged in the analysis of their hands-on work, they may not make the connection between the hands-on task and the science concepts targeted by the task.

During one of these tasks, which occurred in both classrooms, students analyzed their experience viewing and sketching cells in the microscope. For many of the questions, students were directed to read specific sections of their textbook to help explain their observations. Some of the questions were directly related to students' observations. But because students are expected to learn the function of some parts of the cell that are too small to see with the microscopes they used, some questions were based on the textbook information alone. This disconnect between students' hands-on experience and the follow-up analysis may have impact students' feelings of autonomy, competence, and relatedness.

For the other two tasks, students' filled out an experimental design diagram and made a graph related to an investigation they did studying the effect of radiation on seed germinations. For both of these tasks, it is possible that students had trouble understanding the connection between the hands-on investigation and the two different tasks analyzing the investigation.

Implications

Implications for future research. The method for measuring behavioral, emotional, and cognitive engagement in this study was unique. The majority of previous research studying the relationship between engagement and instruction measured engagement statically (Hampden-Thompson & Bennett, 2013; Hipkins, 2012; Lam et al., 2014, 2012). Of the studies that measured engagement dynamically, no previously identified study measured the behavioral, emotional, and cognitive engagement of an entire class in conjunction with identified tasks. Further, no previously identified study measured behavioral engagement continuously over multiple days. Results from this study suggest that engagement fluctuates over the course of an instructional unit and behavioral engagement fluctuates over the course of individual tasks. Therefore, engagement is a fluid trait. Analyzing the pattern of students' behavioral, emotional, and cognitive engagement continuously revealed new insight into the relationship between the use of task characteristics and middle school students' engagement in science in this study. Further use of the methodology used in this study can provide additional insight into the relationship between the pattern of instruction and engagement in middle school science as well as other subjects and grade levels.

A majority of previous research found positive relationships between behavioral, emotional, and cognitive research (Lam et al., 2014; Reeve & Tseng, 2011; Skinner & Belmont, 1993). Findings from the present study support a relationship between emotional and cognitive engagement. However, the present study did not find a relationship between behavioral engagement and emotional or cognitive engagement.

Previous research primarily measured all dimensions of engagement through self-report (Lam et al., 2014; Reeve & Tseng, 2011; Skinner & Belmont, 1993). Research measuring engagement both through observation and self-report found mixed results concerning the relationship between observed and perceived engagement (Appleton & Lawrenz, 2011; Hyungshim et al., 2010). Further research is need to determine the relationship between students' perception of their effort, attention, and involvement and an observed measure of students' on-task involvement.

Findings from this study as well as previous research portray a complicated relationship between student choice and student engagement. Further research is needed to determine what types of choices and choices in what context are related to student engagement. The present study found a pattern of increasing engagement over the course of four high choice tasks within a single project. Further research is needed to see if this pattern is common during an extended set of related high choice tasks. Also, since findings from previous research found that students' perception of choice may not be related to the amount of choice offered to students, research is needed to study students' interpretation of choice.

In the present study, the three assessment tasks had low task characteristic scores, but high behavioral engagement and medium or high total engagement. Although the cumulative task characteristic scores were low, all tasks had a strong expectation of future teacher feedback in the form of a grade. More research is needed to explore the role of expected grades and expected teacher feedback.

Hipkins (2012) found that students were much more likely to “assess each other’s work and give feedback” in their most enjoyed class compared to their least enjoyed class. Few tasks in the present study included peer feedback, which was an indicator that contributed to both the feedback and collaboration score. The tasks associated with the cell project included the expectation of peer feedback. Those tasks were unique in many other ways so it is hard specify whether the expectation of feedback was related to students’ engagement with the project. Future research should explore the relationship between peer feedback and students engagement.

Little previous research has investigated the relationship between hands-on learning and students’ engagement in science class. One reason for this may be that little research in general has specifically considered students’ engagement in science class. Only one previously identified study specifically considered the influence of instruction on middle school students’ engagement in science (Liu et al., 2009). In the present study, most of the tasks in which students were most engaged involved student manipulation of a scientific tool or tools and/or a living thing. Research is needed to further investigate students’ engagement in middle school science generally and more specifically, the relationship between hands-on learning and student engagement. In the present study, students were highly engaged in hands-on tasks, but less engaged in follow-up tasks analyzing hands-on work. Research is needed to understand how to maintain students’ engagement in the analysis of hands-on tasks where learning is extended, synthesized, and solidified.

Many factors, such as student background, family and peer support, and school factors are related to engagement (Newmann et al., 1992; Wylie & Hodgen, 2012). This study specifically focused on instruction because schools and teachers have more control over factors associated with instruction. More specifically, this study focused on characteristics of the specific activities that students complete in class. Except for the feedback characteristic, the task characteristics in this study did not consider the teacher's role implementing tasks. In the present study feedback was positively related both to total engagement as well as emotional engagement. Further, the importance of the teacher's role in giving feedback is exemplified by comparing the same tasks implemented in both classrooms. The task, Observe and sketch privet leaf and blood vessels, was implemented in both classrooms, but with a different amount of teacher feedback. In the classroom with more feedback (score of 3 compared to a score of 1 because of a difference in teacher feedback), students were more engaged (total engagement score of 11.49 compared to a total engagement score of 9.88) compared to the other classroom. Future research should further consider the role of the teacher in implementing tasks.

