

MEASURING STUDENT ENGAGEMENT IN SCIENCE CLASSROOMS: AN
INVESTIGATION OF THE CONTEXTUAL FACTORS AND LONGITUDINAL
OUTCOMES

By

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ABSTRACT

MEASURING STUDENT ENGAGEMENT IN SCIENCE CLASSROOMS: AN INVESTIGATION OF THE CONTEXTUAL FACTORS AND LONGITUDINAL OUTCOMES

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This dissertation includes three separate but related studies that examine the different dimensions of student experiences in science using data from two different datasets: the High School Longitudinal Study of 2009 (HSLS:09), and a dataset constructed using the Experience Sampling Method (ESM). This mixed-dataset approach provides a unique perspective on student engagement and the contexts in which it exists. Engagement is operationalized across the three studies using aspects of flow theory to evaluate how the challenges in science classes are experienced at the student level. The data provides information on a student's skill-level and efficacy during the challenge, as well as their interest level and persistence. The data additionally track how situations contribute to *optimal learning moments*, along with longitudinal attitudes and behaviors towards science.

In the first part of this study, the construct of optimal moments is explored using in the moment data from the ESM dataset. Several different measures of engagement are tested and validated to uncover relationships between various affective states and optimal learning experiences with a focus on science classrooms. Additional analyses include investigating the links between in the moment engagement (situational), and cross-situational (stable) measures of engagement in science.

The second part of this dissertation analyzes the ESM data in greater depth by examining how engagement varies across students and their contextual environment. The contextual

characteristics associated with higher engagement levels are evaluated to see if these conditions hold across different types of students. Chapter three more thoroughly analyzes what contributes to students persisting through challenging learning moments, and the variation in levels of effort put forth when facing difficulty while learning in science.

In chapter four, this dissertation explores additional outcomes associated with student engagement in science using the results for chapters two and three to identify aspects of engagement and learning in science. These findings motivate a set of variables and analytic approach that is undertaken in chapter four. Specifically, the questions how engagement influences experiences in ninth grade science and students' interest in pursuing a career in STEM using the HSLS:09 data.

This multifaceted study contributes to the conceptualization of student engagement, and will help bring clarity to the relationship among engagement, context, and long-term outcomes in science. Engagement is more than being on-task or paying attention, but is a condition influenced by many factors including student background, the learning context of the classroom, teacher characteristics, and the features of instruction. Understanding this relationship between engagement and contextual factors is helpful in uncovering teacher actions and instructional activities that may elicit higher engagement in science classes. These findings highlight the importance of science instruction using more cognitively-demanding activities, such as problem-based learning.

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TABLE OF CONTENTS

LIST OF TABLES	ix
LIST OF FIGURES	xi
CHAPTER 1: INTRODUCTION	1
Theoretical Framework	3
Experience Sampling Method	5
Study Design	7
REFERENCES	10
CHAPTER 2: MEASURING ENGAGEMENT	13
The Experience of Engagement	14
Self-Efficacy and Motivation	16
Persistence and Commitment	17
Measures of Engagement	17
Experience Sampling Method	18
Theoretical Framework	20
Research Questions	21
Methodology	22
Sample	23
Measures	26
Analytic Approach	27
Results	29
Discussion	37
Limitations	37
Implications	38
APPENDICES	40
Appendix A: Student ESM Questionnaire	41
Appendix B: Student Background Survey	42
REFERENCES	45
CHAPTER 3: CONTEXTUALIZING VARIATION OF ENGAGEMENT EXPERIENCES: THE ROLE OF OPTIMAL LEARNING MOMENTS IN SCIENCE	49
Dimensions of the Optimal Experiences and Learning	49
Engagement in Science	50
Teachers and Instruction	51
Teacher Behavior	52
Instruction	52
Student Background	54
Theoretical Framework	54
Research Questions	56
Methodology	56

Data and Sample.....	56
Measures.....	57
Analytic Approach	58
Results.....	59
Discussion.....	67
Limitations.....	69
Implications	70
APPENDICES.....	72
Appendix A: ESM Response Sample Restrictions.....	73
Appendix B: Relationship between Persistence and Challenge	74
REFERENCES	75
CHAPTER 4: THE ROLE OF ENGAGING EXPERIENCES IN SCIENCE AND LONGITUDINAL OUTCOMES IN HIGH SCHOOL	79
Pathways in Science during High School	79
Strengthening the STEM Pipeline	79
Course-taking	80
Science Instruction	81
School Context	83
Theoretical Framework.....	83
Research Questions	85
Data and Methods	86
Measures.....	86
Student variables	87
Teacher variables.....	88
Weighting and missing data	89
Analytic Approach	89
Results.....	90
Discussion.....	98
Limitations.....	100
Implications	101
APPENDIX	103
REFERENCES	106
CHAPTER 5: CONCLUSION	109
Summary of Findings.....	110
Limitations	111
Policy Implications	112
REFERENCES	115

LIST OF TABLES

Table 2.1 ESM School Sample Descriptives	23
Table 2.2 Descriptive Characteristics of the Sample	25
Table 2.3 Summary Statistics for ESM Variables	30
Table 2.4 Summary Statistics of Cross-Situational Engagement Measures	31
Table 2.5 Percentage of Time Students are in Flow	33
Table 2.6 Correlations with Optimal Moments (challenge, interest, & skill).....	34
Table 2.7 Flow Measures Compared to Validations Items	35
Table 2.8 Percentage of Students Engaged in Science	36
Table 3.1 Descriptive Characteristics of Two-Level Data.....	57
Table 3.2 Optimal Learning Moments by Gender	64
Table 3.3 Optimal Learning Moments by Student Characteristics.....	64
Table 3.4 Student-reported Task in Science	65
Table 3.5 HGLM Predicting Optimal Learning Moments-Level 1	66
Table 3.6 HGLM Predicting Optimal Learning Moments- Full Model	67
Table 3.7 Sample Restriction Comparisons.....	73
Table 3.8 Correlations with High Challenge and Persistence.....	74
Table 4.1 Descriptive Characteristics of the HSLS:09	87
Table 4.2 Science Course Enrollment by Student Characteristics.....	92
Table 4.3 Teacher Instructional Variables	94
Table 4.4 HGLM Predicting Usefulness of 2009 Science Course- Full model.....	95
Table 4.5 HGLM Predicting Skills of 2009 Science Course- Full model	96

Table 4.6 HGLM Predicting Interest of 2009 Science Course- Full model	97
Table 4.7 HGLM Predicting STEM Career in 2012 - Full model	98

LIST OF FIGURES

Figure 1.1 A Conceptualization of Engagement in High School.....	6
Figure 2.1 Frequency of Students by Response Rate	24
Figure 2.2 Relationship between Engagement Construct and Learning	28
Figure 3.1 Contextualizing Optimal Learning Moments in Science	55
Figure 3.2 Student Volition of Task during an Optimal Learning Moment	60
Figure 3.3 Student Perception of Activity during an Optimal Learning Moment	61
Figure 3.4 Percentage of Students with Higher Challenge and Wanting to Give Up.....	74
Figure 4.1. Longitudinal Engagement Experiences in High School.....	84
Figure 4.2 Science Course Enrollment of 9 th Graders from 2009-2010	91

CHAPTER 1: INTRODUCTION

Increasing student engagement in classrooms is a high priority yet ambiguous goal atop many education policy agendas. While the idea of engaging students in learning is desirable and often elicits images of eager students on the edge of their seats with hands raised, or a group of students working together to build a model that demonstrates their understanding of a new science idea— the physical manifestations of engagement may look different for each student, teacher, classroom, and subject. The experience of engagement may also vary depending on a number of contextual factors that comprise daily activities, such as the company one is with, or the value of the activity in relation to one's future goals. Research demonstrates that high student engagement is an important condition that can contribute to multiple student outcomes, including improved classroom behavior, increased student achievement, reduced likelihood of dropping out, increased high school completion, and college matriculation (Klem & Connell, 2004; National Research Council [NRC], 2004; Shernoff, D., Csikszentmihalyi, Schneider, & Shernoff, E., 2003; Csikszentmihalyi & Schneider, 2000).

Secondary schools have an even greater challenge than elementary schools in engaging students because as students progress from elementary to their middle and high schools, general attitudes and interests in academics decline (Gonzales et al., 2008) and schools grapple with effective ways to provide meaningful and motivational experiences for students who often see themselves as passive participants in a large anonymous mass (Larson & Richards, 1991) where students and teachers may just be “passing time” (Cusick, 1983). High school science classrooms are of particular importance given the increased number of advanced courses needed to earn a diploma (Schiller & Muller, 2003) and the increased demand for individuals to either pursue postsecondary education or a career in the fields of science, technology, engineering, and

mathematics (STEM) (National Academies, 2010; National Science Board, 2010). As educational policy continues to pursue higher standards and demand high quality teaching, understanding the relationship between teacher instruction and student engagement is a critical component in the evaluation of these reforms.

To gain a better understanding of student engagement, many research studies have collected data on engagement through classroom observations and surveys, yet these measures may not fully be able to get into the black box of student learning. What does engagement in learning look like for each student, and not just the average student? What is engaging to students? Specifically, what creates an optimal learning experience in school? Is the current lesson interesting? Does it have personal value? How does the activity or lesson make the student feel? While survey measures and observations of classrooms give one aspect to understanding student engagement, the actual engagement experiences are not captured. This study provides a diverse set of analyses of student engagement and is designed to understand how student engagement varies, particularly in science classrooms, as well as analyze the relationship of student engagement to long-term outcomes. These analyses use data from two different datasets to gain a more comprehensive understanding of student engagement that not only includes the outcomes associated with these engagement measures, but also discusses how the use of different measures of engagement impact the outcomes of interest.

This study examines student engagement using data from the High School Longitudinal Study of 2009 (HSL:09), and a unique dataset constructed using the Experience Sampling Method (ESM). This mixed-dataset study allows for the analysis of student interests and behaviors in high school while considering additional factors related to their experiences in high school, including their teachers, the types and frequency of instruction they are exposed to, and

characteristics of their classroom and school, that contribute to the daily contextual environment in which engagement occurs. The contextual environment can include the beliefs, goals, values, perceptions, behaviors, classroom management, social relations, physical space, and social-emotional space (Turner & Meyer, 2000). The ESM data enhance the ability to look more closely within the classroom and these contextual characteristics, thus complementing the HSLS:2009 analysis by supporting the exploration of the preconditions of engagement, which can provide information for teachers on how to develop and sustain science engagement for adolescents. While the field on student engagement is rich, diverse, and expanding, there are a limited number of studies that consider the *dimensionality* of engagement across multiple contexts as they contribute to the variation in learning moments. For example, are similar classroom tasks related to similar engagement experiences? Are there differences between boys and girls? Additionally, this research also examines the relationship of engagement and the different ways it is defined to outcomes such as increased interest in science and taking additional courses in science.

Theoretical Framework

The conceptualization of student engagement is diverse and often understood using a multi-disciplinary perspective. The variety of ways in which engagement is defined and subsequently measured can create a *jingle fallacy* (Thorndike, 1904) or *jangle fallacy* (Kelley, 1927). In a jingle fallacy, an identical term can be used to identify several situations (e.g. using “engagement” to describe several different phenomena). In a jangle fallacy, there are similar situations that are defined by different labels (e.g. using engagement, motivation, or interest to describe the same outcome). Theoretical reviews about different definitions suggest that research be clear about the specific components included and excluded in the definition, and that studies

align their theory and measurement fit, meaning, the applied measures should assess the components that are relevant for the research questions and conclusions (Fredricks, Blumenfeld, & Paris, 2012). Engagement is often described as an "in the moment" experience, but it is hardly ever measured in the moment in which it occurs (Fredricks et al., 2012). Despite the reviews of theories and the recognition of the need for a consistent understanding of how engagement is studied, there are still many ambiguous methods being used to examine academic engagement, thus leading to inconsistencies in the research.

Understanding the academic context is also an important factor in ascertaining how students may engage in learning differently. Turner and Meyer (2000) offer three explanations for considering classroom context when studying learning: (1) teaching and effective instruction often varies with context (Good & Brophy, 2003); (2) teaching and learning vary by content area (Stodolsky, 1988); and (3) theoretical frameworks should include an interpretative structure for considering the role of contexts. With this in mind, when examining engagement, research questions and instruments should be sensitive to the different contexts in which they are operating, and include measures that capture the context and assess subject-specific aspects of engagement.

In an earlier review of the literature, Fredricks, Blumenfeld, and Paris (2004) operationalize engagement in three ways: (1) behavioral engagement, which is the action or participation of the individual in academic or social activities; (2) emotional engagement, which includes the positive and negative reactions to teachers and peers as well as an individual's willingness to work; and (3) cognitive engagement, which includes the investment of an individual to comprehend new ideas and master challenging skills. While engagement can be described using these paradigms, engagement types can also overlap. For example, behavioral

engagement can entail student conduct and completing tasks (Finn, Pannozzo, & Voelkl, 1995). There are several ways of studying cognitive engagement that examine students' investment in learning, such as self-regulation and enjoying a challenge (Newmann et al., 1992).

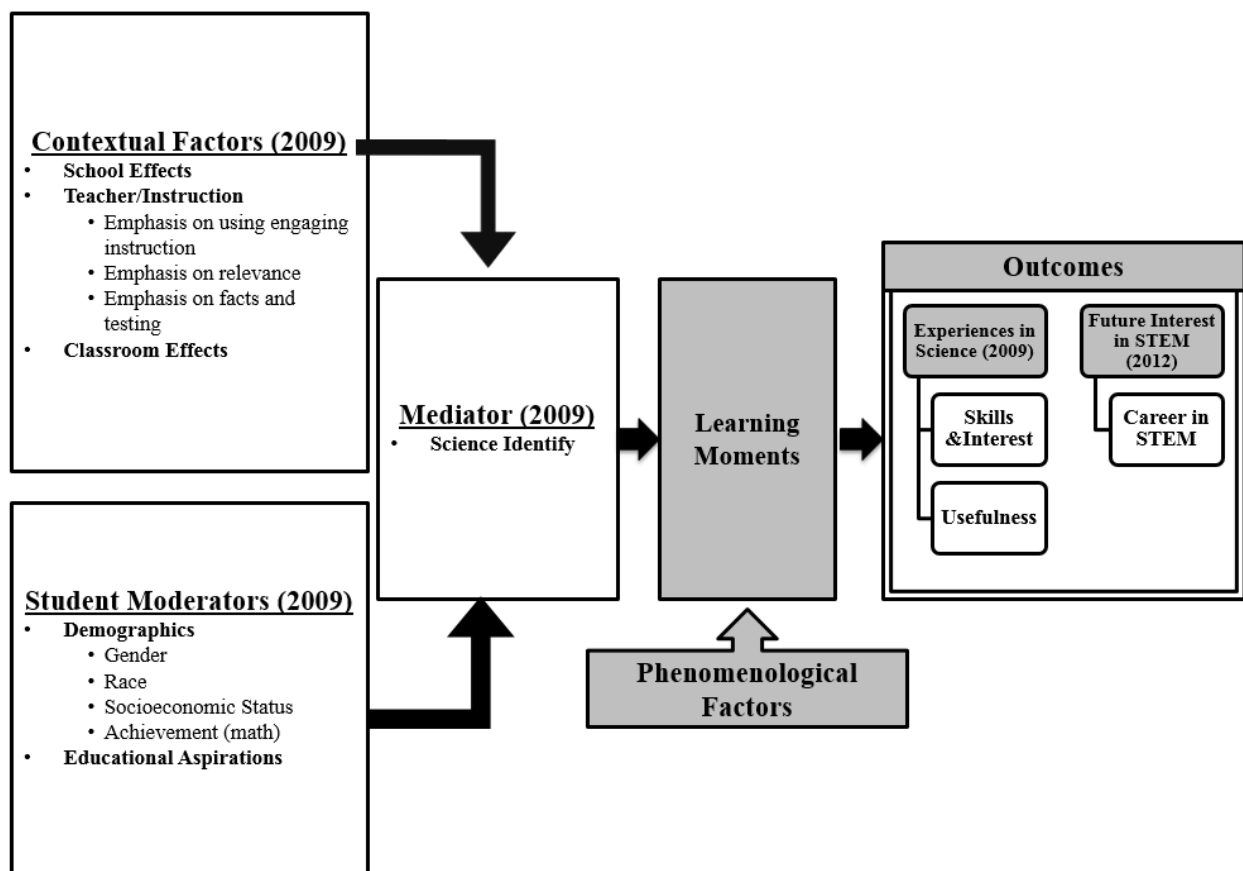
Experience Sampling Method

One way to measure engagement while capturing the contextual academic environment is to examine the daily experiences of students using the ESM. Developed by Csikszentmihalyi and colleagues (1977), ESM provides a way of capturing the immediate activities and emotions of an individual's daily life in real time and at random intervals (Hektner, Schmidt, & Csikszentmihalyi, 2007). Recognizing the multifaceted nature of student engagement and how it varies across contexts, ESM allows students to record their behavioral, cognitive, and emotional experiences. These data can be used to operationalize engagement. For example, using the self-reported levels of challenge and skill can provide evidence of being in "flow," which is defined as a state of deep absorption in an activity that is intrinsically enjoyable (Csikszentmihalyi, 1990). In flow, the challenge of an activity is well matched (balanced) to an individual's skill level (Csikszentmihalyi, 1975). Shernoff, D., Csikszentmihalyi, Schneider, and Shernoff (2003) used specific components of flow to measure student engagement based on the occurrence of high concentration, enjoyment, and interest in learning. When considering an individual's concentration as a central component of flow, the participant's interest is strongly correlated to their attention and motivation, and their enjoyment is related to their performance of the tasks.

This dissertation study uses flow theory, which argues that optimal experiences occur when individuals experience a balance of challenge of skills in a task, as a way to operationalize student engagement and understand optimal learning experiences using the ESM data. By measuring these modifiable learning moments, instructional implications can be made. In

addition, these findings support the examination of characteristics of engagement in analyses of the HSLs:09 dataset in Chapter 4. As shown in Figure 1.1, the analyses of learning moments in the ESM data complement the examination of secondary science experiences in the HSLs:09 dataset. These datasets are aligned and provide an opportunity to explore the dimensions of challenge, interest, and skill in relation to science outcomes, such as advanced course-taking in high school and postsecondary ambitions. Learning experiences, represented below by the gray box, are the primary focus of

Figure 1.1 A Conceptualization of Engagement in High School



chapters two and three. This conceptual model refers more generally to “learning moments,” which recognizes that not all of these experiences are *optimal* and that this study more narrowly

examines *academic* contexts of learning as opposed to optimal experiences that may not involve learning (e.g. chess or rock climbing). The phenomenological factors box represents the extensive set of affective dimensions that are captured by the ESM data (e.g. happiness, cooperation, stress).