Implications for teachers. Student engagement is important because it positively predicts students' grades, conduct, long-term motivation, and college performance (Finn & Rock, 1997; Lam et al., 2012, 2014; Shernoff, 2010). Students' interest in science begins to decline as early as age 11 (Osborne et al., 2003) and student engagement in general declines during the transition to middle school (Eccles et al., 1993, 1991; Eccles & Midgely, 1990). Therefore, it is important to engage middle school students in science. Overall, the cumulative use of choice, challenge, feedback, collaboration, and real-life significance is related to middle school students' engagement in science. Teachers should integrate these task characteristics, especially choice, feedback, and collaboration, into the middle school science curriculum.

Little real-life significance was observed in the present study. The scale of possible real-life significance scores ranged from zero to six, but the average score for all tasks was only 1.03. Forty-five percent of tasks received a score of zero and 91% of tasks received a score of zero, one, or two. Real-life significance was not emphasized in seventh grade science in the two classrooms in this study. Considerable evidence from previous research suggests a positive relationship between student engagement and real-life significance (Hampden-Thompson & Bennett, 2013; Hipkins, 2012; Lam, Wong, Yang, & Liu, 2012; Shernoff et al., 2016; Yazzie-Mintz, 2010) as well as achievement and real-life significance (Schroeder et al., 2007). Therefore, teachers should strive to incorporate more real-life significance in the classroom.

The limited presence of all task characteristics throughout the cell unit in both classrooms suggests teachers may be reluctant to implement choice, challenge, feedback, collaboration, and real-life significance. This may be partially explained by the fact that teachers are more likely to be aware of students' behavioral engagement, which is an observable trait compared to students' emotional and cognitive engagement, which are internal traits. During the present study, it was students' emotional and cognitive engagement that was correlated with the cumulative use of choice, challenge, feedback, collaboration, and real-life significance rather than students' behavioral engagement. Specifically the use of choice, feedback, and collaboration was related to students' emotional and cognitive engagement. Although unobservable, emotional engagement is important to student learning (Sinatra et al., 2015) and students' choice to pursue further study in science (Lin et al., 2012). Therefore, teachers should integrate these task characteristics, especially feedback and collaboration, in the seventh grade science classroom.

In the present study, the tasks with the highest task characteristic scores were all associated with the cell project. Student engagement working on this project started low and increased throughout the project. Further, the use of choice was negatively correlated with behavioral engagement. Therefore, when implementing tasks with high choice and/or high use cumulative use of choice, challenge, feedback, collaboration, and real-life significance, teachers should give students time to make the choices necessary to personally invest in the project. During early parts of the task or long term project, students may exhibit lower engagement. Once students have made the difficult choices associated with project, they may exhibit higher engagement later in the project.

In this study nine out of 10 tasks with the highest engagement scores involved hands-on learning. Therefore, teachers should integrate hands-on learning into the seventh grade science classroom. Specifically, within these units studying cells, students were highly engaged in tasks in which they used a microscope to view and sketch cells. Therefore, when studying cells during middle school science, students should be given ample opportunity to use a microscope to view different types of cells.

In the present study, students did not maintain engagement during follow-up analysis of hands-on tasks. This suggests that students may not be connecting their work during hands-on experiences with new conceptual knowledge. Teachers should be aware of the importance of maintaining students' engagement during the analysis of hands-on experiences so that students connect their hands-on experience with the conceptual knowledge related to the experience. It maybe be helpful if teachers continually ask questions and provide explanations before and during hands-on tasks so that students' can connect hands-on tasks to the science concepts targeted by the task.

Limitations

The findings from this study are limited by the sample size. Because of the large amount of data collected in each classroom, only two classroom teachers and thirty-four students were included. Replicating this study in more classrooms would reveal new patterns between students' fluctuating engagement and classroom instruction. Further, the entire study took place during the investigation of one particular unit on cells. Some of the findings may be unique to that particular topic within seventh grade science.

In order to limit the time taken away from student instruction, the student survey included only one item to measure emotional engagement, cognitive engagement, and challenge. Many previous studies used multiple items to measure students' engagement (Hampden-Thompson & Bennett, 2013; Lam et al., 2014; Reeve & Tseng, 2011; Skinner & Belmont, 1993). Similar to the present study, others used a single item to measure engagement (Hipkins, 2012) or challenge (Shernoff et al., 2014, 2003). Using two or three items for each construct could provide a more accurate or robust depiction of the construct as it was defined in previous literature.

Summary

Student engagement is important because it positively predicts students' grades, conduct, long-term motivation, and college performance (Finn & Rock, 1997; Lam et al., 2014, 2012; Shernoff, 2010). Students' interest in science begins to decline as early as age 11 (Osborne et al., 2003) and student engagement in general declines during the transition to middle school (Eccles et al., 1991, 1993; Eccles & Midgely, 1990). Therefore, it is important to understand what engages middle school students in science. In the present study, the cumulative use of choice, challenge, feedback, collaboration, and real-life significance was related to middle school students' engagement in science. Specifically, the use of choice and feedback was positively related to cognitive engagement and feedback and collaboration was positively related to emotional engagement. On the other hand, the use of choice was negatively related to behavioral engagement. Students' increase in engagement during four related high choice tasks suggests that it may take time for students to engage in high-choice projects.

Nine out of ten of tasks with the highest student engagement involved hands-on learning. However, students' engagement decreased during follow-up analysis of these hands-on tasks. Further research is needed to understand how to maintain students' engagement during the follow-up analysis of hands-on tasks.

Appendix A: IRB Exempt Letter

GEORGE MASON UNIVERSITY

Office of Research Integrity and Assurance

Research Hall, 4400 University Drive, MS 6D5, Fairfax, Virginia 22030
Phone: 703-993-5445; Fax: 703-993-9590

DATE:	April 30, 2015
TO:	Seth Parsons, Ph.D.
FROM:	George Mason University IRB
Project Title:	[736421-1] The Influence of Instruction on Seventh Grade Students' Engagement in Science Class
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	April 30, 2015
REVIEW CATEGORY:	Exemption category #2

Thank you for your submission of New Project materials for this project. The Office of Research Integrity & Assurance (ORIA) has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations.

Please remember that all research must be conducted as described in the submitted materials.

Please note that any revision to previously approved materials must be submitted to the ORIA prior to initiation. Please use the appropriate revision forms for this procedure.

If you have any questions, please contact Karen Motsinger at 703-993-4208 or kmotsing@gmu.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within George Mason University IRB's records.

Appendix B: IRB Exempt Letter Amendments

Office of Research Integrity and Assurance

Research Hall, 4400 University Drive, MS 6D5, Fairfax, Virginia 22030
Phone: 703-993-5445; Fax: 703-993-9590

DATE:	January 4, 2016
TO:	Seth Parsons, Ph.D.
FROM:	George Mason University IRB
Project Title:	[736421-3] The Influence of Instruction on Seventh Grade Students' Engagement in Science Class
SUBMISSION TYPE:	Amendment/Modification
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	January 4, 2016
REVIEW CATEGORY:	Exemption category #1 & 2

Thank you for your submission of Amendment/Modification materials for this project. The Office of Research Integrity & Assurance (ORIA) has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations.

Please remember that all research must be conducted as described in the submitted materials.

Please note that any revision to previously approved materials must be submitted to the ORIA prior to initiation. Please use the appropriate revision forms for this procedure.

If you have any questions, please contact Karen Motsinger at 703-993-4208 or kmotsing@gmu.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within George Mason University IRB's records.

Appendix C: Student Assent Form

College of Education and Human Development
4400 University Drive, MS 4B3, Fairfax, Virginia 22030
Phone: 703-993-6559 Fax: 703-993-2013

Instructional Characteristics and Seventh Grade Students' Engagement in Science Class

STUDENT ASSENT FORM

My name is Mrs. Glassman and I am from George Mason University, College of Education and Human Development.

I want to talk to you about a research study I am doing. In our study, we want to learn more about what types of activities are most interesting and engaging to students in science class. Your parents have already agreed that you may take part in the study, so feel free to talk with them about it before you decide whether you want to join the study.

What will happen to me in the study?
We would like you to participate because your feelings and behaviors in science class can help us understand what interests and engages students. If you would like to participate in the study, you will be asked to answer 3 questions about each activity you do during some days of your science class this year. The questions will take less than 5 minutes to complete. The purpose of the questions is to learn what you thought about the activities you did in class. It is not a test. Also, a researcher will observe and videotape some days of your science class. The observer will keep track of students' behavior during the activities. The videotape will be used to record what science activities you do.

What are the risks?
There are no known risks to you for participating in this research.

What are the benefits?
There are no benefits to you as a participant other than to further research in science teaching methods and student engagement.

Will anyone know that I am in the study? (Confidentiality)
The short surveys that you complete, the notes recorded by the observer, and the videotapes will only be viewed by researchers in the study. When the results of the project are shared in presentations and papers, your real name and the real name of this school will not be used.

What if I do not want to participate or decide later to withdraw?
Being in this study is voluntary. You don't have to be in this study if you don't want to or you can stop being in the study at any time.

Will I receive anything for being in the study?
No.

Who can I talk to about this study?
If you have questions about the study or have any problems, you can talk to you parents, or call the PI at 703-993-6559. If you have questions about the study but want to talk to someone else who is not a part of the study, you can call the Office of Research Integrity & Assurance at George Mason University at 703-993-4121.

Your signature below means that you have read the above information about the study, have had a chance to ask questions to help you understand what you will do in this study, and you are willing to be in the study. Your signature also means that you have been told that you can change your mind later if you want to.

I have read this form and agree to participate in this study.

____ ________________
Child's Name (printed) and Signature Date

Appendix D: Parent Letter

Dear Parent/Guardian,

The George Mason University College of Education and Human Development is conducting a research study in your child's science classroom. The purpose of the research is to study the relationship between instruction and seventh grade students' engagement in science class. There are no known risks or benefits to your child for participating in the study. Please read the attached consent form. If you agree to your child's participation in the study, please sign the form and return it to school with your child.

Thank you,
(science teacher's name)

Appendix E: Parent Consent Form

College of Education and Human Development
4400 University Drive, MS 4B3, Fairfax, Virginia 22030
Phone: 703-993-6559 Fax: 703-993-2013

Instructional Characteristics and Seventh Grade Students' Engagement in Science Class

PARENT INFORMED CONSENT FORM

RESEARCH PROCEDURES

Research is being conducted in your child's science classroom to study the relationship between various methods of instruction and student engagement. The methods being studied are already used in your child's science classroom. Therefore participation in the research does not impact the instructional program your child will receive in science class. If your child agrees to participate, he/she may be observed and videotaped during his/her science class. The purpose of the videotape is to record the teaching methods used during the class period. The video camera will be focused on the teacher and the front of the classroom. The observations and videotaping will take place over two instructional units this year. At the end of each class period he/she will be asked to complete a short (approximately two minute) survey about his/her engagement during the class period.

RISKS

There are no foreseeable risks to your child for participating in this research.

BENEFITS

There are no benefits to your child as a participant other than to further research in science teaching methods and student engagement.

CONFIDENTIALITY

The data in this study will be confidential. Only your child's initials will be written on the completed surveys and no real names of the participants in the class will be used in any public documentation about the research. Videotape data collected during the research will be stored in a secure area. Only the researchers will have access to the tapes. After five years, the video and audio tapes will be destroyed.