These learning experiences are influenced by both student background characteristics (moderators), and contextual factors such as the characteristics of the school, teacher, and class level as shown on the left side of Figure 1.1. The instructional factors include how the teacher reports emphasizing certain methods of instruction. The student moderating variables include demographic characteristics as well as their educational expectations. The outcomes explored in chapter four are represented by the box on the right, and include the students' experiences in their 2009 science course and their later interest in a STEM career in 2012.

This approach specifically supports the examination in both datasets of student behavior (what a student is doing), cognitive engagement (their efficacy and concentration), and emotional state (how one feels about the activity). While prior ESM research often examines the occurrence of engagement and how engagement varies, more research is needed to understand longitudinal outcomes associated with being engaged (see Christenson, Reschley, & Wylie, 2012), an issue that is discussed in this study.

Study Design

This study examines how engagement, measured within optimal moments, varies across students and their contextual environment. In chapter two, the ESM dataset explores the following questions: (1) How do challenge, skill, and interest levels inform measures of optimal experiences? (2) What is the relationship between different constructs of engagement, and how can these be validated? (3) How do these measures of engagement and optimal learning hold

across contexts, specifically, what do these moments look like in science classrooms compared to other school settings? The constructs of engagement are examined using multiple descriptive analyses using momentary measures, aggregated student-level measures, and nested analyses.

Chapter three provides an in-depth analysis of the ESM data, which contributes to understanding optimal experiences. Analyses of this dataset focus on the contextual characteristics associated with variation in engagement. This part of the study will test if the certain contexts associated with increased engagement experiences hold across different types of students and instruction. The guiding questions for this portion of the study are: (1) How does engagement (as measured by optimal learning moments) vary across students? (2) What instructional factors are associated with optimal learning moments? And (3) What characteristics can predict optimal learning moments?

In the final chapter, data from the first follow-up of HSLS:09 are analyzed to address: (1) How do experiences in science class vary by student characteristics and contextual factors? (2) How do experiences in ninth grade science predict future interest in a STEM career? It is hypothesized that having more engaging learning experiences in science courses can lead to an increase in positive attitudes in science and contribute to future interest in STEM. This analytic framework and approach to analyzing HSLS:09 is informed by the ESM data. Using this ESM data to compliment HSLS:09 allows for the articulation of engagement measures to be explored further by a weighted sample that can be generalized to the national population of students.

The goal of this three-part study is to contribute to the research and understanding of how engagement is measured in the field, as well as studying the influence of engagement on the experiences of students in high school science, specifically, its contribution to the development and sustained interest in science. Improving engagement in science, and more broadly in STEM

education, is one policy lever utilized to strengthen the pipeline of talent from high schools into the STEM workforce. Understanding how student engagement is defined and measured in high school not only adds to the existing research on the conceptualization of engagement, but also reveals new insights on instructional approaches that can increase engagement and ultimately learning. While providing an understanding of the relationship between engagement and instruction for researchers and policymakers, this type of research can also provide teachers with insight regarding the experiences of students in their classes, which has implications for their instruction, and could potentially be used as a tool for improvement. As higher standards and increased expectations continue to be upheld as the policy of choice for improving education, particularly in STEM, understanding the engagement of students in high school and the role of teachers in fostering engagement is an important area to continue to research.

REFERENCES

REFERENCES

- Christenson, S., Reschly, A., & Wylie, C. (2012). *Handbook of research on student engagement*. New York: Springer.
- Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. New York: Harper Perennial.
- Csikszentmihalyi, M., & Schneider, B. (2000). *Becoming adult*. New York: Basic Books.
- Connell & Wellborn, (1991). Competence, autonomy, and relatedness: A motivational analysis of self-system processes. In M. Gunnar & L. A. Sroufe (Eds.), *Minnesota symposium on child psychology (Vol. 23)*. Chicago: University of Chicago Press.
- DiBianca, R. (2000). *Teaching adolescents: Relationships between features of instruction and student engagement in high school mathematics and science classrooms*. Chicago: University of Chicago Press.
- Fredricks, J. A., Blumenfeld, P.C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of evidence. *Review of Educational Research*, 74(1), 50-109.
- Good, T.L. & Brophy, J.E. (2003). *Looking in Classrooms*, 9th Edition. Boston, MA: Pearson.
- Kelley, T.L. (1927). *Interpretation of educational measurements* (pp. 62–65). Yonkers-on-Hudson, N.Y.: World Book Company.
- Klem, A.M. & Connell, J. (2004). Relationships matter: Linking teacher support to student engagement and achievement. *Journal of School Health*, 74(7), 262-273.
- National Academies. (2010). *Rising above the gathering storm, revisited: Rapidly approaching category 5*. Washington, DC: The National Academies Press. Retrieved from <http://www.nap.edu/catalog/12999.html>.
- National Science Board. (2010). *Preparing the next generation of STEM innovators: Identifying and developing our nation's human capital*. Arlington, VA: National Science Foundation. Retrieved from <http://www.nsf.gov/nsb/publications/2010/nsb1033.pdf>.
- National Research Council. (2004). *Engaging schools: fostering high school student's motivation to learn*. Committee on Increasing High School Students' Engagement and Motivation to Learn. Board on Children, Youth, and Families, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

- Sherhoff, D. & Csikszentmihalyi, M. (2009). Flow in schools: Cultivating engaged learners and optimal learning environments. In R. Gilman, E. S. Huebner, & M. Furlong (Eds.), *Handbook of Positive Psychology in Schools* (pp. 131-145). New York: Routledge.
- Sherhoff, D., Csikszentmihalyi, M., Schneider, B., & Sherhoff, E. (2003). Student engagement in high school classrooms from the perspective of flow theory. *School Psychology Quarterly*, 18(2), 158-176.
- Sherhoff, D. (2001). *The experience of student engagement in high school: A phenomenological perspective*. Chicago: University of Chicago Press.
- 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* 85(4), 571-581.
- Stodolsky, S. (1988). *The subject matters: Classroom activity in math and social studies*. Chicago: University of Chicago Press.
- Thorndike, E. L. (1904). *An introduction to the theory of mental and social measurements*. New York: Teachers College, Columbia University.

CHAPTER 2: MEASURING ENGAGEMENT

Ancient Greek writer Sophocles wrote that “One must learn by doing the thing, for though you think you know it—you have no certainty until you try.” This is indeed a guiding principle today for many teachers and their students. Buzzwords like, “hands-on learning” and “active learning” fill many professional development sessions aimed at improving student experiences in school through engaged learning. However, there is much ambiguity and little consensus of what “engagement” in the classroom actually is (Reschley & Christenson, 2012). Often it is something that a teacher can recognize when it happens (or when it does not), but there is a current need for clarity in the definition and study of engagement.

Research on engagement focuses on multiple areas, two of which include: (1) behaviorally disengaged students, such as those who may drop out of high school or are considered “at-risk” (see Easton, 2008; Finn, 1989; Newmann, 1992; Ream & Rumburger, 2008), and (2) the psychologically and emotionally engaged student, which includes self-determination theory, achievement goal theory, achievement motivation theory, attribution theory, self-efficacy theory, and expectancy-value theory (see Ames & Archer, 1988; Ames, 1992; Bandura, 1977; Eccles et al., 1983; Dweck, 1986; Schunk, Pintrich, & Meece, 2008). Both of these related approaches seek to understand academic success and failure, but with different definitions, measures, and outcomes of engagement. While the field of engagement research is robust, without clarity in how engagement is studied (e.g. defined and measured), the implications of the research can be difficult to apply due to the ambiguity of the desired outcome and specific conditions that can facilitate better learning experiences for students.

This chapter examines several measures of engagement, proposes a definition of engagement motivated by psychological theory, creates and tests constructs of engagement, and

analyzes how and when engagement occurs in secondary schools. What follows is a brief overview of the engagement literature and related aspects of motivation and perseverance, in addition to exploring some of the different methods of measuring engagement. Next, a theoretical framework for defining and measuring engagement is discussed, which motivates the research questions for this part of the study: (1) How can engagement be defined? (2) What is the relationship between different constructs of engagement? (3) How do measures of engagement hold across contexts? Based on the theoretical framework, several different measures of engagement are then tested to address these primary research questions. Following these analyses is a discussion of the findings and the implications for the next two chapters.

It is important to note that this chapter will not offer any new definitions of engagement, but rather validate existing measures and examine the relationships between them. This study, including the present chapter and the ones that follow, will also not offer ways to increase engagement or create higher motivation, as these types of outcomes are not measurable, and are indeed one of the challenges to this type of research. Instead, this study contributes to understanding the environments, student background characteristics, and instructional approaches that may lead to increased moments of engagement, which are considered *optimal experiences* (Csikszentmihalyi, 1975). Because the experiences in question are specific to educational settings they will be referred to as optimal *learning* moments (see Schneider et al., under review; Shernoff & Csikszentmihalyi, 2009).

The Experience of Engagement

In the simplest approach, situational engagement is often depicted in a linear relationship— within a context there is a motivation that leads to engagement and a subsequent outcome (see Connell & Wellborn, 1991; Finn & Zimmer, 2012; Lawson & Lawson, 2013).

However, this linear relationship is dynamic and subject to additional influences including affective/emotional states, behaviors/activities/tasks (Fredericks et al., 2004), and surrounding cultures and varying contexts. In a review of the recently published *Handbook of Research on Student Engagement* (Christenson, Reschley, & Wiley, 2012) and the extant literature on engagement, Lawson and Lawson (2013) suggest three primary assumptions about engagement: (1) it is malleable; (2) it has a direct relationship with learning; and (3) it is distinct from motivation. Thus, research on engagement should recognize and be able to measure the phenomenon given these assumptions. Eccles and Wang (2012) also suggest that student engagement research needs to define constructs, achieve internal and external validity, and interpret findings, in addition to studying learning experiences across multiple contexts and over time, which is how this study is designed and organized. Engagement is relational and dynamic, which suggests that research should be conducted in a way to allow this dynamic type of data to be collected.

Research should also be able to measure and delineate across different settings in which engagement occurs, operating under the assumption that engagement can happen both in and out of school, as well as in academic and non-academic settings. Studies that focus solely on the engagement of students while they are within the confines of their school are limited if they aren't able to compare the in-school engagement to that which occurs outside of school. Indeed, it could very well be the case that students are equally engaged in both settings, as this study will show. Therefore, research needs to distinguish between different settings, as well as recognize the diverse levels of context where engagement occurs (e.g. classroom-level or school-level) (Skinner & Pitzer, 2012). The research should also recognize the different time-frames of student

engagement, such as in-the-moment task engagement versus more long-term engagement or the individual's commitment to a particular subject area (Finn & Zimmer, 2012).

Self-Efficacy and Motivation

Engagement and motivation are closely related concepts and are often used interchangeably when discussing ways to improve learning or increase the interest and pursuit of STEM education and careers. Skinner and Pitzer (2012) demonstrate that “‘engagement’ is the outward manifestation of motivation.” Motivation is also closely related to the feelings of efficacy a student experiences while learning. Bandura (1977) explains self-efficacy as the expectation of successfully executing the behavior required for an outcome. Thus, increasing self-efficacy of students could influence their behavior and actions. If the desired behavior is persistence in a challenging activity, the perceived self-efficacy in the form of confidence or doubt can influence one’s behavior. Students should have perceptions of their high ability to engage in a challenging task, or they run the risk of engaging in low challenge tasks to conceal or protect themselves from a negative evaluation (Dweck, 1986).

While the self-efficacy framework provides a way of investigating underlying mechanisms that influence performance and choice, expectancy-value theory provides a different construct for understanding an individual’s expectation of success (Wigfield & Eccles, 2000). Expectancy-value theory of achievement motivation argues that the choice, persistence, and performance of individuals can be explained by their valuation of the activity and their perception of how well they can perform on it (Eccles et al., 1983). One assumption of this model is that expectancies and values directly influence achievement choices, performance, effort, and persistence—these expectations and values can be both for the short- or long-term. This theory is used to study domain-specific motivation, such as mathematics for example.

Motivation itself, however, is often not enough to improve learning. Feeling good about school or in certain subject areas can only propel a student so far in their acquisition of new knowledge and skills. Students who are actively engaged in learning should not only feel enjoyment and satisfaction, but their engagement should lead to continued learning and the improvement of their actual competencies (Skinner & Belmont, 1993).

Persistence and Commitment

Accompanying feelings of enjoyment and satisfaction during an activity are the additional components of heightened concentration (Shernoff et al., 2003), active commitment (Fredricks et al., 2004), persistence, and a reaction to challenge (Fredricks & McColskey, 2012). Skinner and Belmont (1993) showed that persistence, effort, and attention were related to engagement during learning activities. While engaged in learning, persistence in the task is linked to receiving praise and redirection (Martens, Bradley, & Eckert, 1997), indicating that the context of the learning moment, such as the actions of the teacher, can influence the type of social and emotional experiences the student has when engaged. To persist or continue despite a challenge requires both cognitive engagement in an activity as well as affective engagement, such as feelings that the task is of value and worth pursuing (Finn & Zimmer, 2012).

Measures of Engagement

Several different survey instruments and observational protocols are often used to measure student engagement (Fredricks et al., 2004). These approaches include teacher reports of student engagement, students self-reporting of their engagement, and third party observations of events and activities occurring in classrooms. Measures of engagement commonly asked of teachers and students include the completion of work, levels of effort and persistence, and class participation. For example, a teacher item might include, “Student participates actively in class

discussion” (Finn et al., 1995). Newmann (1992) provides an observational tool for observers to rate engagement on a five-point scale from “off-task” to “deeply involved.” Student self-reported measures often include items such as, “Math will be useful to my future” (Finn et al., 1995), and “When I’m in class, I usually think about other things” (Skinner & Belmont, 1993).

The use of surveys to assess student engagement allows for the measurement of multiple factors shown to influence engagement to be evaluated, such as teacher expectations, time on-task behavior, and general interests and attitudes about learning. Many of the surveys in use also include items related to classroom and school context. Observational protocols either used in conjunction with surveys or on their own also contribute a valuable perspective of learning and engagement, both in terms of teacher actions and student behaviors. However, there are limitations to both of these methods. Data collected on surveys often rely on retrospective responses of engagement, that is, students and teachers have to think back to the moment, class, subject, etc. to assess their relative levels of engagement, which allows for error, distortions, or rationalizations in the data (Csikszentmihalyi & Larson, 1987). Observations of engagement may reduce the error in retrospective reporting by recording data in real-time, but are subject to different measurement errors in the form of rater reliability and is limited to only collecting data that can be observed. For example, a student’s level of challenge or ability to persist on a difficult task might not be visible to the observer.

Experience Sampling Method

One approach to measuring engagement that allows for the multiple dimensions of engagement to be evaluated while collecting data in real time is the Experience Sampling Method (ESM). Developed by Csikszentmihalyi and colleagues (1977), ESM provides a way of capturing the moments of an individual’s daily life—immediate activities and emotions at

random intervals (Hektner, Schmidt, & Csikszentmihalyi, 2007). Recognizing the multifaceted nature of student engagement and how it varies across contexts, ESM allows students to report their cognitive and emotional experiences. ESM supports the examination of not just moments of optimal learning, but the context in which it occurs. Using ESM with additional points of data from student and teacher surveys as well as instructional information can enhance the ability of the research to contextualize the engagement.

Several studies have used ESM to examine learning using a programmed wristwatch or pager that activates at random intervals throughout the day over a period of one to two weeks. The number of “beeps” and duration of the study are determined by the research questions and design, with an average of eight beeps a day. When an individual is beeped, they are to complete a questionnaire that includes open-ended and scaled items. An example of an open-response item is: “As you were beeped, what were you doing?” A scaled item might ask, “Did you enjoy what you were doing?” (Csikszentmihalyi & Schneider, 2000). By collecting these data at multiple moments throughout the day, error due to recall, distortion, and rationalization can be reduced (Shernoff & Csikszentmihalyi, 2008).

While ESM is not the only method to examine how teachers and students engage in teaching and learning, it is the only approach that allows for within-person analyses. For example, if a student reports high levels of engagement in a particular class on a “traditional” survey, the researcher is unable to situate this engagement level to the rest of the individual’s day. With the traditional survey, the researcher is unable to ascribe the high level of engagement reported by the student to the class, or determine if the student is highly engaged all day, and thus their reported engagement level would not be a reflection of the specific class or teacher. Using ESM supports the analysis of within-person experiences, and through using standardized

scores of constructs from the within-person analysis allows for the comparison of engagement across different contexts, both in- and out-of-school.

While several of these measures attempt to tap different aspects of engagement that contribute to learning, each approach has its limitations. Survey measures of engagement may capture a perceived overall engagement experience, rather than while it is happening. These measures may also be distorted by recall and influenced by prior dispositions. For example, if a student has lower self-efficacy in math, they may perceive their engagement in math classes as lower. With in-the-moment ESM measures, this type of data collection can be burdensome for the participant, and there may be selection bias in that students with a higher perceived self-efficacy may be prone to be “more engaged” in the study with higher rates of response and participation, and less-engaged students might not be as represented in the sample. However, examining multiple engagement measures, both stable and in-the-moment, not only addresses the limitations of using any singular approach, but also allows for the ability to understand the relationship between different measures of engagement, thus providing a more comprehensive perspective.

Theoretical Framework

To measure experiences in the moment, ESM is used and flow theory is applied to operationalize engagement, building on several previous studies examining what optimal learning is in a classroom (Shernoff & Csikszentmihalyi, 2009; Shernoff et al., 2003; Csikszentmihalyi & Schneider, 2000). “Flow” is defined as a state of deep absorption in an activity that is intrinsically enjoyable (Csikszentmihalyi, 1990). In flow, the challenge of an activity is well matched to an individual’s skill, and successful actions seem effortless despite a high demand for physical or mental energy (Shernoff & Csikszentmihalyi, 2009). Misaligned

levels of challenge and skill can produce different psychological states, such as low challenge and low skill can result in apathy, or high challenge and low skill resulting in anxiety.