PARTICIPATION

Your child's participation is voluntary, and your child may withdraw from the study at any time and for any reason. If your child withdraws from the study, there is no penalty or loss of benefits to which your child is otherwise entitled. There are no costs to you or any other party.

IRB: For Official Use Only

Office of Research Integrity & Assurance

Project Number: 736421-2

Page 1 of 2

ALTERNATIVES TO PARTICIPATION
If your child does not participate in the research, there will be no change to the instructional program your child will receive during science class. The video camera will be placed so that your child will not be filmed.

CONTACT
This research is being conducted by Seth Parsons, Assistant Professor, and Sarah Glassman, graduate student, in the College of Education and Human Development at George Mason University. Seth may be reached at 703-993-6559. Sarah may be reached at 518-396-7043 for questions or to report a research-related problem. You may contact the George Mason University Office of Research Integrity & Assurance at 703-993-4121 if you have questions or comments regarding your child's rights as a participant in the research.

This research has been reviewed according to George Mason University procedures governing your child's participation in this research.

CONSENT
I have read this form and agree to allow my child to participate in this study.

____
Name of Student

____
Parent or Guardian Signature

____
Date of Signature

Appendix F: Teacher Consent Form

College of Education and Human Development
4400 University Drive, MS 4B3, Fairfax, Virginia 22030
Phone: 703-993-6559 Fax: 703-993-2013

Instructional Characteristics and Seventh Grade Students' Engagement in Science Class

TEACHER INFORMED CONSENT FORM

RESEARCH PROCEDURES
This research is being conducted to study the relationship between instruction and seventh grade students' engagement in science class. The instruction being studied is already used in your classroom. Therefore participation in the research does not impact the instructional program you are already using. If you agree to participate, your class will be observed and videotaped during two instructional units this year. The purpose of the videotape is to record the teaching methods used during your classes. The video camera will be mainly focused on the teacher and the front of the classroom. The observer will measure the percent of students on task at regular intervals. At the end of each class period, your students will be asked to complete a short survey about their engagement during different instructional tasks used during the class period.

RISKS
There are no foreseeable risks to you for participating in this research.

BENEFITS
There are no benefits to you as a participant other than to further research in science teaching methods and student engagement.

CONFIDENTIALITY
The data in this study will be confidential. The real names of participants in the class will not be used in any public documentation about the research. Videotape data collected during the research will be stored in a secure area. Only the researchers will have access to the tapes. After five years, the videotapes will be destroyed.

PARTICIPATION
Your participation is voluntary, and you may withdraw from the study at any time and for any reason. If you withdraw from the study, there is no penalty or loss of benefits to which you are otherwise entitled. There are no costs to you or any other party.

CONTACT
This research is being conducted by Seth Parsons, Assistant Professor, and Sarah

Glassman, graduate student, in the College of Education and Human Development at George Mason University. Seth may be reached at 703-993-6559. Sarah may be reached at 518-396-7043 for questions or to report a research-related problem. You may contact the George Mason University Office of Research Integrity & Assurance at 703-993-4121 if you have questions or comments regarding your rights as a participant in the research.

This research has been reviewed according to George Mason University procedures governing your participation in this research.

CONSENT
I have read this form and agree to participate in this study.

____
Name of Teacher

____
Date of Signature

Appendix G: Student Survey

First initial___ Middle initial___ Last initial___

Circle a number between 1 (not at all) and 5 (very much) based on your experience:

	not at all		sometimes		Very much
Were you interested in this activity?	1	2	3	4	5
Did you connect what you were learning to what you already knew?	1	2	3	4	5
Was is challenging?	1	2	3	4	5

Appendix H: Behavioral Engagement Rating Scale

Students' Behavioral Engagement Rating Scale

Adapted from Lutz et al. (2006) and Appleton and Lawrenz (2011)

Observer: ____

Date: _________

School: ____

Teacher name: ____

Grade/subject: ____

# of students in the class: _________

Class start time: _____ Class end time: _____

Expected tasks:	Start time	End time
1.		
2.		
3.		
4.		

Directions: Spend a minute scoring the behavioral engagement of the class every minute.

Behavioral Engagement: Visually inspect each student for a couple seconds in order to count the number of students (out of the total number of students) displaying on-task and involved actions relevant to the academic tasks of classroom instruction. Indicators of on-task behavior include eye movement, posture toward the speaker, hand-raising, writing, speaking, and clearly listening. If the student is doing individual work, he/she looks like he/she is focused on his/her work. If the teacher is talking, he/she looks like he/she is listening or following his/her own work in a way that is related to what the teacher is saying. If he/she is working in a collaborative group, he/she looks like he/she is working on his/her work or talking to group members. While non-academic tasks, such as sharpening a pencil, are not necessarily wrong, they are not considered on-task for this measure. For each time, record the number of students on-task on the chart below. Determine the percent of students on-task and record a score based on the rubric below.

Time	Number of students “on-task”	% of students “on-task”	Time	Number of students “on-task”	% of students “on-task”

Time	Number of students “on-task”	% of students “on-task”	Time	Number of students “on-task”	% of students “on-task”

Appendix I: Task Characteristics Rating Scale

Task Characteristics Rating Scale

Adapted from Shernoff et al. (2014)

Observer: ____

Date of class: _________

Task # and label: _______________________

Task start time:___________

Task end time:___________

School: ____

Teacher name: ____

Grade/subject: ____

Coder Directions: Please rate each **overall** characteristic of instruction based on the presence or absence of the subindicators listed according to the following scale:

Score	Frequency of subindicators
0	**Not Observed**: None, or barely any, of the indicators were present.
1	**Few**: Few indicators were present, or indicators were present only infrequently.
2	**Some/Sometimes**: Some of the indicators were present (i.e., less than 50%) some of the time.
3	**Half**: Approximately half of the indicators were present, or some were present approximately half of the time.
4	**Most/Frequent**: Most of the indicators were present (i.e., over 50%)
5	**Most/Frequent**: Most, or almost all of the indicators were present with some of the indicators stable or present frequently.
6	**All/Exemplary**: All of the indicators were present OR most of the indicators were present in an exemplary way.

Task Characteristics	**Score**
<u>Student Choice</u> - Teacher provides more than one format of task for students to choose from - Students have flexibility within the task - Student choice over what they learn (choice over specific topics within more general required topic) - Opportunities for choice beyond teacher pre-selected options are provided <u>Notes:</u>	
<u>Feedback</u> - Students receive verbal or written teacher feedback while working on the task - Students are told they will receive verbal or written teacher feedback on the task at a later time - Students receive verbal or written feedback from peers - Students are told they will receive verbal or written feedback from peers at a later time - Feedback consists of comments, suggestions and areas of improvement beyond or instead of grades - Feedback gives students clear direction about what they need to do <u>Notes:</u>	

Student Collaboration - Students work in pairs or groups to accomplish a common group task - Students get help and support from each other - Students participate in peer assessment/ peer feedback Notes:	
Real Life Significance - Importance or relevance of the task is clarified - Importance or relevance of the science learning in the task is clarified - Examples are relevant to students' experiences - Task incorporates a real world problem or scenario Notes:	

References

American Association for the Advancement of Science. (1993). *Benchmarks for Scientific Literacy*. New York, NY: Oxford University Press.

Anderman, E. M., & Patrick, H. (2012). Achievement goal theory, conceptualization of ability/ intelligence, and classroom climate. In Christenson, S. L., Reschley, A. L., & Wylie, C. (Eds.), *Handbook of Research on Student Engagement* (pp. 173–191). New York, NY: Springer. doi.org/10.1007/978-1-4614-2018-7_8

Appleton, J. J., & Lawrenz, F. (2011). Student and teacher perspectives across mathematics and science classrooms: The importance of engaging contexts. *School Science and Mathematics*, *111*(4), 143–155. doi:10.1111/j.1949-8594.2011.00072.x

Assor, A., Kaplan, H., & Roth, G. (2002). Choice is good, but relevance is excellent: Autonomy-enhancing and suppressing teacher behaviors predicting students' engagement in schoolwork. *British Journal of Educational Psychology*, *72*, 261–278. doi:10.1348/000709902158883

Blumenfeld, P. C., Kemplar, T. M., & Krajcik, J. S. (2006). Motivation and cognitive engagement in learning environments. In *The Cambridge Handbook of the Learning Sciences* (pp. 475–488). New York, NY: Cambridge University Press.

Blumenfeld, P. C., Mergendoller, J. R., & Swarthout, D. W. (1987). Task as a heuristic for understanding student learning and motivation. *Journal of Curriculum Studies*, *19*(2), 135–148. doi:10.1080/0022027870190203

Broughton, S. H., Pekrun, H., & Sinatra, G. M. (2012). *Climate change, genetically modified foods, airport body scanners: Investigating students' emotions related to science topics*. Paper presented at the annual meeting of the American Education Research Association Conference, Vancouver, BC.

Chin, C., & Osborne, J. (2008). Students' questions: A potential resource for teaching and learning science. *Studies in Science Education*, *44*, 1–39. doi:10.1080/03057260701828101

Christenson, S. L., Reschley, A. L., & Wylie, C. (2012). Epilogue. In Christenson, S. L., Reschley, A. L., & Wylie, C. (Eds.), *Handbook of Research on Student Engagement* (pp. 813-816). New York, NY: Springer. http://dx.doi.org/10.1007/978-1-4614-2018-7

Cicchetti, D. V. (1994). Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. *Psychological Assessment*, *6*(4), 284–290. doi:10.1037/1040-3590.6.4.284

Cleary, T. J., & Zimmerman, B. J. (2012). A cyclical self-regulatory account of student engagement: Theoretical foundations and applications. In Christenson, S. L., Reschley, A. L., & Wylie, C. (Eds.), *Handbook of Research on Student Engagement* (pp. 237–257). New York, NY: Springer. doi:10.1007/978-1-4614-2018-7_11

Connell, J. P., & Wellborn, J. G. (1991). Competence, autonomy, and relatedness: A motivational analysis of self-system processes. In *Minnesota Symposium on Child Psychology* (Vol. 22, pp. 43–77). Hillsdale, NJ: Erlbaum.

Crawford, B. A. (2014). From inquiry to scientific practices in the science classroom. In Lederman, N. G. & Abell, S. K. (Eds.), *Handbook of Research on Science Education* (Vol. 2, pp. 515–541). New York, NY: Routledge.

Danner, F., & Lonky, E. (1981). A cognitive-developmental approach to the effects of rewards on intrinsic motivation. *Child Development*, *52*, 1043–1052. doi:10.2307/1129110

Deci, E. L. (1975). *Intrinsic motivation*. New York, NY: Plenum Press. doi:10.1007/978-1-4613-4446-9

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic Motivation and Self-Determination in Human Behavior*. New York, NY: Plenum Press. doi:10.1007/978-1-4899-2271-7

Deci, E. L., & Ryan, R. M. (1987). The support of autonomy and the control of behavior. *Journal of Personality and Social Psychology*, *53*(6), 221-233. doi:10.1037/0022-3514.53.6.1024

Deci, E. L., & Ryan, R. M. (1991). A motivational approach to self: Integration in personality. In R. Dienstbier (Ed.), *Nebraska symposium on motivation: Perspectives on motivation* (pp. 237–288). Lincoln, NE: University of Nebraska Press.