There are several studies that have used ESM and flow to assess optimal experiences across diverse contexts and with varied age, SES, and cultural study samples (see Shernoff et al., 2003; Shernoff & Csikszentmihalyi, 2009; Shumow & Schmidt, 2014). Being in flow can occur in school and other academic settings, but also during leisure. The ESM approach is also designed to capture the activity as well as the affective states, which allows for the examination of the multiple dimensions of engagement (i.e. behavior, cognitive, and emotional), and the assessment of how optimal learning is related to additional measures of learning, such as enjoyment, absorption, and persistence. The multi-level structure of ESM, which nests situations within individuals, also strengthens the analyses of the variation within- and between-students, allowing analyses to condition on factors previously associated with variation in engagement, such as gender, race, and other stable person-level measures.

Research Questions

This study uses multiple measures of engagement to construct and validate measures of engagement. Specifically:

1. How is engagement defined? How do challenge, skill, and interest measures inform measures of engagement?
2. What is the relationship between different constructs of engagement, and how can these be validated by related measures?
3. How do measures of engagement hold across contexts, specifically, is there a difference in engagement in and out of science classrooms, and in and out of school?

Examining the construction of engagement measures and the relationships between measures of

engagement not only contributes to how engagement is defined and conceptualized, but is also an essential first step in the subsequent studies of this dissertation. These analyses will provide evidence of the validity of the proposed engagement measure, which will be used in subsequent analyses of this dissertation

Methodology

Unlike previous ESM studies which employ wristwatches or pagers, this study uses a smartphone equipped with an ESM application¹ that randomly signals students eight times a day over the course of a week, including the weekend. Each time a student is beeped, they complete a short series of questions on the phone about what they are doing and how they feel. It took students an average of 1.5 minutes to complete the form each time they were notified. Collecting these data at multiple moments throughout the day reduces error due to recall, distortion, and rationalization (Hektner, Schmidt, & Csikszentmihalyi, 2007). For this study, the science class was the primary sampling unit and each student in the targeted science was asked to participate, and the variation of student background characteristics are similar across the classes and schools.

Data for this portion of the study are collected from two primary instruments. An ESM instrument (see Appendix A) for students was developed based on similar protocols used in the Sloan Study of Youth and Social Development (Csikszentmihalyi & Schneider, 2000). Measures from the ESM instruments include open-ended items such as task behavior (e.g. “What were you doing when you were signaled?”) and affective states rated on a 4-point Likert scale (e.g. “How challenged did you feel by the activity you were doing?”). The signaling schedule was a hybrid of planned and random alerts to allow for at least one beep during science class, while the rest of the beeps outside of science remained random. A student questionnaire (see Appendix B) is also used to collect information about beliefs and experiences related to science, and was developed

¹ “Paco” developed by Robert Evans, see pacoapp.com for more information.

using items from the Programme for International Student Assessment (PISA) (OECD, 2003) and the schoolwork engagement inventory (Salmela-Aro & Upadaya, 2012). Additional demographic information on gender and race was collected from the school.

Sample

Four partner schools were identified and incorporated a range of school types, including one urban school, two rural schools, and one suburban school. Table 2.1 shows the demographic information and student samples from each school. The students were sampled from their science courses, primarily from biology, physics, or chemistry classes. The data collection took place in two phases (Spring 2013 and Fall 2013), with slight modifications made in the ESM instruments between phases one and two. Once the schools were identified, science teachers that were willing to participate were chosen based on their subject, schedule, and class size. All students in the “target class” were asked to participate, which was a total of 280 students. Two students declined to participate, leaving the final analytic sample of 278 students. Each phase lasted one week. While some ESM studies restrict the analytic sample to students with a certain percentage of responses (see Hektner, Schmidt, & Csikszentmihalyi, 2007), since these analyses primary focused on the situation-level responses, all observations are included in initial analyses.

Table 2.1
ESM School Sample Descriptives

	Number of study Teachers	Number of ESM Classes	Students with ESM	School Type	School Size	Percent Minority	Percent FRPL
School 1	3	4	69	Urban	1,730	66%	61%
School 2	2	3	85	Rural	466	5%	37%
School 3	4	4	71	Suburban	1,304	34%	33%
School 4	1	2	53	Rural	645	8%	17%

SOURCE: Study Dataset and Common Core of Data 2012-2013

About the same number of students participated in each phase of the data collection as shown in Table 2.2, however, because of the differences in participating teachers and classes between phases, there are fewer non-white students in phase two (32% in phase one compared to 19% in phase two), as well as a higher percentage of biology students (42% in phase one compared to 74% in phase two). The overall sample is approximately 56% biology students, 26% physics students, and 17% physics students. The gender is mostly balanced, with a slightly higher percentage of males in the sample, 54% compared to 46%, this is not significantly different between phases. The average response rate is 52%, meaning that on average a student responded to about 29 signals over the duration of the study. Figure 2.1 shows the variation in response rates. There were 57 students that responded to less than 20% of their total signals, in contrast to 51 students that responded to at least 81 percent of their signals. The total number of momentary data from these 278 students totaled 8,485 situational observations.

Figure 2.1 Frequency of Students by Response Rate

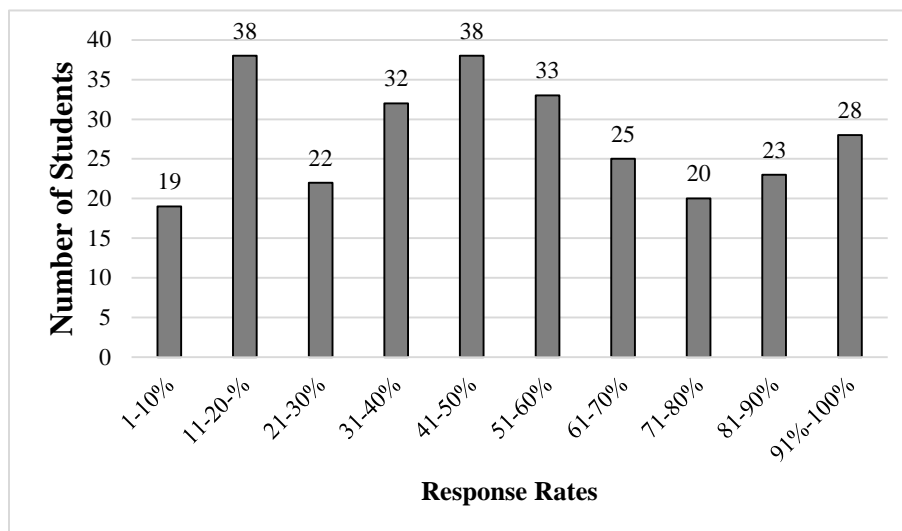


Table 2.2**Descriptive Characteristics of the Sample**

	Sample Average	Phase		School			
		<i>1</i>	<i>2</i>	<i>Urban 1</i>	<i>Rural 2</i>	<i>Suburban 3</i>	<i>Rural 4</i>
<i>n of students</i>	278	137	141	69	85	71	53
Average ESM response rate	52%	56%	48%	46%	63%	47%	48%
Percent female	46%	45%	48%	39%	49%	45%	53%
Percent nonwhite	25%	32%	19%	64%	10%	20%	8%
Science Course							
<i>Biology</i>	56%	42%	74%	80%	37%	45%	100%
<i>Chemistry</i>	17%	25%	8%	--	28%	16%	--
<i>Physics</i>	26%	33%	18%	20%	35%	39%	--

SOURCE: Study Dataset

Measures

One of the strengths of collecting repeated measures through ESM is that within-person metrics can be determined (Hektner, Schmidt, & Csikszentmihalyi, 2007). For example, a reported score of “3” for interest might have different meanings across individuals, so standardizing these scores across individuals with a mean of zero and a standard deviation of one, allows the raw score to be transformed into a Z-score that reflects each moment’s value relative to the average reported scores over the week. One limitation of transforming the ESM variables in this way is that it creates the same mean and distribution within all students, which may influence how the variance is attributed between levels in a multi-level model.

In this study, both standardized and raw engagement scores are examined in their ability to measure engagement. By applying flow theory to determine if a student is engaged in the moment, their level of challenge and skill in the moment is examined as well as a third dimension of situational interest. The situational engagement construct is created in two ways: (1) simultaneously reporting a “3” or “4” on a 4-point-Likert scale for their feeling of challenge, interest, and skill in a given activity, referred to as “raw scores,” and (2) creating a standardized measure when their reported challenge, interest, and skill during a given moment are above their mean (zero), these are referred to as the “standardized score.” Each construct is compared with two validation items often associated with being in flow: the feeling that time is flying by, and persistence. The engagement measures are also correlated with other affective states, such as enjoyment and boredom, to evaluate how the state of engagement is associated with other social and emotional variables.

The ESM measures are situated in context to allow exploration of additional influences such as teaching or classroom characteristics on learning. Using both cross-situational and in the

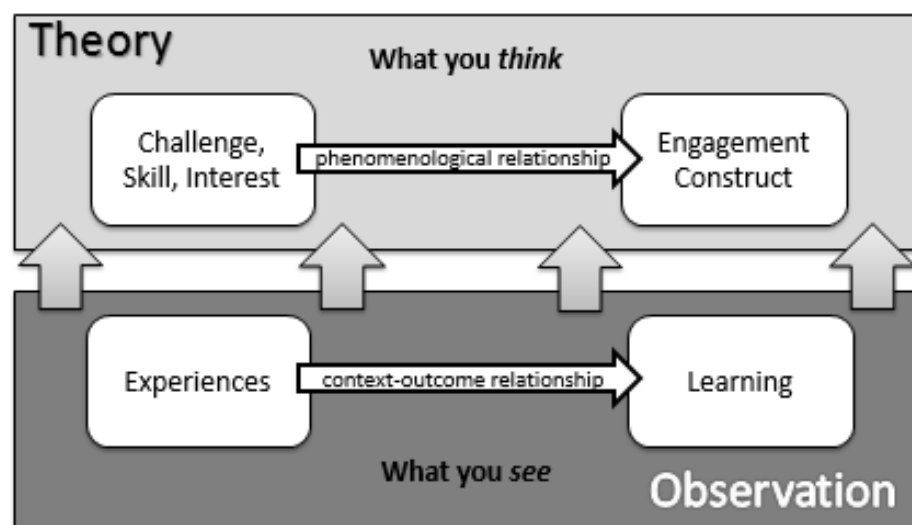
moment measures of engagement may also reduce measure bias. For example, self-concept and anxiety tend to have substantial gender differences when assessed cross-situationally, but much less so when assessed in the moment (Goetz et al., 2013). The engagement measures from PISA use a diverse set of items that are domain-specific to science including: a sense of belonging and participation; a disposition towards learning, including hedonic experiences, interest, value of school success, class attendance, identification, being socially integrated, and the acceptance of school rules (OECD, 2003). Five science-specific scales are created from these items and measure science enjoyment, interest, value, motivation, and self-concept. For this present study, these items were tailored to measure the specific science course each participating student was enrolled in, such as biology, chemistry, or physics. These five constructs were created from the same scales used in PISA. Two additional cross-situational constructs developed by Salmela-Aro and colleagues were used to measure overall engagement and burnout in schoolwork (Salmela-Aro & Upadaya, 2012).

Analytic Approach

To analyze the validity of engagement measures, tests that measure the different dimensions of construct validity are conducted. These analyses answer the general question of whether the proposed engagement measures actually capture engagement, including how the operationalization of engagement using student's report of their challenge, skill, and interest is a reflection of the occurrence. As shown in Figure 2.1 (adapted from Trochim, 2006), the overall goal of establishing construct validity is the process of validating what is seen and observed, which in this study is the student experiences as captured by the ESM and survey instruments, with the proposed theory explaining the phenomenon. More specifically, in this study's setting

the daily experiences of the students can be observed and their self-reported behaviors and affective states are recorded. It is hypothesized that these different experiences, influenced by the

Figure 2.2 Relationship between Engagement Construct and Learning



Note. Adapted figure from Trochim (2006)

individual, their context, and activity is related to an outcome, such as learning or not learning. These analyses will test the relationships between the observed experiences and the theory of flow creating moments of optimal experiences as measured by the ESM.

To examine the validity of the engagement measures, each construct is first compared with three validation items often associated with being in flow: the feeling that time is flying by (absorption), concentration, and persistence (not giving up). Because these items were only asked in the second phase of data collection, a sub-sample of students are included.² The engagement measures are also correlated with other affective states, such as enjoyment, persistence, and boredom to evaluate how the state of engagement is associated with other social and emotional variables. The ESM measures are also compared at the person-level with students' PISA and schoolwork engagement items. It is hypothesized that students who show higher levels

² There are no significant differences between the students in phases 1 and 2.

of overall school engagement would experience higher frequencies of optimal learning moments in school. To address the third research question, the measures of engagement are tested across contexts, how does engagement occur in science specifically, and does this look different than engagement outside of science?

Results

The summary statistics presented in Table 2.3 highlight the differences between calculating the average across all momentary observations (un-nested) and the average of the person-level (nested) averages. This nested average is calculated using each student's mean for every ESM variable, both overall and in science class. Examining the standard deviations between raw scores compared to the nested scores, the variation is lower for the nested values as some of the variation is explained by the differences between students. Overall, there are not practical differences in the means between the raw and nested scores when averaged across all

Table 2.3
Summary Statistics for ESM Variables

	Overall		In Science	
	<i>Raw</i>	<i>Nested</i>	<i>Raw</i>	<i>Nested</i>
	<i>Scores</i> <i>n=8,485</i>	<i>Raw Scores</i> <i>n=278</i>	<i>Scores</i> <i>n=1,813</i>	<i>Raw Scores</i> <i>n=278</i>
Anxious	1.89 (1.04)	1.91 (.67)	1.88 (.99)	1.93 (.69)
Active	2.17 (1.12)	2.20 (.75)	2.14 (1.08)	2.20 (.79)
Bored	2.31 (1.17)	2.37 (.64)	2.40 (1.13)	2.50 (.70)
Challenge	1.85 (1.03)	1.92 (.51)	2.08 (1.05)	2.00 (.55)
Competitive	1.88 (1.04)	1.88 (.68)	1.77 (.96)	1.88 (.69)
Concentrate*	2.64 (.99)	2.62 (.47)	2.76 (.91)	2.69 (.46)
Confident	2.59 (1.05)	2.56 (.73)	2.45 (1.02)	2.56 (.74)
Confused	1.62 (.90)	1.68 (.54)	1.79 (.95)	1.77 (.57)
Cooperative	2.46 (1.07)	2.44 (.69)	2.46 (1.04)	2.49 (.71)
Enjoy	2.72 (1.11)	2.66 (.56)	2.49 (1.05)	2.53 (.71)
Give up*	1.52 (.86)	1.54 (.45)	1.57 (.88)	1.59 (.52)
Happy	2.85 (1.06)	2.81 (.65)	2.58 (1.06)	2.74 (.71)
Important future	2.26 (1.15)	2.25 (.62)	2.29 (1.09)	2.32 (.68)
Important you	2.62 (1.11)	2.57 (.58)	2.54 (1.03)	2.87 (.68)
In control	3.02 (1.05)	2.97 (.62)	2.78 (1.06)	2.87 (.68)
Interest	2.71 (1.12)	2.67 (.58)	2.63 (1.06)	2.58 (.62)
Lonely	1.58 (.92)	1.61 (.64)	1.52 (.85)	1.59 (.67)
Other's expectations	2.91 (1.01)	2.85 (.69)	2.88 (.96)	2.86 (.69)
Proud	2.31 (1.09)	2.26 (.74)	2.11 (1.02)	2.26 (.75)
Self expectations	3.04 (.99)	2.98 (.67)	2.98 (.96)	2.98 (.68)
Success	3.22 (.92)	3.16 (.53)	3.05 (.92)	3.13 (.53)
Skill	3.15 (.99)	3.06 (.58)	2.87 (.99)	2.99 (.60)
Stress	1.88 (1.04)	1.92 (.71)	2.00 (1.06)	1.98 (.74)
Time fly*	2.57 (1.11)	2.56 (.55)	2.36 (1.05)	2.44 (.58)

Notes. Means with standard deviations reported in parentheses. *Items only included in second phase of data collection (n of 3,844 observations and n of 141 students)

observations. The highest reported affective state overall and in science is feeling successful, with a mean above three. Feeling in control, skillful, and meeting self-expectations also have means above three overall using the raw scores. In science, for raw scores and nested, there are no means greater than three. Lower averages are reported for feeling lonely both overall ($\mu=1.58$

for raw and $\mu=1.61$ for standardized) and in science ($\mu=1.52$ for raw and $\mu=1.59$ for standardized). Over all daily experiences, feeling active varies the most ($\sigma=1.11$ for the raw scores and $\sigma=.67$ for the nested scores). The variation in the activeness of students also has the highest variation in science using the standardized scores ($\sigma=.79$), however, feeling bored has the highest variation using the raw scores ($\sigma=1.13$). These slight differences in means and variation capture how sensitive these measures can be to each experience and situation and underscore the importance of measuring these social and emotional aspects of learning in science.

Table 2.4 shows the summary statistics for the cross-situational measures of science and school engagement. There are some differences between hard sciences and life science, as well as gender, with females in life science reporting significantly higher levels of burnout compared to males in life sciences and females in the hard sciences. Both males and females enrolled in the hard sciences have higher science value and self-concept compared to those in the life sciences. This may be due to selection effects of students in physics classes in the sample, a class which is often taken in eleventh or twelfth grade and may also attract higher ability students.

Table 2.4
Summary Statistics of Cross-Situational Engagement Measures

<i>PISA Scales</i>	<i>Life Science^a</i>		<i>Hard Sciences</i>	
	F	M	F	M
Science Enjoyment ^b	71%	63%	77%	83%
Science Value	83%	77%	84%	89%
Science Motivation	65%	59%	66%	68%
Science Self-Concept	60%	66%	80%	83%
Future Aspirations in Science	33%	27%	41%	40%
School Burnout ^c	58%	38%	45%	48%
School Engagement	40%	30%	29%	42%

Notes. ^aLife science includes biology students, hard science includes physics and chemistry ^bPISA-scaled items. ^cSchoolwork Inventory. Bolded values statistically different using a t-test at $p < .05$.