Deci, E. L., & Ryan, R. M. (2000). The “what” and “why” of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, *11*, 227–268. doi:10.1207/S15327965PLI1104_01

Doyle, W. (1983). Academic work. *Review of Educational Research*, *53*(2), 159–199. doi:10.3102/00346543053002159

Eccles, J. S., Lord, S., & Midgley, C. (1991). What are we doing to early adolescents? The impact of educational contexts on early adolescents. *American Journal of Education*, *99,* 521–542. doi:10.1086/443996

Eccles, J. S., & Midgely, C. (1990). Changes in academic motivation and self-perception during early adolescence. In Montemayor, R., Adams, G., & Gullotta, T. P. (Eds.), *From Childhood to Adolescence: A Transitional Period?* (pp. 134-155) Newbury Park, CA: Sage Publications, Inc.

Eccles, J. S., Midgley, C., Wigfield, A., Buchanana, C. M., Reuman, D., Flanagan, C., & Mac Iver, D. (1993). Development during adolescence: The impact of stage-environment fit on young adolescents' experiences in schools and in families. *American Psychologist*, *48*(2), 90–101. doi:10.1037/0003-066X.48.2.90

Finn, J. D., & Rock, D. (1997). Academic success among students at risk for school failure. *Journal of Applied Psychology*, *82*(2), 221–234. doi:10.1037/0021-9010.82.2.221

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research*, *74*(1), 59-109. doi:10.3102/00346543074001059

Fredricks, J. A., & McColskey, W. (2012). The measurement of student engagement: A comparative analysis of various methods and student self-report instruments. In Christenson, S. L., Reschley, A. L., & Wylie, C. (Eds.), *Handbook of Research on Student Engagement* (pp. 763–781). New York, NY: Springer. doi:10.1007/978-1-4614-2018-7_37

Greene, B. A. (2015). Measuring cognitive engagement with self-report scales: From over 20 years of research. *Educational Psychologist*, *50*(1), 1–17. doi:10.1080/00461520.2014.989230

Guthrie, J. T., & Klauda, S. L. (2014). Effects of classroom practices on reading comprehension, engagement, and motivations for adolescents. *Reading Research Quarterly*, *49*(4), 387–416.

Hallgren, K. (2012). Computing inter-rater reliability for observational data: An overview and tutorial. *Tutorials in Quantitative Methods for Psychology*, *8*(1), 23–24. doi:10.20982/tqmp.08.1.p023

Hampden-Thompson, G., & Bennett, J. (2013). Science teaching and learning activities and students' engagement in science. *International Journal of Science Education*, *35*(8), 1325–1343. doi:10.1080/09500693.2011.608093

Hipkins, R. (2012b). The engaging nature of teaching for competency development. In Christenson, S. L., Reschley, A. L., & Wylie, C. (Eds.), *Handbook of Research on Student Engagement* (pp. 441–456). New York, NY: Springer. doi:10.1007/978-1-4614-2018-7_21

Hyungshim, J., Reeve, J., & Deci, E. L. (2010). Engaging students in learning activities: It is not autonomy support or structure but autonomy support and structure. *Journal of Educational Psychology*, *102*, 588–600. doi:10.1037/a0019682

Koch, S. (1956). Behavior as "intrinsically" regulated: Work notes toward a pre-theory of phenomena called "motivational." *Nebraska Symposium on Motivation*, *4*, 42–87.

Koch, S. (1961). Psychological science vs. the science-humanism antinomy: Intimations of a significant science of man. *American Psychologist*, *16*, 629–639. doi:10.1037/h0048714

Lacy, S., & Riffe, D. (1996). Sampling error and selecting intercoder reliability samples for nominal content categories. *Journalism and Mass Communication Quarterly, 73*, 963–973. doi:10.1177/107769909607300414

Lam, S., Pak, T. S., & Ma, W. Y. K. (2007). Motivating instructional contexts. In Zelick, P.R. (Ed), *Issues in the Psychology of Motivation* (pp. 115–132). New York, NY: Nova Science Publishers, Inc.

Lam, S., Wong, B. P. H., Shin, H., Hatzichristou, C., Polychroni, F., Negovan, V., … Zollneritsch, J. (2014). Understanding and measuring student engagement in school: The results of an international study from 12 countries. *School Psychology Quarterly*, *29*(2), 213–232. doi:10.1037/spq0000057

Lam, S., Wong, B. P. H., Yang, H., & Liu, Y. (2012). Understanding student engagement with a contextual model. In Christenson, S. L., Reschley, A. L., & Wylie, C. (Eds.), *Handbook of Research on Student Engagement* (pp. 403–419). New York, NY: Spring. doi:10.1007/978-1-4614-2018-7_19

Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex Publishing Corporation.