Examining optimal experiences more closely, Table 2.5 shows the standardized measures (using z-scores) compared to optimal moments calculated using the raw scores. Overall for both measures, students are in optimal moments about 14% of the time. In science, these optimal moments are lower for both measures, occurring about 12% of the time using the raw scores compared to 10% of the time using standardized scores. Both optimal experience measures are consistent with previous studies showing that flow moments are the exception, not the norm, and occur relatively infrequently (Csikszentmihalyi, 1998).

Given that both standardized and raw scores of optimal moments occur about the same frequency, Table 2.6 shows how the measures are correlated with other affective states. Overall, both measures function similarly. They are both moderately correlated with enjoyment, and importance to self, while negatively correlated with boredom. The raw measures are also correlated with feelings of competition, concentration, importance to future, and being active. Both engagement measure correlations are slightly different in science, with being confused negatively correlated with both constructs. For the standardized flow measure, happiness is positively correlated in science while stress is negatively correlated. While there are slight differences, these correlations are consistent with optimal moments, thus additional tests are needed to determine how these constructs may function differently.

More narrowly examining the relationship between optimal experiences, concentration, persistence, and time flying specifically, Table 2.7 shows how the raw and standardized measures are related to these feelings associated with being in flow. If a student was in an optimal experience, the percentage of responses in each of the four Likert scale options was calculated. The standardized measure shows more responses at the higher end of time flying by

Table 2.5**Percentage of Time Students are in Flow**

	Overall		In School (no science)		In Science	
	<i>Raw</i>	<i>Standardized</i>	<i>Raw</i>	<i>Standardized</i>	<i>Raw</i>	<i>Standardized</i>
<i>N of moments</i>	1099	1,077	459	439	209	178
<i>% of moments</i>	14%	14%	14%	14%	12%	10%

Notes. Flow is a dummy variable where 1= flow, calculated two ways. "Raw Scores" use the values reported from the 4-point likert scale. When students report a 3 or 4 for challenge, skill, and interest, this is coded as a 1, all other combinations are a 0. For the standardized values, a z-score is created for each student and when these moments are the mean zero, this is coded as a 1. All moments are included in these figures, low responders included.

Table 2.6
Correlations with Optimal Moments (challenge, interest & skill)

	Overall (n=8,485)		Science (1,813)	
	Raw	Standard	Raw	Standard
Anxious	0.1658	0.0943	0.1179	0.0793
Active	0.2155	0.1643	0.1816	0.1395
Bored	-0.0893	-0.0992	-0.1204	-0.1435
Competitive	0.2587	0.1824	0.2372	0.184
Concentrate*	0.2605	0.2128	0.2335	0.1348
Confident	0.1573	0.1715	0.1540	0.1655
Confused	0.1079	0.0271	-0.0016	-0.0322
Cooperative	0.1370	0.1355	0.0973	0.0647
Enjoy	0.2312	0.2510	0.2322	0.2603
Happy	0.1583	0.1764	0.1741	0.2187
Give Up*	0.0869	-0.0254	0.024	-0.0087
Important Future	0.2674	0.1949	0.2573	0.1453
Important Self	0.2527	0.2262	0.2816	0.2332
In Control	0.1359	0.1715	0.1496	0.1820
Lonely	0.0612	0.0281	0.0114	0.0165
Other Expect	0.1526	0.1661	0.1431	0.1087
Self Expect	0.1442	0.1636	0.1560	0.1712
Proud	0.1952	0.1802	0.1863	0.1501
Success	0.1011	0.1633	0.1133	0.1808
Stress	0.1032	0.0452	0.0416	-0.0260
Time Fly*	0.199	0.2053	0.2035	0.2097

Notes. The raw flow measures is correlated with raw scores of the other affective states. The standardized flow variable is correlated with the other standardized values

(46% vs. 39%), concentration (49% vs. 40%), and at the lower end of wanting to give up (70% vs. 58%). This suggests that standardized measures may more precisely tap into person-specific engagement than using raw scores.

Table 2.7**Flow Measures Compared to Validation Items**

	Time flies by				Wants to give up				Concentrate			
	1	2	3	4	1	2	3	4	1	2	3	4
Raw (<i>n</i> =539)	5%	18%	38%	39%	58%	21%	15%	6%	2%	9%	49%	40%
Standardized (<i>n</i> =473)	6%	19%	29%	46%	70%	17%	6%	6%	4%	13%	44%	49%

Notes. These are percentages of each category that a student reports feeling in the moment when the flow measure is equal to 1.

Lastly, Table 2.8 shows how the cross-situational measures are associated with in-the-moment optimal learning. As one might expect, students that enjoy science, who are highly motivated in learning science, and who have a higher self-concept in science all experience more frequent optimal learning moments in science more frequently than those in the lower groups. Examining the school engagement and burnout measures, students that have higher schoolwork engagement, have more engaging experiences in science, and those students who show higher burnout, experience engagement less often than those students who have low levels of burnout. These findings show that there are consistent relationships between different measures of engagement, and that using multiple measures can help assess the components of optimal learning experiences, both in and out of science classes.

Table 2.8
Percentage of Students Engaged in Science

	<i>In Science</i>	<i>Other Academic</i>
High Enjoyment	13%	14%
Low Enjoyment	7%	15%
High Motivation	15%	16%
Low Motivation	6%	13%
High Self-Concept	13%	16%
Low Self-Concept	9%	12%
High Aspirations in Science	19%	18%
Low Aspirations in Science	8%	13%
High School Engagement	15%	20%
Low School Engagement	10%	12%
High School Burnout	9%	14%
Low School Burnout	14%	14%

Notes. The italicized percentages are statistically significant ($p < .05$). The N of students is 278, with a total of 8,474 momentary observations. "Percent Engaged" is calculated over the school day, in science compared to out of science.

Discussion

These findings show that there are indeed relationships between different measures of engagement, and that using multiple measures of engagement can help assess the components of creating optimal learning experiences. Using both cross-situational and in the moment measures of engagement provide data that is domain-specific, can tap situation-specific variation, and can be analyzed with corresponding measurement models (e.g. formative vs. reflective). Although there were some similarities and differences in how the raw scores and standardized engagement measures functioned, both appear to be valid constructs of engagement. Since both of these measures capture optimal experiences, the choice of whether to use raw or standardized scores is a product of the research questions, structure, and context of the model and type of analysis being conducted. While this chapter analyzed the conceptualization and definitions of engagement, it is just a first step in helping to operationalize optimal learning experiences to help improve teaching and learning in science. The subsequent chapters analyze how student background contributes to student engagement as well as how different instructional approaches contribute to student engagement.

Limitations

Despite the many advantages associated with using ESM to measure optimal learning moments there are also drawbacks to this approach. Data collection at multiple points of the day over multiple days can present challenges for the respondent, which can lead to selection bias and attrition in the study sample (Scollon, Kim-Prieto, and Diener, 2003). As seen in this dataset, the average response rate of students is about four responses per day, which is only about half of the total possible responses. While a 50% response rate is often problematic in research because of the bias it can introduce into the analyses, it can be argued that this is still an abundance of

data that can provide rich information about the student experiences, and provides more data than a single-time survey.

The application of these methods for studying student engagement could also be disruptive for learning. On the other hand, it may also provide an opportunity for an individual to re-engage with their task if they perhaps were not on-task. Although ESM collects real-time data, the data are still self-reported and subject to the same limitations of any self-reported data. Despite the time and intensity of collecting ESM data, several participants have noted that it can be a positive experience (DiBianca, 2000) and there could be several positive psychological effects of monitor one's engagement throughout the day, allowing for multiple opportunities for reflection in the moment of experiences.

Implications

With the rapidly growing access to, and use of technology in research and in the classroom, there are greater opportunities for innovation in studying student engagement with new technology. Advances in smartphone and mobile application (app) technology provide new ways to use ESM in the classroom. Using smartphones with ESM apps specially designed to measure optimal experiences reduces some of the burdens related to data collection for both the subjects and researchers compared to previous paper-and-pencil methods.

The use of smartphones in education is also growing in the adolescent population, even those students from low-income households, with approximately one in three students using their phones for help on homework (Khadaroo, 2012). Growth can also be seen in smartphone companies that spend an estimated 20 billion dollars a year on research and development. Contrast that to the annual spending of the National Science Foundation, around 250 million dollars, and it is evident that for this study population and given the direction of advances in

technology, having the ability to use smartphones to study engagement is not only cutting-edge, but is quickly becoming a necessity. Future research could also incorporate additional biological data from the smartphones as well, such as heart-rate or activity levels of the students.

APPENDICES

Appendix A: Student ESM Questionnaire

1. Where were you/in which class?
2. Who were you with?
3. What were you doing?
4. Why? [You wanted to, You had to, You had nothing else to do]
5. Is what you were doing... [more like school work, more like play, both, neither]
6. What were you thinking?

II. How do you feel about what you are doing? (4-point scale):

7. Were you interested in what you were doing? [Not at all/Very much]
8. Did you feel skilled at what you were doing? [Not at all/Very much]
9. Did you feel challenged by what you were doing? [Not at all/Very much]
10. Did you feel like giving up? [Not at all/Very much]
11. How much were you concentrating? [Not at all/Very much]
12. Did you enjoy what you were doing? [Not at all/Very much]
13. Did you feel like you were in control of what you were doing? [Not at all/Very much]
14. Were you succeeding? [Not at all/Very much]

III. How did you feel about the main activity? (4-point scale: Not at all/Very much)

15. Was this important for you?
16. How important was this activity in relation to your future goals/plans?
17. Were you living up to the expectations of others?
18. Were you living up to your expectations?
19. I was so absorbed in what I was doing that the time flew.

IV. How were you feeling? (4-point scale: Not at all/Very much)

20. Were you feeling...Happy
21. Were you feeling...Excited
22. Were re you feeling...Anxious
23. Were you feeling...Competitive
24. Were you feeling...Lonely
25. Were you feeling...Stressed
26. Were you feeling...Proud
27. Were you feeling...Cooperative
28. Were you feeling...Bored
29. Were you feeling...Self-confident
30. Were you feeling...Confused
31. Were you feeling...Active

Appendix B: Student Background Survey

How much do you agree with the statements below:

1 – Strongly disagree, 2 – Disagree, 3 – Agree, 4 – Strongly agree

a. I generally have fun when I am learning Biology	1	2	3	4
b. I like reading about Biology	1	2	3	4
c. I am happy doing Biology	1	2	3	4
d. I enjoy acquiring new knowledge in Biology	1	2	3	4
e. I am interested in learning about Biology	1	2	3	4

How much do you agree with the statements below:

1 – Strongly disagree, 2 – Disagree, 3 – Agree, 4 – Strongly agree

a. Advances in Biology usually improve people's living conditions	1	2	3	4
b. Biology is important for helping us to understand the natural world	1	2	3	4
c. Concepts in Biology help me see how I relate to other people	1	2	3	4
d. Advances in Biology usually help improve the economy	1	2	3	4
e. I will use Biology in many ways when I am an adult	1	2	3	4
f. Biology is valuable to society	1	2	3	4
g. Biology is important to me personally	1	2	3	4
h. Biology helps me to understand the things around me	1	2	3	4
i. Advances in Biology usually bring social benefits	1	2	3	4
j. When I leave school there will be many opportunities for me to use Biology	1	2	3	4

How much do you agree with the statements below:

1 – Strongly disagree, 2 – Disagree, 3 – Agree, 4 – Strongly Agree

a. Making an effort in my Biology class is worth it because this will help me in the work I want to do later on	1	2	3	4
b. What I learn in my Biology class is important for me because I need this for what I want to study later on	1	2	3	4
c. I study Biology because I know it is useful for me	1	2	3	4
d. Studying for my Biology class is worthwhile for me because what I learn will improve my career prospects	1	2	3	4
e. I will learn many things in my Biology class that will help me get a job	1	2	3	4

How much do you agree with the statements below:

1 – Strongly disagree, 2 – Disagree, 3 – Agree, 4 – Strongly Agree

a. Learning advanced Biology topics would be easy for me	1	2	3	4
b. I can usually give good answers to test questions on Biology topics	1	2	3	4
c. I learn Biology topics quickly	1	2	3	4
d. Biology topics are easy for me	1	2	3	4
e. When I am being taught Biology, I can understand the concepts very well	1	2	3	4
f. I can easily understand new ideas in Biology	1	2	3	4

How much do you agree with the statements below:

1 – Strongly Disagree, 2 – Disagree, 3 – Agree, 4 – Strongly Agree

a. I would like to work in a career involving Biology	1	2	3	4
b. I would like to study Biology after High School	1	2	3	4
c. I would like to spend my life doing advanced Biology	1	2	3	4
d. I would like to work on Biology projects as an adult	1	2	3	4

Please choose the alternative that best describes your situation:

1 – Strongly Disagree, 2 – Disagree, 3 – Somewhat Disagree, 4 – Somewhat Agree, 5 – Agree, 6 – Strongly Agree

a. I feel overwhelmed by my schoolwork	1	2	3	4	5	6
b. I feel a lack of motivation in my schoolwork and often think of giving up	1	2	3	4	5	6
c. I often have feelings of inadequacy in my schoolwork	1	2	3	4	5	6
d. I often sleep badly because of matters related to my schoolwork	1	2	3	4	5	6
e. I feel that I am losing interest in my schoolwork	1	2	3	4	5	6
f. I'm continually wondering whether my schoolwork has any meaning	1	2	3	4	5	6
g. I worry over matters related to my schoolwork a lot during my free time	1	2	3	4	5	6
h. I used to have higher expectations of my schoolwork than I do now	1	2	3	4	5	6
i. The pressure of my schoolwork causes me problems in my close relationships with others	1	2	3	4	5	6

Please choose the alternative that best describes your situation (estimation from the previous month):

0- Never, 1 – A couple of times a year, 2 – Once a month, 3 – A couple of times a month

4 – Once a week, 5 – A couple of times a week, 6 –Daily

a. At school I am bursting with energy	0	1	2	3	4	5	6
b. I find the schoolwork full of meaning and purpose	0	1	2	3	4	5	6
c. Time flies when I am studying	0	1	2	3	4	5	6
d. I feel strong and vigorous when I am studying	0	1	2	3	4	5	6
e. I am enthusiastic about my studies	0	1	2	3	4	5	6
f. When I am working at school, I forget everything else around me	0	1	2	3	4	5	6
g. My schoolwork inspires me	0	1	2	3	4	5	6
h. I feel like going to school when I get up in the morning	0	1	2	3	4	5	6
i. I feel happy when I am working intensively at school	0	1	2	3	4	5	6

REFERENCES

REFERENCES

- Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology*, 84(3), 261.
- Ames, C., & Archer, J. (1988). Achievement goals in the classroom: Students' learning strategies and motivation processes. *Journal of Educational Psychology*, 80(3), 260–267.
doi:10.1037/0022-0663.80.3.260
- Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, 84(2), 191-215.
- Csikszentmihalyi, M. (1998). *Finding flow*. New York: Basic Books.
- Csikszentmihalyi, M., & Larson, R. (1987). Validity and reliability of the experience-sampling method. *The Journal of Nervous and Mental Disease*, 175(9), 526-537.
- Csikszentmihalyi, M., Larson, R., & Bruce, S.C. (1977). The ecology of adolescent activity and experience. *Journal of Youth and Adolescence*, 6, 281-294.
- Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. New York: Harper Perennial.
- Csikszentmihalyi, M., & Schneider, B. (2000) *Becoming adult*. New York: Basic Books.
- DiBianca, R. (2000). *Teaching Adolescents: Relationships between features of instruction and student engagement in high school mathematics and science classrooms*. Chicago: University of Chicago Press.
- Dweck, C.S. (1986). Motivational processes affecting learning. *American Psychologist*, 41, 1040-1048.
- Eccles, J.S. & Wang, M. (2012). Part I commentary: So what is student engagement anyway? In S.L. Christenson, A.L. Reschly & C. Wylie (Eds.) *Handbook of Research on Student Engagement*, Springer Sciences, New York. 133-145.
- Finn, J.D. (1993). *School engagement and students at risk*. Washington, DC: National Center for Education Statistics.
- Fredricks, J. A., Blumenfeld, P.C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of evidence. *Review of Educational Research*, 74(1), 50-109.

- Goetz, T., Bieg, M., Lüdtke, O., Pekrun, R., & Hall, N. C., (2013). Do girls really experience more anxiety in mathematics? *Psychological Science*, 24, 2079-2087. doi: 10.1177/0956797613486989
- Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., & Brenwald, S. (2008). *Highlights from TIMSS 2007: Mathematics and science achievement of U.S. fourth-and eighth-grade students in an international context*. Washington, DC: National Center for Education Statistics. Retrieved from <http://nces.ed.gov/pubs2009/2009001.pdf>
- Hektner, J.M., Schmidt, J.A., & Csikszentmihalyi, M. (2007). *Experience sampling method: Measuring the quality of everyday life*. Thousand Oaks, CA: Sage Publications.
- Khadaroo, S. T. (2012). "Not just 4 texting: 1 in 3 middle-schoolers uses smart phones for homework." *The Christian Science Monitor*. Retrieved from: <http://www.csmonitor.com/USA/Education/2012/1129/Not-just-4-texting-1-in-3-middle-schoolers-uses-smart-phones-for-homework>
- Lawson, M. A., & Lawson, H. A. (2013). New conceptual frameworks for student engagement research, policy, and practice. *Review of Educational Research*, 83(3), 432-479. doi: 10.3102/0034654313480891
- National Academies. (2010a). *Rising above the gathering storm, revisited: Rapidly approaching category 5*. Washington, DC: The National Academies Press. Retrieved from <http://www.nap.edu/catalog/12999.html>
- National Center for School Engagement. (2006). *Quantifying school engagement: Research report*. Denver, CO: National Center for School Engagement.
- National Governors Association. (2012). Common Core State Standards Initiative. Retrieved from: <http://www.corestandards.org/>
- National Research Council. (2004). *Engaging schools: Fostering high school student's motivation to learn*. Committee on Increasing High School Students' Engagement and Motivation to Learn. Board on Children, Youth, and Families, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.
- National Science Board. (2010). *Preparing the next generation of STEM innovators: Identifying and developing our nation's human capital*. Arlington, VA: National Science Foundation. Retrieved from <http://www.nsf.gov/nsb/publications/2010/nsb1033.pdf>
- Newmann, F.M. (Ed.) (1992). *Student engagement and achievement in American secondary schools*. New York: Teachers College Press.
- Ream, R. K. & Rumberger, R. W. (2008). Student engagement, peer social capital, and school dropout among Mexican American and non-Latino white students. *Sociology of Education*, 81(2), 109-139.

- Salmela-Aro, K., & Upadaya (2012). The schoolwork engagement inventory: energy, dedication, and absorption (EDA). *European Journal of Psychological Assessment*, 28(1), 60–67.
- Schunk, D. H., Pintrich, P. R., & Meece, J. L. (2008). *Motivation in education: Theory, research, and applications*. New Jersey: Pearson/Merrill Prentice Hall.
- Scollon, C. N., Kim-Prieto, C., & Diener, E. (2003). Experience sampling: Promises and pitfalls, strengths and weaknesses. *Journal of Happiness Studies*, 4, 5-34.
- Shermoff, D. (2001). *The experience of student engagement in high school: A phenomenological perspective*. Chicago: University of Chicago Press.
- Shermoff, D. & Csikszentmihalyi, M. (2009). Flow in schools: Cultivating engaged learners and optimal learning environments. In R. Gilman, E. S. Huebner, & M. Furlong (Eds.), *Handbook of positive psychology in schools* (pp. 131-145). New York: Routledge.
- Shermoff, D., Csikszentmihalyi, M., Schneider, B., & Shermoff, E. (2003) Student engagement in high school classrooms from the perspective of flow theory. *School Psychology Quarterly*, 18(2), 158-176.
- Shumow, L. & Schmidt, J.A. (2014). *Enhancing Adolescents' Motivation for Science: Research-Based Strategies for Teaching Male and Female Students*. Thousand Oaks, CA: Corwin, A Sage Company.
- 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* 85(4), 571-581.
- Stodolsky, S. (1988). *The subject matters: Classroom activity in math and social studies*. Chicago: University of Chicago Press.
- Trochim, William M. (n.d.). *The Research Methods Knowledge Base*, 2nd Edition. Retrieved from <http://www.socialresearchmethods.net/kb/>
- Turner, J. C., & Meyer, D. K. (2000). Studying and understanding the instructional contexts of classrooms: Using our past to forge our future. *Educational Psychologist*, 35(2), 69-85.
- Turner, J. C., & Meyer, D. K. (2004). A classroom perspective on the principle of moderate challenge in mathematics. *Journal of Educational Research*, 97, 311-318.

CHAPTER 3: CONTEXTUALIZING VARIATION OF ENGAGEMENT EXPERIENCES: THE ROLE OF OPTIMAL LEARNING MOMENTS IN SCIENCE

Students experience optimal learning moments about 14% of the time, however, this frequency drops to about 10% when students are in science. What are the students doing in science that contributes to lower occurrences of optimal learning moments? Despite the potential for creating optimal learning experiences motivated by relevant content, such as understanding global warming or stem-cell research, secondary science teachers are battling against declining attitudes and motivation in science (Wigfield & Eccles, 1992; Gonzales et al., 2008; Osborne, Simon, & Collins, 2003). Do optimal learning moments vary by students or instructional characteristics? Moreover, what are the specific circumstances for students, such as individual background and context, that contributes to the student persisting through challenging tasks both in and out of the science classroom, and which supports their efforts despite difficulty? This chapter examines these very questions and what contributes to optimal learning for different types of students and teachers. This chapter specifically explores: (1) How does engagement (as measured by optimal experiences) vary across students? (2) What instructional factors are associated with optimal learning moments in science? and (3) What characteristics can predict optimal learning moments?

Dimensions of the Optimal Experiences and Learning

When individuals are in flow, or having an optimal experience, there are often eight phenomenology components that accompany these moments, including: (1) concentration and focus on the task; (2) clarity, which is knowing what needs to be done and how to do it; (3) knowing that the task is doable, and there is a chance to complete it; (4) the task provides feedback; (5) a sense of serenity, less worry and anxiety; (6) a sense of control and autonomy; (7) the focus on the present task can make time feel as if it is flying by; and (8) the sense of self

disappears, the experience is intrinsic in nature (Csikszentmihalyi, 1990). While these phenomenological factors were studied across a variety of situations and contexts (e.g. interviews with artists and composers), these characteristics of flow most certainly can be applied to learning experiences. Given that optimal experiences occur when the level of challenge and skill are in balance, it is problematic when students report having a low level of challenge in their science classes (Schneider et al., under review; Shumow & Schmidt, 2014). Thus, one can hypothesize that changing the level of challenge, or how students respond to challenge could provide increased opportunities for optimal learning moments, which supports an enjoyable experience in science.

Engagement in Science

While there is a growing need for increasing interest and achievement in science, often the subject of science is grouped together by researchers and stakeholders with math, technology, and engineering as a single field (STEM). However, research on student learning and engagement to shows variation across subjects (Stodolskey, 1988). Therefore, it is important to consider student learning experiences in content-specific settings. In math and science classes in particular, research suggests that students need to be engaged in meaningful learning experiences that mirror similar activities of those in STEM fields (e.g. chemists or engineers), such as simulations, developing models, or collaborative problem solving (Brann, Gray, Piety, & Silver-Pacuilla, 2010). These types of instructional formats often utilize more student-controlled activities compared to teacher-controlled (Stodolskey, 1988).

In high school math classes, several studies show higher levels of engagement compared to other subject areas, however, it is hypothesized that this is due to the aligned nature of math content where teachers are held accountable for preparing their students for the next course level,

and increased pressure from standardized tests and accountability measures (Marks, 2000).

Despite the demand for improved instruction and the desire to increase student engagement in math and science classes, research shows that in most classrooms, students still spend a majority of time on less engaging activities, such as independent work, listening to lectures, and taking notes (DiBianca, 2000; Shernoff et al., 2001; Shernoff et al., 2003).

Teachers and Instruction

Teachers are a key factor in developing conditions for high levels of student engagement as they have knowledge of both the content and of their students. Teachers must not only understand the curriculum and know their students, but also have a strong grasp of instructional strategies, student development, and ways to create optimal learning experiences in their classrooms (Good & Brophy, 2003). As mentioned above, these optimal learning experiences are often present during both intellectual and emotional experiences (Csikszentmihalyi & Schneider, 2000). Thus, instruction should be designed not only to foster these learning moments, but create an environment that supports both the intellectual and emotional experiences of students as they learn. For example, Turner and Meyer (2004) found that in classes with high engagement, teachers fostered intrinsic motivation and included more scaffolded instruction that allowed the content to be adjusted so that a student could match their challenge and skill.

Classrooms are dynamic places, and on a daily basis teachers must plan for, manage, and adapt to a multitude of requirements, expectations, and demands. It is within this complex environment where the relationship between instruction and engagement is observed and measured. It is important to acknowledge that fostering student engagement is just one component of a multifaceted classroom setting. Given these multiple dimensions of teaching and

learning, teachers find themselves fostering student engagement in multiple ways given the contextual environment of the classroom.

Teacher Behavior. While there is substantial research on the different types of instructional activities that can lead to improved student engagement and student outcomes, it is also critical to understand the role of teacher expectations in developing engaged students, acknowledging that although instructional activities are important, they are often not alone in cultivating student engagement. If engagement is the result of matching a student's challenge threshold and skill level, a teacher must first possess an expectation or belief that a student possesses the skills needed for the activity and can engage in a challenging task.

The expectations teachers hold about their students are predictions teachers make about the future behavior of their students based on their present knowledge (Good & Brophy, 2003). These teacher expectations and beliefs often influence the actions teachers take (Skinner & Belmont, 1993), including support and instructional practices. Teacher support is comprised of factors that fulfill a student's basic psychological needs, including: structure, clear expectations and guidelines for learning; autonomy, students having latitude in their own learning as opposed to teacher-controlled or coercive learning; and involvement, which is the interpersonal relationships among the teacher, student, and peers (Connell & Wellborn, 1991; Fredericks et al., 2004; Klem & Connell, 2004; Skinner & Belmont, 1993). Research shows that students with high levels of teacher support are more likely to be engaged; Klem and Connell (2004) found that highly supported students in secondary schools were approximately three times more likely to show high levels of engagement than students with low levels of teacher support.

Instruction. A teacher can use a variety of instructional methods in the classroom, including lecture, taking notes, completing worksheets, class discussion, taking quizzes or tests,

group projects, and class presentations. In math and science classes, the most common instructional methods include lecture, discussion, testing, demonstration, lab work, and seat work (DiBianca, 2000; Weiss, 1997). These different instructional methods may influence how students engage in learning and are an important factor in measuring and understanding student engagement. Despite research that students are engaged by instructional activities that are student-controlled, less teacher-centered, and provide a match between challenge and skill, all while experiencing enjoyment (Csikszentmihalyi & Schneider, 2000; DiBianca, 2000; Shernoff, 2001; Shernoff et al., 2003; Singh, Granville, & Dika, 2002; Skinner & Belmont, 1993), students in science and mathematics classes often spend their time on less-engaging tasks. Shernoff (2001) found that students were more likely to be engaged in non-academic classes (e.g. art and vocational education) than their academic courses, and that academic classes in general used high-engaging tasks less frequently than non-academic classes.

The other component of instruction that is important for understanding student engagement is the instructional *relevance*, or as Newmann, Wehlage and Lamborn (1992) proposed, authentic instruction, which is the significance and value for the student of what is being learned. Newman et al. (1992) set forth three student outcomes of authentic achievement in which authentic instruction should aim to create, including: constructing meaning and producing knowledge; using disciplined inquiry; and working towards completing products or performances that have value beyond just success in school. Given these desired student outcomes, authentic instruction calls for five standards, which align well with the literature on student engagement: (1) higher-order thinking; (2) depth of knowledge; (3) connectedness to world beyond the classroom; (4) substantive conversation; (5) social support for student achievement. Instruction that targets active student involvement in challenging activities contributes to high student engagement,

providing optimal learning experiences and construction of knowledge (Newmann et al., 1992). However, as several have argued, engaged students must connect what they are learning to larger goals or interests beyond the classroom, which implies that not only is the context inside the classroom important, but the context outside of the class-such as the culture of the school (Easton, 2008; Marks, 2000; Newmann, 1992; Schlechty, 2011).

Student Background

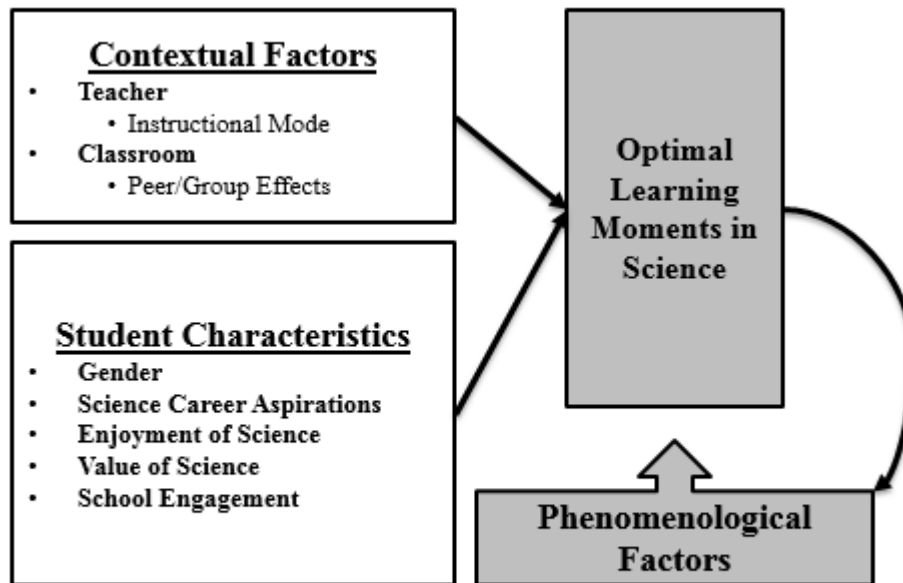
Student engagement in school also varies across different student background characteristics such as gender, race/ethnicity, and socioeconomic status. Across all grades, girls are consistently more engaged than boys (Finn & Cox, 1992; Lee & Smith, 1995). In high school, minority students are more likely to be engaged in academic work compared to their white counterparts, reversing the trend in elementary school where minority students were less likely to be engaged compared to white students (Lee & Smith, 1995). Students from higher socioeconomic (SES) backgrounds are also more likely to be more engaged compared to their low-SES peers (Finn & Cox, 1992; Lee & Smith, 1995). While student background is an important factor in understanding student engagement, teachers remain the central component to increasing student engagement by fostering academically challenging environments that create authentic learning experiences (DiBianca; 2000; Newmann, 1992; Shernoff, 2001; Shernoff et al., 2003; Singh, Granville, & Kika, 2010; Skinner & Belmont, 1993).

Theoretical Framework

The framework for this chapter follows that of the dissertation, and similar to chapter two, this chapter will more intensively examine optimal learning experiences in science using the ESM data. Building on the results of chapter two, this chapter will evaluate additional layers of context for understanding variation in how optimal learning moments occurs, with a specific

focus in science classrooms. Using a smaller version of the larger conceptual framework, Figure 3.1

Figure 3.1 Contextualizing Optimal Learning Moments in Science



shows the relationships that will be examined between students, contexts, and optimal learning experiences. These optimal learning moments, represented by the gray box, are subject to a student's context as well as their in the moment subjective states. Student characteristics, including gender, career plans in science, enjoyment and value of science, and overall engagement may also influence optimal learning moments. The contextual factors explored in these analyses include instructional modes reported by the teachers as well as the student. As mentioned earlier, being in an optimal experience often supports feelings such as enjoyment, concentration, and control, which is represented here by the arrow that proceeds from the optimal learning moment box to the phenomenological factors.

Research Questions

To more narrowly investigate these moments of optimal learning along with the other phenomenological dimensions, this chapter examines:

1. How does engagement (as measured by optimal learning experiences) vary in and out of science and across students by gender, future occupation, enjoyment and value of science, and overall school engagement?
2. What instructional factors are associated with optimal learning moments?
3. What student and instructional factors can predict optimal learning moments? Does this vary for science classes?

Methodology

Data and Sample

The same ESM dataset used in chapter two is used in this set of analyses. Since comparisons are made between science and other academic contexts, the sample is restricted to students who have at least one response in science class and five responses outside of science. While traditional ESM methodology suggests keeping only participants who responded to at least 15 notifications (Hektner, Schmidt, & Csikszentmihalyi, 2007), since engagement is a primary outcome, removing students who have lower response rates may bias the sample by leaving in students who exhibit high rates of overall optimal learning moments. Sensitivity analyses comparing the full sample, restricted sample of six responses, and using a threshold of 15 responses are included in Appendix C. The final full sample size for the descriptive analysis included 256 students and a total of 7,908 momentary observations. However, because the measure of persistence was only measured during the second phase of data collection, the sample

for the multi-level analysis is 129 students with a total of 3,449 momentary observations. Table 3.1 shows the sample used for these analyses.

Table 3.1
Descriptive Characteristics of Two-Level Data

<i>Level-1 Descriptive Statistics</i>					
VARIABLE NAME	N	MEAN	SD	MINIMUM	MAXIMUM
Optimal Learning	3,449	0.13	0.34	0	1
In science	3,485	0.36	0.48	0	1
Enjoyment	3,485	0.61	0.49	0	1
Importance to self	3,485	0.39	0.49	0	1
Importance to future	3,485	0.57	0.5	0	1
Persistence	3,468	0.65	0.48	0	1
<i>Level-2 Descriptive Statistics</i>					
VARIABLE NAME	N	MEAN	SD	MINIMUM	MAXIMUM
Male	129	0.52	0.5	0	1
Female	129	0.48	0.5	0	1
High Science Enjoyment	129	0.82	0.38	0	1
High Science Value	129	0.86	0.35	0	1
Science Aspirations	129	0.34	0.48	0	1
School Engagement	129	0.36	0.48	0	1

Notes. FLOWZ is a composite variable equal to 1 when a student is experiencing higher than average challenge, skill, and interest.

Measures

The outcome of interest is a binary measure for an optimal learning moment. This measure is equal to one when a student's level of challenge, skill, and interest are reported above their average level. These analyses use the standardized measure of optimal learning moments as opposed to using raw scores as described in the previous chapter to take advantage of the ESM's ability to capture each student's variation from their own person-centered value for each affective state. A nested model is used to analyze the data, with level-1 (moment-level) responses nested within level-2 (students). Five control variables were included at level-1 (moment-level) including how important the student felt the task was to them and to their future, their enjoyment

of the task, their persistence, and if the response occurred in science. At level-2, student-level covariates included gender, overall enjoyment of science, overall value of science, their interest in a science career, and their overall school engagement.

Analytic Approach

To address the first research question of how optimal learning moments vary, descriptive analyses are conducted to examine how these learning situations across a variety of settings. This first set of analyses also explores the student's reported volition in moments when they are in optimal learning environments—both in and out of science class as well as in and out of school and also observes how students perceive their task (more like work or more like play) across contexts. Then, variation in optimal learning moments is explored by gender and student attitudes towards science. The final step in the descriptive analyses observes the predominant forms of instruction when students are in an optimal learning moment.