Lin, H., Lawrenz, F., Lin, S.-F., & Hong, Z.-R. (2012). Relationships among affective factors and preferred engagement in science-related activities. *Public Understanding of Science*, *28*(8), 941–954. https://doi.org/10.1177/0963662511429412

Liu, M., Toprac, P., & Yuen, T. T. (2009). What factors make a multimedia learning environment engaging: A case study. In Zheng, R. (Ed.), *Cognitive Effects of*

Multimedia Learning (pp. 173–192). Hershey, PA: IGI Global. doi:10.4018/978-1-60566-158-2.ch010

Lumpe, A. T., & Oliver, J. S. (1991). Dimensions of hands-on science. *The American Biology Teacher*, *53*, 345–348. doi:10.2307/4449322

Lutz, S. L., Guthrie, J. T., & Davis, M. H. (2006). Scaffolding for engagement in elementary school reading instruction. *Journal of Educational Research*, *100*(1), 3–20. doi:10.3200/JOER.100.1.3-20

Mahtmya, D., Lohman, B. J., Matjasko, J. L., & Farb, A. F. (2012). Engagement across developmental periods. In Christenson, S. L., Reschley, A. L., & Wylie, C. (Eds.), *Handbook of Research on Student Engagement* (pp. 45-63). New York, NY: Springer. doi:10.1007/978-1-4614-2018-7_3

McGraw, K. O., & Wong, S. P. (1996). Forming inferences about some intraclass correlation coefficients. *Psychological Methods*, *1*, 30–46. doi:10.1037/1082-989X.1.1.30

Mozgalina, A. (2015). More or less choice? The influence of choice on task motivation and task engagement. *System*, *49*, 120–132. doi:10.1016/j.system.2015.01.004

National Research Council. (1996). *National Science Education Standards*. Washington DC: National Academy Press.

National Research Council. (2000). *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning*. Washington DC: National Academy Press.

National Research Council. (2010). *Preparing Teachers: Building Evidence for Sound Policy*. Washington DC: National Academies Press.

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington DC: The National Academies Press.

National Research Council, & Institute of Medicine. (2004). *Engaging schools*. Washington D.C.: The National Academies Press.

National Science Board. (1999). Preparing our children: Math and science education in the national interest. Retrieved from National Science Foundation website http://www.nsf.gov/pubs/1999/nsb9931/nsb9931-4.htm

Newmann, F. M. (1992). Higher-order thinking and prospects for classroom thoughtfulness. In Newmann, F. M. (Ed.), *Student Engagement and Achievement in American Schools* (pp. 62–91). New York, NY: Teachers College Press.

Newmann, F. M., Wehlage, G. G., & Lamborn, S. D. (1992). The Significance and Sources of Student Engagement. In Newmann, F. M. (Ed.), *Student Engagement and Achievement in American Schools* (pp. 11-39). New York, NY: Teachers College Press.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington DC: The National Academies Press.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, *25*(9), 1049–1079. doi:10.1080/0950069032000032199

Parsons, S. A., Malloy, J. A., Parsons, A. W., & Burrowbridge, S. C. (2015). Students' engagement in literacy tasks. *The Reading Teacher*, *69*, 223–231. doi:10.1002/trtr.1378

Parsons, S. A., Parsons, A. W., & Malloy, J. A. (2013). *Sixth grade student engagement in literacy tasks.* Paper presented at the annual meeting of the Association of Literacy Educators and Researchers, Dallas, TX.

Reeve, J. (2012). A self-determination theory perspective on student engagement. In Christenson, S. L., Reschley, A. L., & Wylie, C. (Eds.), *Handbook of Research on Student Engagement* (pp. 149–171). New York, NY: Springer. doi:10.1007/978-1-4614-2018-7_7

Reeve, J., Nix, G., & Hamm, D. (2003). Testing models of the experience of self-determination in intrinsic motivation and the conundrum of choice. *Journal of Educational Psychology*, *95*, 375–392. doi:10.1037/0022-0663.95.2.375

Reeve, J., & Tseng, C.-M. (2011). Agency as a fourth aspect of students' engagement during learning activities. *Contemporary Educational Psychology, 36*, 257–267. doi:10.1016/j.cedpsych.2011.05.002

Reschley, A. L., & Christenson, S. L. (2012). Jingle, jangle, and conceptual haziness: Evolution and future directions of the engagement construct. In Christenson, S. L., Reschley, A. L., & Wylie, C. (Eds.), *Handbook of Research on Student Engagement* (pp. 3-19). New York, NY: Springer.

Rotgans, J. I., & Schmidt, H. G. (2011). Cognitive engagement in the problem-based learning classroom. *Advances in Health Sciences Education*, *16*(4), 465–479. doi:10.1007/s10459-011-9272-9

Rumberger, R. (2004). Why students drop out of school. In Orfield, G. (Ed.), *Dropouts in America: Confronting the Graduation Rate Crisis* (pp. 131–155). Cambridge, MA: Harvard Education Press.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78. doi:10.1037/0003-066X.55.1.68

Ryan, R. M., & Grolnick, W. S. (1986). Origins and pawns in the classroom: Self-report and projective assessments of individual differences in children's perceptions. *Journal of Personality and Social Psychology*, *50*(3), 550–558. doi:10.1037/0022-3514.50.3.550

Schroeder, C. M., Scott, T. P., Tolson, H., Huang, T.-Y., & Lee, Y.-H. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching, 44*(10), 1436–1460. doi:10.1002/tea.20212

Shernoff, D. J. (2010). *The Experience of Student Engagement in High School Classrooms: Influences and Effects on Long Term Outcomes*. Saarbruken, Germany: Lambert Academic Publishing.

Shernoff, D. J. (2013). *Optimal Learning Environments to Promote Student Engagement (Advancing Responsible Adolescent Development)*. New York, NY: Springer. doi:10.1007/978-1-4614-7089-2

Shernoff, D. J., Cavanaugh, R. F., Abdi, B., & Tonks, S. (2014). *The influence of empirically-based dimensions of the learning environment on student engagement and classroom experience*. Paper presented at the annual meeting of the American Educational Research Association, Philadelphia, PA.