The nested structure of the ESM data (repeated measures within students) is analyzed using a multi-level model, which is able to account for the shared variance of the ESM data of moments occurring within individuals (Raudenbush & Bryk, 2002). Since the primary outcome of interest is binary (equal to 1 when a student experiences higher than average levels of challenge, skill, and interest), a Hierarchical Generalized Linear Model (HGLM) is used. The full model estimated for predicting optimal learning moments is:

Level 1 (moment-level i)

$$\eta_{ij} = \pi_{0j} + \pi_{1j}(\text{importanceyou}) + \pi_{2j}(\text{enjoy}) + \pi_{3j}(\text{persist}) + \pi_{4j}(\text{inscience})$$

Level 2 (student j)

$$\pi_{0j} = \beta_{00} + \beta_{01}(\text{female}) + \beta_{02}(\text{hi_enjoy}) + \beta_{03}(\text{hi_futur}) + \beta_{04}(\text{hi_engag}) + \varepsilon_{0j}$$

where $\eta_{ij} = (\varphi_{ij}/1 - \varphi_{ij})$ is the logit link function and

- φ_{ij} is the probability of optimal learning (at moment i for student j),

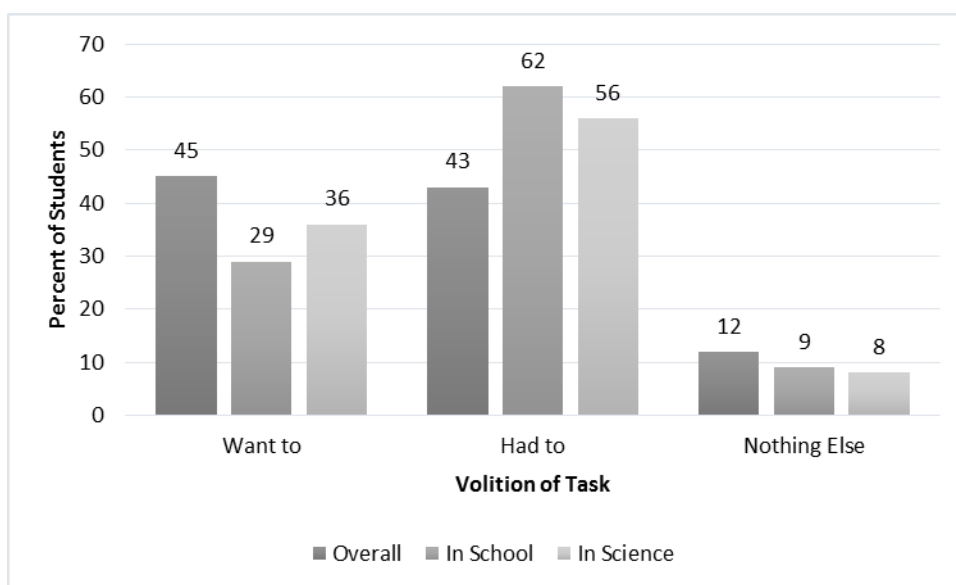
- *importanceyou* is a binary variable equal to 1 if the z-score for the importance of the task is greater than 0
- *enjoy* is a binary variable equal to 1 if the z-score for the enjoyment of the task is greater than 0
- *persist* is a binary variable equal to 1 if the z-score for wanting to give up is less than 0
- *inscience* is a binary variable equal to 1 if the response is in science class
- *female* is a binary variable equal to 1 if the student is female, and 0 if student is male
- *hi_enjoy* is a binary variable equal to 1 if the average for the PISA enjoyment scale is greater than 3 on a 4-point scale
- *hi_futur* a binary variable equal to 1 if the average for the desiring a future in science scale is greater than 3 on a 4-point scale
- *hi_engag* a binary variable equal to 1 if the average for the schoolwork engagement scale is greater than 4 on a 7-point scale
- ε_{0j} is a random effect for student j

Results

Examining what a student experiences when in an optimal learning moment across contexts, Figure 3.2 shows the volition a student reports during a task when they are in an optimal learning moment, meaning when students are engaged do they find the task something that they *want* to do, *had* to do, or they had *nothing* else to do? Overall, students report wanting to do their task 45% of the time when they are in an optimal moment overall, compared to only 29% of the time when they are in school. However in science students report higher levels of wanting to do their task compared with being at school with 36% of students reporting that they wanted to do their task in science compared to 29% while at school. Examining when students

felt like they had to do their task, in school was the highest category with 62% of students in an optimal learning moment marking this response, in science was slightly lower at 56%, while overall 43% of students report feeling that they had to do their task. Students in an optimal moment did not often identify the reason for their activity as “because there was nothing else to do,” which serves as an additional validation for this engagement measure as this is consistent with the literature discussed above— that when a students is having an optimal experience, there is a sense of control, concentration, and focus that would not be present if students did not have anything else to do.

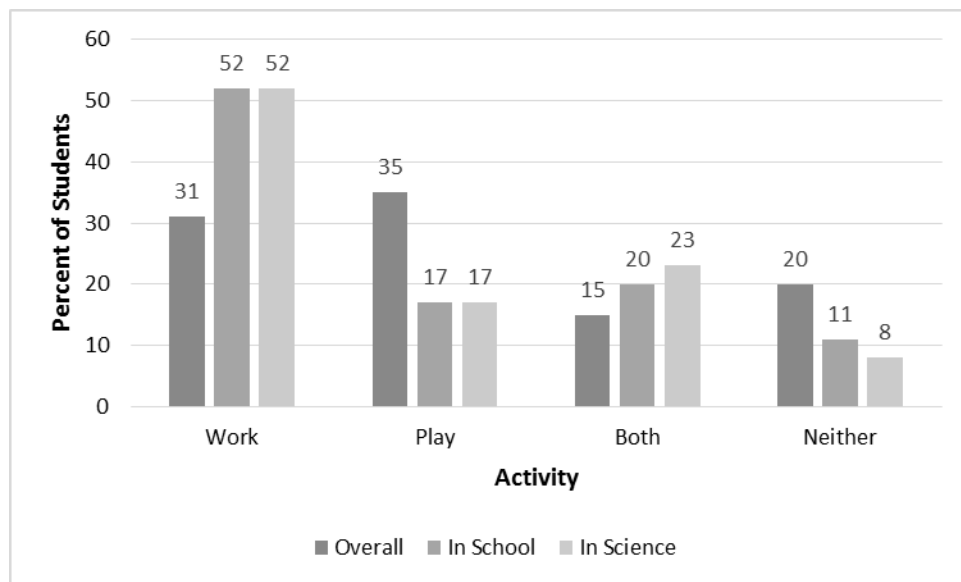
Figure 3.2 Student Volition of Task during an Optimal Learning Moment



Analyzing how a student in an optimal learning moment perceived their activity as work or play, Figure 3.3 demonstrates there is variation across contexts. Students in an optimal moment report 52% of the time that their activity as more like work in school and in science compared to overall to 31% of the overall time. Students who are in an optimal moment report higher levels of play at 35% compared to when in school and in science, which was 17% of the time. In

science, however, 23% of students report that their task feels like both work and play compared to 20% in school, and 15% overall. This is a positive outcome for science experiences when there is a certain amount of work and play that is present during a task. Students in an optimal learning moment report that their activity does not feel like work or play 20% of the time overall, compared to lower percentages in school (11%) and in science (8%). Similar to the results shown in Figure 3.2, these findings further validate the measure of optimal learning, while also demonstrating some positive results for the experiences of students in science class, that when engaged the task is more likely to feel like work and play compared to other academic settings, also a lower percentage of students report that their task feels neither like work or play, which could indicate a lack of purpose or value in their activity.

Figure 3.3 Student Perception of Activity during an Optimal Learning Moment



Next, exploring how optimal learning experiences vary by student, Table 3.2 shows that there are differences by gender in the total number of optimal learning moments, 16.74% of all

occurrences were male students compared to 10.38% for females. Male students, on average, have more optimal moments, with an average of 4.80 compared to 3.34 for female students. Restricting the time frame to during school hours reveals a similar trend that males in school experience more optimal learning moments than females, 1.89 compared to 1.4 moments, however this is not statistically significant. This gender difference holds in science as well, but the gap is slightly smaller between males and females, about 12% compared to 9%. There is no statistical significant difference between the number of optimal learning moments in science between male and females, males experience an average of .82 compared to .61 for females—both experience a low number.

Examining the gender differences more closely, Table 3.3 shows how students with higher levels of science enjoyment, value, and career aspirations, and overall school engagement experience optimal learning moments. The general trend of males experiencing more moments of optimal learning than females holds. However when looking at these students that have more positive attitudes associated with science, especially for males, these students experience higher levels compared to all students. For example, for males who indicate that science is important for their career, they experience an optimal learning moment about 21% of the time. Although these percentages still remain lower in science classes compared to in school and overall, these percentages are still higher than the full student sample. It may also very well be the case that these student are highly motivated in all areas, not just in their science classes.

When analyzing what the students report working on when signaled in science, differences can be observed between students in an optimal learning moment and students not in an optimal experiences as shown in Table 3.4. The top five reported activity categories for these students in an optimal learning moment include: science (20%); taking a test or quiz (19%); homework or

studying (14%); being in class (12%); and working on school work (11%). The rest of the responses were varied and combined to equal 24%. While these answers may be less descriptive about the kinds of “work” or “science” the student is doing, overall it is evident that these students are at least demonstrating on-task behavior. Students not in an optimal learning moment report working on: science (16%); school work (11%); a test or quiz (9%); homework or studying (8%); and general work (3%). One key difference is that the high percentage of students

Table 3.2**Optimal Learning Moments by Gender**

	<u>Overall</u> <i>n=7,908</i>			<u>In School</u> <i>n= 4,909</i>			<u>In Science</u> <i>n= 1,740</i>		
	<i>female</i>	<i>male</i>	<i>p</i>	<i>female</i>	<i>male</i>	<i>p</i>	<i>female</i>	<i>male</i>	<i>p</i>
Percentage of time in Optimal Moments	10.38%	16.74%	0.00	10.54%	17.25%	0.00	8.52%	11.85%	0.02
Average number of Optimal Moments	3.34	4.80	0.02	1.4	1.89	0.19	0.61	0.82	0.19

Notes. Full ESM sample used from phase I and II. Chi-squared used to test for significance for the percentages and a t-test is used for the average number of learning moments

Table 3.3**Optimal Learning Moments by Student Characteristics**

	<u>Overall</u> <i>n=7,908</i>			<u>In School</u> <i>n= 4,909</i>			<u>In Science</u> <i>n= 1,740</i>		
	<i>Percent of time in optimal learning moments</i>		<i>chi- square</i>	<i>Percent of time in optimal learning moments</i>		<i>chi- square</i>	<i>Percent of time in optimal learning moments</i>		<i>chi- square</i>
	<i>male</i>	<i>female</i>	<i>(p)</i>	<i>male</i>	<i>female</i>	<i>(p)</i>	<i>male</i>	<i>female</i>	<i>(p)</i>
Science Enjoyment	17.44%	10.86%	0.00	16.73%	10.37%	0.00	13.11%	9.41%	0.00
Future Aspirations in Science	20.60%	10.41%	0.00	21.79%	11.42%	0.00	20.54%	9.54%	0.04
Science Value	17.76%	10.87%	0.00	18.55%	10.80%	0.00	12.31%	8.49%	0.02
Schoolwork Engagement	18.84%	12.28%	0.00	21.16%	14.44%	0.01	18.25%	9.43%	0.00

Source: Full ESM sample from phase I and II are used.

Table 3.4
Student-reported Task in Science

<i>Optimal Learning</i>	<i>%</i>	<i>Not in Optimal Learning</i>	<i>%</i>
Science	20%	Science	16%
Taking a test/quiz	19%	School Work	11%
Homework/Study	14%	Taking a test/quiz	9%
In Class	12%	Homework/Study	8%
School Work	11%	General Work	3%
Other Categories (combined)	24%	Other Categories (combined)	53%

Notes. Open-response categories coded using codes from the 500 Family Study. The "Science" category includes general science, biology, chemistry, and physics

(53%) reporting working on other types of activities, some examples reported include “listening to announcements,” “watching a video,” “sitting,” “reading,” and “answering this survey.”

The second set of analyses uses HGLMs to examine the likelihood of being in an optimal learning moment in science, conditioning on covariates that occur at that same moment (level-1) in addition to student variables (level-2). Table 3.5 shows a partial model that examines the influence of only level-1 variables on the outcome of optimal learning. When students are in science, there are lower odds of being in an optimal learning moment compared to outside of science ($p=0.016$). A student that is enjoying their task is almost six times more likely to be in an optimal learning moment ($p=0.000$) and students who find importance in the task are also more likely to be in an optimal learning moment than students who do not find importance in their activity. These findings are consistent with previous research on optimal experiences (see Shernoff et al., 2003).

Table 3.5
HGLM Predicting Optimal Learning Moments - Level 1

<i>Level-1 (moments) Effects (n=3,485)</i>				
Variable	Coefficient	s.e.	Odds Ratio	<i>p</i>
In science	-0.321	0.133	0.725	0.016
Enjoy	1.938	0.157	6.950	0.000
Important for you	0.838	0.135	2.312	0.000
Persistence	-0.345	0.143	0.708	0.013

Notes. Reliability estimate for random level-1 coefficient is .535

Persistence in a task, on the other hand, while hypothesized to influence optimal learning moments is negatively associated with these experiences. Further analyses (see Appendix D) reveal that this is largely driven by the effect of *challenge*. Examining the relationship between challenge and giving up, the distribution of responses is bifurcated, with challenge either associated more strongly with giving up or persisting. The moments when a student is experiencing high levels of challenge and report not wanting to give up are correlated with a mixture of positive affects (concentration and importance), but also negative affective states (confusion and stress). These relationships among the different emotional states may influence how persistence is able to predict an optimal learning moment.

When covariates are added to level-2 as shown in Table 3.6, the level-1 estimates remain mostly similar to those in Table 3.5. None of the level-2 variables are significant predictors of optimal learning moments in science, and the reliability estimate also remains the same between models. While male students do show a positive relationship with optimal learning moments, in this sample it is not a significant predictor when in science classes. Students that enjoy science more, have higher value of science for their careers and higher levels of overall engagement are not more likely to experience optimal learning moments in science. This may indicate that these situations of engagement are indeed more sensitive to the in-the-moment context of the task and the environment shaping the social and emotional experiences than the contributions of stable

(level-2) variables, such as overall engagement. It is not the case that these level-2 covariates offer no use in helping to contextualize the students learning experiences, it is just the case that for this particular outcome for this sample of students, no relationships were observed.

Table 3.6
HGLM Predicting Optimal Learning Moments - Full Model

<i>Level-1 (moments) Effects (n=3,485)</i>				
Variable	Coefficient	s.e.	Odds Ratio	p
In science	-0.317	0.132	0.728	0.016
Enjoy	1.939	0.163	6.950	0.000
Important for you	0.848	0.133	2.336	0.000
Persistence	-0.346	0.145	0.707	0.000
<i>Level-2 (student) Effects (n=128)</i>				
Variable	Coefficient	s.e.	Odds Ratio	p
Male	0.277	0.173	1.318	0.112
Science enjoyment	-0.025	0.198	0.976	0.901
Science future	-0.017	0.191	0.983	0.930
School engagement	-0.069	0.172	0.933	0.688

Notes. Reliability estimate for random level-1 coefficient is .535

Discussion

The purpose of this chapter was to examine the student background characteristics and their learning contexts to see how these might contribute to optimal learning experiences. Specifically, how optimal learning experiences vary across students, what instructional characteristics are associated with optimal learning moments, and what in-the-moment-level and student-level characteristics can predict optimal learning moments? The research on optimal experiences posits that these moments are subject to the contextual components that comprise the daily events of adolescents. These factors can include whether to student is in or out of school, the subject, and their social and emotional state at a given point in time. Capturing these temporal situations can be a complex endeavor, however, this study collected multiple layers of

data using ESM and survey instruments that provide a multi-dimensional perspective of these learning moments.

The first set of analyses examined how optimal learning moments varied across students and contexts. Unlike previous research on gender and flow, this study found that males experience more optimal learning moments than female students. Csikszentmihalyi and Schneider (2000), using a slightly different measure for flow (high challenge and high skill without a measure of interest), found that female students experienced higher levels of flow in school than male students, 12% compared to around 6%. Their data was collected in four waves during the 1990s, included a larger sample of students ($n=1,215$) than the data in this study, and consisted of a slightly higher proportion of females than males (53% compared to 47%). While it is not necessarily clear why this present study yielded different results for male and female students, because there several other measures within this study as shown in chapter two and this chapter which argue reliability and validity of the measures, it is not a concern that the experiences of genders is different the prior research—and may in fact suggest a shift in how males and females experience school differently compared to 15 years ago. Further analyses of these gender differences would be an important line of future research, but is beyond the scope of this current study.

The previous research on optimal experiences also found that these situations are often accompanied with other phenomenology components such as enjoyment, concentration and a sense of control (Csikszentmihalyi, 1990). This present study was consistent with these findings; enjoyment and importance were found to be present during optimal learning moments. However, persistence, hypothesized to be positively associated with an optimal experience, was associated with having lower odds of being in an optimal learning moment. This may be due to the complex

relationship challenge, persistence, stress, and anxiety, which under some circumstances can be a productive and positive learning moment, but if there is too much stress or challenge (unbalance), this may compromise the learning moment, as discussed in more detail by Schneider et al. (under review).

Limitations

One of the more challenging aspects of this research is determining the relationships between the different affective states, it can not necessarily be assumed that there is a linear relationship between the social and emotional responses, or that this relationship is similar in nature for each situation. For example, this present study assumed that finding importance or enjoyment in a task could predict an optimal learning moment (higher than average challenge, skill, and interest), which would assume a linear relationship importance, enjoyment and optimal learning. It could very well be the case that *because* a student is experiencing an optimal learning moment and are engaged in the task at hand, that creates importance and enjoyment in the activity. It is beyond the scope of this research to test the directionality and relationship of different affective states and contexts, however, future research could explore these dynamic connections during optimal experiences.

A second limitation is the lack of an achievement measure in this dataset. While the goal of this chapter was to examine how optimal learning moments varied across students and contexts, analyzing how these situations vary by students of different achievement levels or using an achievement measure in the HGLMs would have strengthened these analyses. However, based on the findings from the HGLMs that no student-level predictors could significantly predict optimal learning moments, it could be hypothesized that students of different achievement levels have similar odds of being in an optimal learning moment. Future data

collection of this current NSF project includes plans to collect an achievement measure and this hypothesis could be tested. Additionally, chapter four of this dissertation allows for the use of a math achievement score to examine experiences of ninth graders in their science classes from the HSLS:09 dataset.

Finally, the ability to contextualize learning in science classes was constrained by the level of detail provided by the students and the teachers. When students were prompted to record their activity, often the responses were vague and brief, for example, when asked what that they are doing while in science, a common response was “science.” This study also collected lesson plan forms from the teachers, however, the ability to link this information with the students was limited because the teachers’ activities were often broad classroom objectives, which could not be linked directly to a given moment of the day/lesson. Future data collection instruments were refined to allow the students to select from a list of customized science ideas and practices that provide more detail about the specific modes (e.g. analyzing data, evaluating information) and content (e.g. energy and matter) of their learning.

Implications

This study contributes to the measurement of student engagement through optimal learning moments and sheds light on the relationship between these optimal learning moments and their sources of variation. These findings highlight that these moments in science are indeed dependent on several contextual factors of the classroom, which for teachers in particular signals that there are opportunities for them to create environments conducive to optimal learning moments. Students from a variety of backgrounds, with diverse attitudes toward science can be engaged, often if they can find relevance and importance in the content being presented to them (Osborne, 2002).

For all contexts, including those outside of science classrooms, there are implications for how teachers can approach creating optimal learning moments. Examining the student responses for their activities when engaged, it is not full of responses often associated with “active” or student-led activities, but filled with a list of common instructional approaches. This may indicate that it is not necessary for teachers to always use modes and methods of instruction that are time and resource intensive to create environments for optimal learning—having students complete a lab activity every day is just not feasible. However, results suggest that the instruction needs to convey importance, relevance, value, and that the learning is enjoyable, and this can occur in a variety of instructional settings.

These findings about importance and relevance align well with the goals of Next Generation Science, which specifically outline that “all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology” (National Academies, 2012, pp. 1-4). These new standards emphasize the skills and practices learned in science as tools that can be applied across all subjects (e.g. biology, chemistry, physics), but are also aimed at developing students with sufficient science literacy regardless of their intended plans after high school, which should improve the experiences in science for all students.

APPENDICES

Appendix A: ESM Response Sample Restrictions

Table 3.7

Sample Restrictions Comparisons

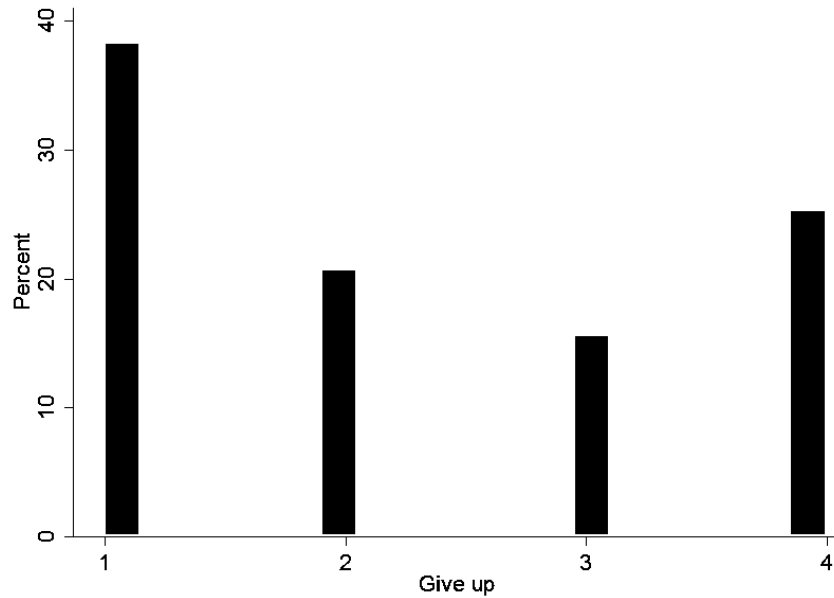
	Full Sample <i>n=141</i>	At least 6 responses <i>n=137</i>	At least 15 responses <i>n=111</i>	Significance <i>(p)</i>
Male	51%	53%	53%	<i>0.528</i>
Nonwhite	19%	19%	20%	<i>0.405</i>
Average Optimal Learning Moments	3.35	3.45	4.09	<i>0.929</i>
Science Enjoyment	82%	82%	79%	<i>0.409</i>
Science Value	86%	85%	82%	<i>0.472</i>
Future Aspirations	34%	33%	30%	<i>0.220</i>
School Engagement	36%	34%	33%	<i>0.189</i>

Notes. Phase II data used in these comparisons. A chi-squared test was used for significance for categorical data and a t-test was used for the average number or optimal learning moments.

Appendix B: Relationship between Persistence and Challenge

Figure 3.4

Percentage of Students with High Challenge and Wanting to Give Up



Notes. Figure 3.4 shows when challenge is high (equal to 4) that about 37% of responses show not wanting to give up (1) and about 25% of responses wanting to give up (4).

Table 3.8

**Correlations with High
Challenge and Persistence**

Active	0.1205
Bored	-0.0295
Concentrate	0.2539
Confused	0.1716
Enjoy	-0.0258
Importance	0.1787
Self-expect	0.0410
Success	-0.0484
Skill	-0.0934
Stress	0.1600

REFERENCES

REFERENCES

- Brann, A., Gray, T., Piety, P.J., & Silver-Pacuilla, H. (2010). Using technology to support struggling students in science. Center for Implementing Technology in Education. Retrieved from <http://www.cited.org/library/resourcedocs/UsingTechnologytoSupportScience.pdf>
- Connell, J.P. & Wellborn, J.G. (1991). Competence, autonomy, and relatedness: A motivational analysis of self-system processes. In M. Gunnar & L. A. Sroufe (Eds.), *Minnesota Symposium on Child Psychology* (Vol. 23). Chicago: University of Chicago Press.
- Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. New York: Harper Perennial.
- Csikszentmihalyi, M., & Schneider, B. (2000) *Becoming adult*. New York: Basic Books.
- DiBianca, R. (2000). *Teaching adolescents: Relationships between features of instruction and student engagement in high school mathematics and science classrooms*. Chicago: University of Chicago Press.
- Easton, L. B. (2008) *Engaging the disengaged: How schools can help struggling students succeed*. Thousand Oaks, CA: Corwin Press.
- Finn, J.D. & Cox, D. (1992) Participation and withdrawal among fourth-grade pupils. *American Educational Research Journal*, 29, 141-162.
- Fredricks, J. A., Blumenfeld, P.C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of evidence. *Review of Educational Research*, 74(1), 50-109.
- Good, T.L. & Brophy, J.E. (2003). *Looking in classrooms*, Ninth Edition. Boston, MA: Pearson.
- Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., & Brenwald, S. (2008). *Highlights from TIMSS 2007: Mathematics and science achievement of U.S. fourth-and eighth-grade students in an international context*. Washington, DC: National Center for Education Statistics. Retrieved from <http://nces.ed.gov/pubs2009/2009001.pdf>
- Hektner, J.M., Schmidt, J.A., & Csikszentmihalyi, M. (2007). *Experience sampling method: Measuring the quality of everyday life*. Thousand Oaks, CA: Sage Publications.
- Klem, A.M. & Connell, J. (2004). Relationships matter: Linking teacher support to student engagement and achievement. *Journal of School Health*, 74(7), 262-273.

- Lee, V.E. & Smith, J.B. (1995). Effects of high school restructuring on gains in achievement and engagement for early secondary students. *Sociology of Education*, 68, 241-270.
- Marks, H.M. (2000). Student engagement in instructional activity: Patterns in the elementary, middle, and high school years. *American Educational Research Journal*, 37(1), 153-184.
- National Academies. (2012). *3 Dimension 1: Scientific and engineering practices. A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press, 2012.
- Newmann, F.M., Wehlage, G.G., & Lamborn, S.D. (1992). The significance and sources of student engagement. In F. M. Newmann (Ed.) *Student Engagement and Achievement in American Secondary Schools* (pp. 11-30). New York: Teachers College Press.
- Osborne, J.F. (2002). The challenge for science education for the twenty-first century. Pontifical Academy of Sciences, *Scripta Varia* 104, Vatican City.
- Osborne, J., Simon, S. & Collins, S. (2003). Attitude towards science: a review of the literature and its implications. *International Journal of Science Education*, 25(9), 1049-1079.
- Schlechty, P. C. (2011). *Engaging students: The next level of working on the work*. San Francisco, CA: Jossey Bass.
- Schneider, B., Krajcik, J., Lavonen, J., Salmela-Aro, J., Broda, M., Spicer, J., Bruner, J., Moeller, J., Linnansaari, J., Juuti, K. & Viljaranta, J. (under review). Optimal learning moments in science classes: An international study in the U.S. and Finland. *Manuscript submitted for publication at Journal for Research in Science Teaching*.
- Sherhoff, D. (2001). *The experience of student engagement in high school: A phenomenological perspective*. Chicago: University of Chicago Press.
- Sherhoff, D., Csikszentmihalyi, M., Schneider, B., & Sherhoff, E. (2003). Student engagement in high school classrooms from the perspective of flow theory. *School Psychology Quarterly*, 18(2), 158-176.
- Shumow, L. & Schmidt, J.A. (2014). *Enhancing adolescents' motivation for science: Research-based strategies for teacher male and female students*. Thousand Oaks, CA: Corwin Publications, A Sage Company.
- Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *Journal of Educational Research*, 95(6), 323-332.
- 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* 85(4), 571-581.

- Stodolsky, S. (1988). *The subject matters: Classroom activity in math and social studies*. Chicago: University of Chicago Press.
- Turner, J. C., & Meyer, D. K. (2004). A classroom perspective on the principle of moderate challenge in mathematics. *Journal of Educational Research*, 97, 311-318.
- Weiss, I. (1997). The status of science and mathematics teaching in the United States. *National Institute for Science Education Brief* 1(3).
- Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Education Psychology* 25, 68-81.
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CHAPTER 4: THE ROLE OF ENGAGING EXPERIENCES IN SCIENCE AND LONGITUDINAL OUTCOMES IN HIGH SCHOOL

As U.S. student achievement in science remains around the international average (OECD, 2013), and student engagement in science remains at or below international averages (OECD, 2007), more closely examining how students experience science in high school can help to shed light on how learning experiences can be optimized, which can help strengthen the pipeline into STEM. How students engage with science during high school may also vary depending on the cumulative experiences with their courses, such as the perceived value of their science class to their future, their efficacy in the subject, and how their teacher organizes instruction.

This chapter analyzes data from the first two waves of the High School Longitudinal Study of 2009 (HSLs:09). The analytic framework and approach to analyzing HSLs:09 is informed by the previous chapters' findings that highlight the role of engaging experiences in science class and instruction that supports persistence in challenging learning activities. Using these ESM findings to complement HSLs:09 allows for the articulation of contexts that are associated with optimal learning moments to be further explored by a weighted sample, which can be generalized to a state and national population of students. These analyses will address the conditions of ninth grade science courses in 2009, more specifically, this portion of the research asks what types of courses did students enroll in and why? What were their experiences in their ninth grade science class, and did these experiences influence future enrollment in advanced courses or alter postsecondary and occupational aspirations in STEM?

Pathways in Science during High School

Strengthening the STEM Pipeline

While it is not expected that all students will be interested in a career in the STEM field, or even enjoy their science classes, the skills and practices learned in science, such as developing

a model to explain a phenomenon, or analyzing data and evaluating information (National Academies, 2012) are tools for critical thinking and problem solving that are beneficial across all disciplines. There are also strong labor market considerations for the career outlook in STEM. According to the Bureau of Labor Statistics, STEM occupations are projected to grow faster than the average for all other occupations, (13% for STEM from 2012 to 2022, compared to 11% for all others), and that the wages for these occupations were higher on average than the median for all occupations (2013). Workers in the “advanced industries” sector in particular, which is largely dependent on STEM-trained labor from all levels of education/training, have seen their wages significantly increase, almost doubling since 1980 (inflation-adjusted), and in 2013 the average earnings of workers in the advanced industries was \$65,680 compared to \$45,360 for all industries (Muro et al., 2015). Providing students with engaging learning in their high school science classrooms could contribute to increased learning and preparation for opportunities such as these in the STEM fields.

Students’ development of their attitudes towards science can be an imprecise concept, often including a range of behaviors such as the enjoyment of science learning experiences, acceptance of scientific inquiry as a way of thinking, or development of an interest in science or science-related career (Osborne, Simon, & Collins, 2003). It is, however, a combination of these affective states with a *behavior* that may contribute to actual outcomes in science, as Ajzen and Fishbein (1980) argue in their theory of planned behavior (TPB). The TPB argues that there is both a cognitive and affective dimension of attitudes that shape behavioral intentions, which along with circumstances motivates an outcome.

Course-taking. One example of a behavioral outcome that could be influenced by attitudes in science and repeated behavioral experiences in science classes is the enrollment and

persistence in advanced science courses in high school. While there is variation from state to state in the required number and level of science courses in high school, students that take more than the required number of class credits may do so as an indication of their future educational and occupational plans in science or STEM. While some aspects of the STEM field are domain-specific, there is also overlap among science, technology, engineering, and mathematics that are important to consider. Demonstrated by Wang (2013), students' desire to major in STEM was directly correlated by their eleventh-grade math achievement, exposure to their science and math courses, and their math self-efficacy beliefs. These findings are consistent with previous research showing how one key to success in high school is completion of advanced coursework in mathematics (Gamoran, 1987; Hallinan & Kubitschek, 1999).

The course-taking sequences in mathematics are often more hierarchical than other subjects, such as social studies or science, making the study of how a student progresses from one course to the next in this nonlinear sequences more difficult. For science in particular, courses are often isolated and taught independently of each other. For example, a chemistry class taken in 10th grade might not build or extend the content from a 9th grade biology class. The lack of a clear progression in science courses not only makes it difficult to measure and analyze course-taking patterns in high school science, but the nature of these independent courses may also contribute to a potential disconnect in how students build upon their previous instruction if they are unable to make connections across their science courses. This is an issue that was addressed in the newly developed Next Generation Science Standards (NGSS) (National Academies, 2012).

Science Instruction

It is also not enough for students to enroll in more math and science classes; students need to be learning in these courses as well, as evidenced by Hanushek, Jamison, Jamison, &

Woessmann (2008) who show that increasing math and science test scores by one standard deviation would lead to a 2.5 percentage point increase in economic growth. Furthermore, their study showed that it is also not a matter of just raising the number of students with basic skills, but also to continue increasing the achievement of the top performing students (Hanushek et al., 2008). The instruction in science should also be relevant to all students' lives, and not just to those intending to pursue science careers. Osborn and Collins (2000) noted this as a recurring theme across several focus groups with adolescents, that there was a lack of perceived relevance to pupils' lives. Osborne (2002) also noted the contrast between teaching science content compared to instruction of skills and practices:

The emphasis of school science on consensual, well-established science, means that there is no space for any consideration the science that dominates contemporary society—the science and technology of informatics, CD-ROMs, mobile phones, lasers, health and disease, modern cosmology, modern imaging systems using computerized techniques, advances in materials technology and polymers, and last but not least, advances in medical genetics. This is the science that interests adolescents and would be included if the curriculum was, instead, organized around the question 'what makes young people want to learn science?' Yet there is as much chance of finding any contemporary science on the curriculum as there is water in a desert. This is not to argue for a curriculum based totally on contemporary science but simply for some aspects to be included as a vital point of engagement. (pg. 128)

Thus, how teachers organize and convey relevance to students by creating learning that is of interest, and by providing opportunities for students—regardless of future educational and occupational aspirations in STEM— supports the cultivation of positive experiences for students

in science classes. As shown in the previous chapter, students are more likely to be in an optimal learning moment in science when they are enjoying their task and when they perceive importance in it.

School Context

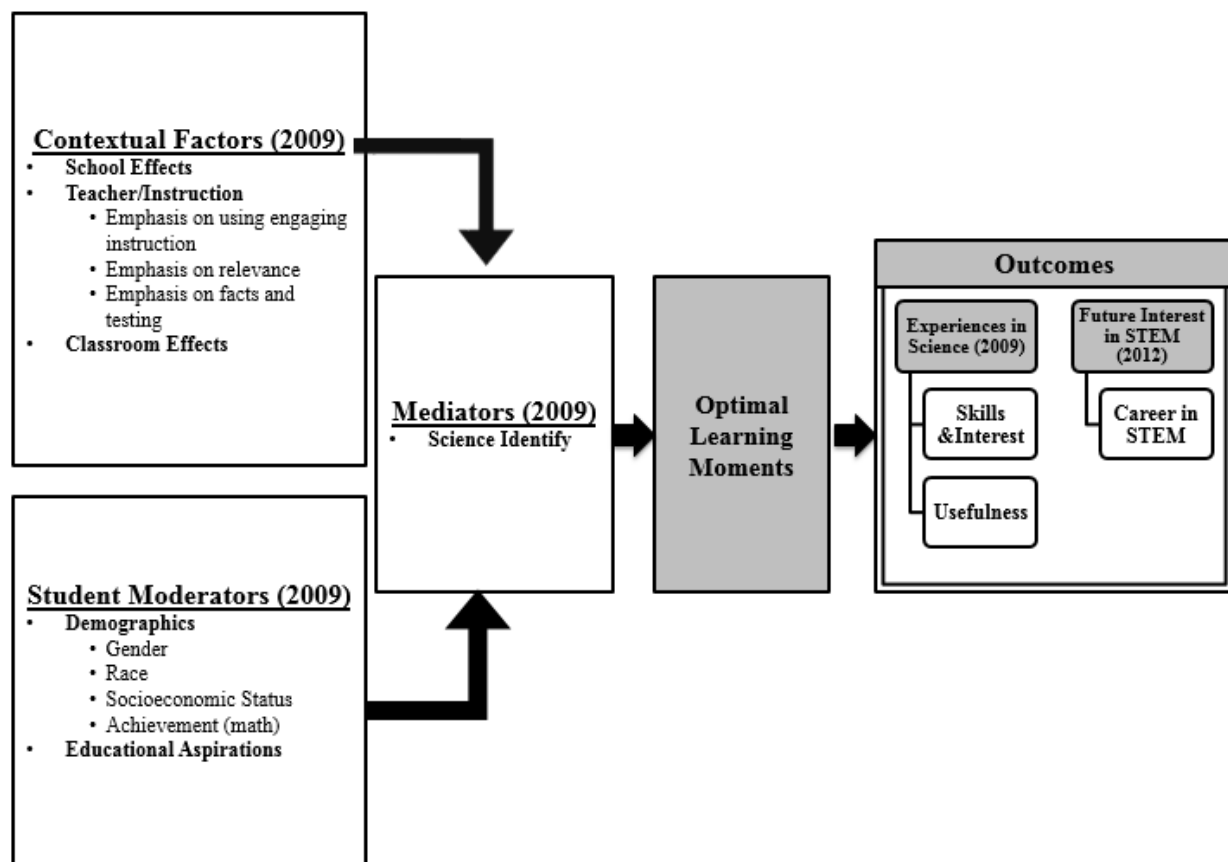
The student experience, as well as the teaching and instruction in science, are also shaped by the surrounding school context. While there are several benefits for schools to promote environments conducive for supporting engaged students, such as improved student achievement, high school completion, and matriculation to college (Csikszentmihalyi & Schneider, 2000; Klem & Connell, 2004; National Research Council [NRC], 2004; Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003), there is significant harm to students, teachers, and schools when students are not engaged. Students that become disengaged not only are subject to decreased learning and engagement, but this disengagement in school could lead to a downward spiral of the individual into dysfunctional and ultimately risky behavior, such as dropping out (Easton, 2008; Marks, 2000). Schools dealing with many disengaged students are at a significant risk of developing a school culture of disengagement—where the values of the disengaged become the dominant values of the student body, teachers, and the school overall. Due to this relationship between student engagement and school culture, promoting engagement as part of the school context in any school reform should be a necessary goal (Elmore et al., 1990).