Shernoff, D. J., Csikszentmihalyi, M., Schneider, B., & Shernoff, E. S. (2003). Student engagement in high school classrooms from the perspective of flow theory. *School Psychology Quarterly*, *18*(2), 158–176. doi:10.1521/scpq.18.2.158.21860

Shernoff, D. J., Kelly, S., Tonks, S. M., Anderson, B., Cavanagh, S.S., & Abdi, B. (2016). Student engagement as a function of environmental complexity in high school classrooms. *Learning and Instruction, 43,* 52-60. doi: 10.1016/j.learninstruc.2015.12.003

Shernoff, D. J., Tonks, S., Anderson, B., & Dortch, C. (2011). *Linking instructional practices with student engagement from moment to moment in high school classrooms.* Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Sinatra, G. M., Broughton, S. H., & Lombardi, D. (2014). Emotions in science education. In Pekrun, R., & Linnenbrink-Garcia, L. (Eds.), *International Handbook of Emotions in Education* (pp. 415–436). New York, NY: Routlege.

Sinatra, G. M., Heddy, B. C., & Lombardi, D. (2015). The challenges of defining and measuring student engagement in science. *Educational Psychologist*, *50*(1), 1–13. doi:10.1080/00461520.2014.1002924

Skinner, E. A., & Belmont, M. J. (1993). Motivation in the classroom: Reciprocal effects of teacher behavior and student engagement across the school year. *Journal of Educational Psychology*, *84*, 571–581. doi:10.1037/0022-0663.85.4.571

Skinner, E. A., & Pitzer, J. R. (2012). Developmental dynamics of student engagement, coping, and everyday resilience. In Christenson, S. L., Reschley, A. L., & Wylie, C. (Eds.), *Handbook of Research on Student Engagement* (pp. 21–44). New York, NY: Springer. doi:10.1007/978-1-4614-2018-7_2

Stillwell, R. (2010). *Public school graduates and dropouts from the common core of data: School year 2007-08*. Washington DC: National Center for Educational Statistics. Retrieved from National Center for Education Statistics website http://nces.ed.gov/pubs2010/2010341.pdf

Swarat, S., Ortony, A., & Revelle, W. (2012). Activity matters: Understanding student interest in school science. *Journal of Research in Science Teaching*, *49*, 515–537. doi:10.1002/tea.21010

Taboada Barber, A., & Buehl, M. M. (2013). Relations among grade 4 students' perceptions of autonomy, engagement in science, and reading motivation. *The Journal of Experimental Education*, *8*(1), 22–43. doi:10.1002/tea.21010

Treagust, D. F., & Tsui, C.-Y. (2014). General instructional methods and strategies. In Lederman, N. G. & Abell, S. K. (Eds.), *Handbook of Research on Science Education* (Vol. 2, pp. 303–320). New York, NY: Routledge.

Turner, J. C., Christensen, A., Kackar-Cam, H. Z., Trucano, M., & Fulmer, S. M. (2014). Enhancing students' engagement: Report of a 3-year intervention with middle school teachers. *American Educational Research Journa*l, *51*(6), 1195–1226. doi:10.3102/0002831214532515

Turner, J. C., Meyer, D. K., Cox, K. E., Logan, C., DiCintio, M., & Thomas, C. T. (1998). Creating contexts for involvement in mathematics. *Journal of Educational Psychology*, *90*(4), 730–745. doi:10.1037/0022-0663.90.4.730

Vrtacnik, M., & Gros, N. (2013). The impact of a hands-on approach to learning visible spectrometry upon students' performance, motivation, and attitudes. *Acta Chimca Slovenica*, *60*, 209–220.

Willms, J. D. (2003). *Student engagement at school: A sense of belonging and participation. Results from PISA 2000.* Paris: Organisation for Economic Co-operation and Development.

Wylie, C., & Hodgen, E. (2012). Trajectories and patterns of student engagement: Evidence from a longitudnal study. In Christenson, S. L., Reschley, A. L., & Wylie, C. (Eds.), *Handbook of Research on Student Engagement* (pp. 585–599). New York, NY: Springer. doi:10.1007/978-1-4614-2018-7_28

Yazzie-Mintz, E. (2010). Charting the Path from Engagement to Achievement: A Report on the 2009 High School Survey of Student Engagement. Bloomington, IN: Center for Evaluation & Education Policy. Retrieved from http://hub.mspnet.org/index.cfm/20806

Zoller, U., & Nahum, T. L. (2012). From teaching to KNOW to learning to THINK in science education. In Fraser, B., Tobin, K, & McRobbie, C. J. (Eds.), *Second International Handbook of Science Education* (pp. 209–229). New York, NY: Springer. doi:10.1007/978-1-4020-9041-7_16

Biography

Sarah J. Glassman graduated from Shaker High School in Latham, NY, in 1997. She received her Bachelor of Arts in Biology from Brown University in 2001. After graduating from college she taught high school math at CITYterm, an experience-based semester program near New York City. After completing at M.A.T. in Biology Teaching at Union Graduate College in Schenectady, NY in 2004, she taught high school biology at Maple Hill High School for one year and middle school science at Van Antwerp Middle School in Niskayuna, NY for two years. In 2007, she moved to Vienna, VA so her husband could begin a new job at the Library of Congress. She began a Ph.D. in Education and teaching seventh grade science at Thoreau Middle School in Vienna, VA. In 2008, her first daughter, Anna, was born. Between 2008 and 2014 she completed the coursework and internship required to gain her K-12 administrative certification while continuing to work on her Ph.D. and caring for Anna, Abigail (born 2010) and Elizabeth (born 2013). In 2014 she began working part time as a research assistant at Project 2061 of the American Association for the Advancement of Science. In her free time she enjoys being outdoors with her family, doing artwork with her children, and tasting new beers, wines, and cheeses with her husband.