Theoretical Framework

The framework for how students move through their high school science experiences, including decisions to pursue advanced coursework in science during high school and future ambitions in science, builds off of the conceptualization of engagement discussed in chapter one.

While the ESM analyses focused on moments of optimal learning, this section “zooms out” to consider additional contextual influences, such as the role of school factors, and student achievement measures. Recognizing the multidimensionality of learning and engagement and the need to understand longitudinal outcomes associated with being engaged (see Christenson, Reschley, & Wylie, 2012), these analyses will include the evaluation of both outcomes and additional mediators and moderators of science experiences not available to be analyzed with the ESM dataset, but is motivated by the findings of skill and interest in science class as well as the role of science importance (as measure by usefulness in this chapter) to positive outcomes in science.

Figure 4.1. Longitudinal Engagement Experiences in High School



As chapters two and three demonstrated, optimal learning moments, albeit rare in science classes, provided several key findings about factors associated with these situations of high challenge, skill, and interest. This portion is motivated by the circumstances and contexts that supported students' optimal learning moments in chapter three, as well as the findings related to the importance of the activity during science learning. Given the findings from the in-the-moment analyses of chapters two and three, how do these compare to a nationally representative dataset examining similar conditions of learning experiences in science classes? Specifically, using the HSLS:09 dataset, the "Outcomes" of Figure 4.1 box is examined.³ Specific school-level variables are not used in these analyses, however, by using a multi-level analytic approach, the variation within and between schools can still be accounted for.

Research Questions

- (1) How do experiences in ninth grade science vary, and how are they influenced by teacher and school characteristics?
 - a. What science courses are students enrolled in, and does this vary by student race, gender, socioeconomic status, and career aspirations?
 - b. What types of instruction and approaches to teaching do students' science teachers emphasize?
- (2) How do instructional variables predict usefulness, skills, and interest in ninth grade science courses?
- (3) How do experiences in ninth grade predict future aspirations in STEM?

³ There is no phenomenological factors box for these analyses because it is not able to be measured with this data. The variable "science identity" is used as a proxy of prior experiences with science

It is hypothesized that having more positive experiences in a science course may increase future interest in science and contribute to continued pursuit of advanced science coursework and a career in STEM.

Data and Methods

The HSLs:09 data is a nationally representative sample of 21,444 students in the ninth grade from 944 schools. The study uses a stratified, two-stage random sampling design, sampling the schools at stage one, and the students within schools at stage two. Currently, the HSLs:09 study contains two waves of data: the base year, which was in the fall of 2009 when the student sample was enrolled in the ninth grade, and the first follow-up, which occurred in the spring of 2012 when the sample was enrolled in the eleventh grade. HSLs:09 was specifically designed to capture students' experiences in high school, particularly in math and science. The dataset includes algebraic reasoning scores from an adaptive mathematics assessment in addition to contextual data from school administrators, guidance counselors, math and science teachers, and parents.

Measures

Data from both available waves of public-use HSLs:09 dataset are used to measure experiences of adolescents in their science classes. To capture experiences in science during the 2009 base year and to examine future aspirations in science in the first follow-up, variables from their ninth grade year are used. While the measures will include items from the student questionnaire, teacher questionnaire, and school (administrative) questionnaire, these variables are only representative of the student population, not of science teachers or high schools. Table 4.1 is a summary table of the HSLs:09 sample. There are two columns, one for the un-weighted

summary statistics and a second with the weights applied to create national population of close to 4.2 million ninth graders.

Table 4.1
Descriptive Characteristics of the HSLS:09

	National Sample	
	Unweighted	Weighted
<i>N of students</i>	21,444	4,197,724
Female	49%	50%
Race		
Asian/Pacific Islander	8%	4%
Black/African American	11%	14%
Hispanic	16%	22%
Other race/More than one	9%	8%
White	49%	48%
English is Native Language	72%	76%
Below Poverty Threshold	11%	13%
Individualized Education Plan	9%	10%
Postsecondary Ambitions		
Don't know	18%	8%
High School/GED	10%	6%
Complete Associate's Degree	5%	6%
Complete Bachelor's Degree	14%	20%
Complete Higher than Bachelor's	35%	28%
Previously in 9th grade	4%	5%

Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base-Year

Student variables. The first outcomes of interest include the student's reported experiences in their ninth grade science class, specifically their interest, skills, and their perception of the class' usefulness for everyday life. The second outcome examined is their career aspirations in STEM from their first follow-up survey. Demographic variables used in the analyses include a dummy variable for gender (recoded from X1SEX), race (a dummy variable was created for white, black, Hispanic, and other using X1RACE). For socioeconomic status a

dummy variable was created for if at least one of their parent's holds a bachelor's degree (X1MOMEDU and X1DADEDU). An achievement measure (X1TXMQUINT) is the student's quintile from a math reasoning standardized score from a computer-adaptive assessment administered during the base year. A dummy variable was created from X1STUEDEXPCT to indicate if the student expects to attain at least a bachelor's degree. As a mediating variable, the scaled item for the student's science identity (X1SCIID) is used, that is how the student views themselves as a "science person." It is hypothesized that this variable captures prior experiences with science.

Teacher variables. This analysis is focused on contextualizing students' experiences in their ninth grade science courses using data self-reported by their science teachers regarding the instruction and classroom environment. HSLs:09 contains eleven instructional variables used in this analysis to determine to what extent teachers emphasize the following aspects of their teaching in science: (a) increasing students' interest in science; (b) teaching basic science concepts; (c) important science terms/facts; (d) science process/inquiry skills; (e) preparation for further science study; (f) evaluating arguments based on evidence; (g) communicating science ideas; (h) business/industry applications; (i) relationship between science/technology/society; (j) history/nature of science; and (k) standardized test preparation (see Appendix E for questionnaire items).

A principal component analysis was conducted and item reliability check performed to create three instructional constructs: (1) *ENGAGE* created using N1INTEREST, N1SKILLS, N1PREPARE, N1EVIDENCE, and N1IDEAS with an *alpha* of 0.7769; (2) *RELEVANCE* created using N1BUSINESS, N1SOCIETY, and N1HISTORY with an *alpha* of 0.7196; and (3) *FACTS* created using N1CONCEPTS, N1TERMS, and N1TEST with an *alpha* of 0.4764.

Weighting and missing data. The estimates used were weighted according to recommended specifications in the HSLS:09 documentation. Balanced repeated replication procedures for variance estimation/standard error calculation methods were used to adjust for the unequal probability of selection into the sample. The base-year weight (W1STUDENT) is used for the descriptive analyses of the base-year data, and the longitudinal student weight (W2W1STU) is used for analyzing outcomes from 2012 and accounts for the base-year school nonresponse and student nonresponse in both the base-year and the first follow-up.

Analytic Approach

The HSLS:09 dataset is analyzed first using a series of descriptive analyses to examine trends and variation in science course-taking experiences as well as instructional characteristics as reported by the student's science teacher. Then, primary outcomes of interest: (1) experiences in ninth grade science class and (2) future aspirations in STEM are analyzed using an HGLM, with students (level-1) nested within classrooms/schools (level-2). Due to the sampling structure of HSLS:09, the classroom and school effects are at the same level. The full estimated HGLM for each outcome is:

Level 1 (student-level i)

$$\eta_{ij} = \pi_{0j} + \pi_{1j}(\text{male}) + \pi_{2j}(\text{minority}) + \pi_{3j}(\text{mathqint}) + \pi_{4j}(\text{stuBA}) + \pi_{5j}(\text{parBA}) + \pi_{6j}(\text{sciperson})$$

Level 2 (classroom/school j)

$$\pi_{0j} = \beta_{00} + \beta_{01}(\text{ENGAGE}) + \beta_{02}(\text{RELEVANCE}) + \beta_{03}(\text{FACTS}) + \beta_{04}(\text{PCTFRPL}) + \varepsilon_{0j}$$

where $\eta_{ij} = (\varphi_{ij}/1 - \varphi_{ij})$ is the logit link function and

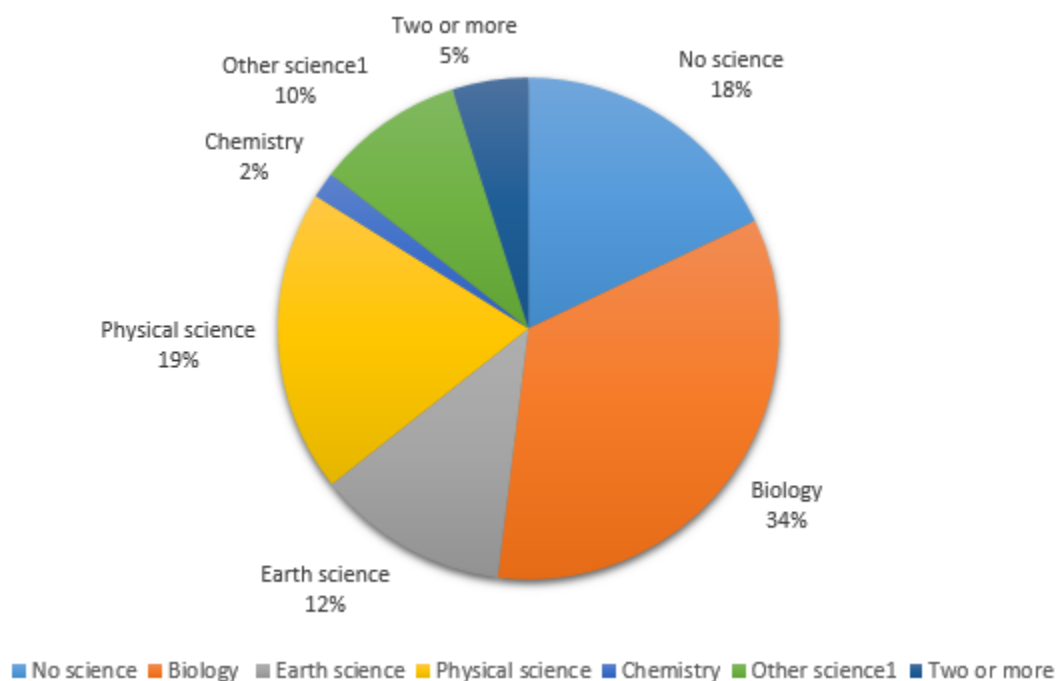
- φ_{ij} is the probability of the primary outcome (for student i in classroom/school j),
- *male* is a dummy variable equal to 1 for boys and 0 for girl students
- *minority* is a dummy variable if the race/ethnicity is Hispanic, Black, or Asian

- *mathquint* is a dummy variable equal to 1 if the student is in the top two quintiles
- *stuBA* is a dummy variable equal to 1 if a student expects to attain at least a bachelor's
- *parBA* is a dummy variable equal to 1 if a parent holds at least a bachelor's
- *ENGAGE* is a composite variable of the science teacher's emphasis on engaging instruction
- *RELEVANCE* is a composite variable of the science teacher's emphasis on relevant instruction
- *FACTS* is a composite variable of the science teacher's emphasis on fact-based instruction
- *PCTFRPL* is the percentage of students at a school receiving a free or reduced price lunch
- ε_{0j} is a random effect for classroom/school j

Results

To examine how experiences in ninth grade science may influence future outcomes, it is helpful to explore the characteristics of these ninth grade science classes. The science subject that students are enrolled in varies as there is no standardized course-sequencing from state to state. As shown in Figure 4.1, the majority of 9th graders (34%) were enrolled in a biology class, followed by 19% in physical science, and 12% in earth science. There were about 18% of students who were not enrolled in a science class at all.

Figure 4.2 Science Course Enrollment of 9th Graders from 2009-2010



Next, Table 4.2 examines how this enrollment in the top four categories (no science, biology, earth science, and physical science) varied by gender, race, and parent's education level.

⁴There does not appear to be enrollment difference by gender, with male and female students enrolled at similar rates across all courses. There are however, differences by race with Black and Hispanic students taking fewer science courses their 9th grade year, 25% and 22% respectively, and that is compared to an average non-enrollment of 18% across all races/ethnicities. There is a higher percentage of Asian students (44%) enrolled in biology

⁴ There were small cell sizes for the categories of chemistry, other science, and two or more science classes. If all categories were represented, the columns across each science category would sum to 100%.

Table 4.2
Science Course Enrollment by Student Characteristics

Characteristic	No science	Biology	Earth science	Physical science
Gender				
Male	19%	34%	13%	19%
Female	17%	35%	12%	20%
Race/Ethnicity				
White	15%	32%	14%	23%
Black	25%	31%	7%	21%
Hispanic	22%	28%	13%	10%
Asian	13%	44%	7%	16%
All other races	16%	33%	13%	19%
Parent/guardian education				
High school GED, or less	22%	31%	13%	19%
Associate's degree	15%	32%	13%	22%
Bachelor's degree	13%	39%	14%	19%
Graduate/professional	11%	44%	11%	18%
Career in STEM[^]	17%	44%	17%	12%

Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSL:09), Base-Year. Weighted with the W1STUDENT weight using BRR. [^]This dummy variable was coded using X1STU30OCC2 variable and the NSF classification list of STEM occupations

classes, compared to an average enrollment of 34% across all ninth graders. Both Asian and Black students are enrolled at lower rates in earth science courses, while Hispanic and Asian students enroll at lower rates in physical science courses. Students whose parents have at least a bachelor's degree enroll in higher rates in biology than students of parents with less education. However, across all parental education levels, students enroll most frequently in biology, including those who aspire to have a career in the STEM field.

While there is quite a bit of variation in the science enrollment of ninth graders, which is to be expected because of the diverse state policies regarding high school credit and graduation requirements, the next part of these analyses examine the instructional characteristics of the science teachers. Table 4.3 shows how the science teachers of the sampled students report emphasizing certain aspects of their instruction. It should be noted this is generalizable to the *student population*, not the population of teachers.⁵ The largest reported instructional emphasis is on basic concepts (40%), followed by science facts (29%) and inquiry skills (29%). The lowest reported instructional categories were emphasizing application (11%), history/nature (13%), and evaluating information. These instructional summary statistics, while obtained prior to the development of the new NGSS standards, reflect the environments in which the standards were beginning development and show how the current instructional practices in science class could become more aligned with what is outlined in the NGSS (e.g. focus on skills/practices, evaluating information, and communicating about ideas).

⁵ There is a high percentage of missing data from the science teachers. This is partially due to around 18% of the sample (about 3,900 students) not being in a science course, so they would not have an observation from their science teacher, which leaves about 5,400 observations missing from student-level file.

Table 4.3
Teacher Instructional Variables

	Students <i>N</i> =2,108,889
Emphasis on interest in science*	25%
Emphasis on basic concepts	40%
Emphasis on science facts	29%
Emphasis on inquiry skills	29%
Emphasis on further science	23%
Emphasis on evaluating	15%
Emphasis on communication	19%
Emphasis on application	11%
Emphasis on science/society	18%
Emphasis on history/nature	13%
Emphasis on test preparation	19%

Notes. The teacher data is not representative of all teachers. These data need more cleaning/work as there is a high percentage of missing items.

*Top categories (heavy) reported for the emphasis items.

The next set of analyses uses 2-level HGLMs to explore the relationship between the instructional variables, student background characteristics, and their experiences in their ninth grade science course. Table 4.4 shows how useful the student reported their 2009 science course was, and students who are a minority students who have a higher science identify are more likely to indicate their science class was useful. There were no significant differences between male and female students as well as students across different achievement levels for the usefulness of the class. The engagement factor at level-2 is a marginally significant predictor of students finding their science class useful, meaning that students with teachers who emphasize increasing interest, process skills, preparation for future study in science, evaluating evidence, and communicating ideas are more likely to view their class as useful for everyday life.

Table 4.4
HGLM Predicting Usefulness of 2009 Science Course - Full model

<i>Level-1 (students)</i>				
Variable	Coefficient	s.e.	Odds Ratio	<i>p</i>
Male	0.065	0.100	1.07	<i>0.518</i>
Minority	0.279	0.089	1.32	<i>0.002</i>
Student BA	0.055	0.096	1.06	<i>0.562</i>
Parent BA	-0.095	0.089	0.91	<i>0.284</i>
High Math Quintile	-0.137	0.096	0.87	<i>0.155</i>
Science Identity	0.984	0.110	2.68	<i>0.000</i>
<i>Level-2 (Classroom/School)</i>				
Variable	Coefficient	s.e.	Odds Ratio	<i>p</i>
Engage	0.246	0.129	1.28	<i>0.057</i>
Relevance	0.137	0.105	1.15	<i>0.194</i>
Facts	-0.117	0.125	0.89	<i>0.194</i>
Percent FRPL	0.002	0.003	1.00	<i>0.439</i>

Notes. Reliability estimate for random level-1 coefficient is .370

Examining the relationship between the level-1 and level-2 predictors and how skilled a student feels in their science class, Table 4.5 shows that students who have higher educational expectations, that have a parent with a bachelor's degree, have higher math achievement, and view themselves as a science person have a higher likelihood of feeling skilled in their science class. Students with a higher science identity in particular are three times more likely to report higher levels of skills in their science class. It is important to note that there are no differences between gender and races/ethnicities. None of the level-2 variables are significant, which could indicate that the efficacy a student experiences in their science class is a product of prior experiences and is less sensitive to the instruction or context of their course.

Table 4.5
HGLM Predicting Skills of 2009 Science Course - Full model

<i>Level-1 (students)</i>				
Variable	Coefficient	s.e.	Odds Ratio	<i>p</i>
Male	0.106	0.120	1.11	<i>0.374</i>
Minority	0.059	0.126	1.06	<i>0.639</i>
Student BA	0.296	0.120	1.35	<i>0.013</i>
Parent BA	0.238	0.105	1.27	<i>0.023</i>
High Math Quintile	0.401	0.113	1.49	<i>0.001</i>
Science Identity	1.500	0.110	4.49	<i>0.000</i>
<i>Level-2 (Classroom/School)</i>				
Variable	Coefficient	s.e.	Odds Ratio	<i>p</i>
Engage	0.163	0.174	1.18	<i>0.349</i>
Relevance	0.139	0.123	1.15	<i>0.259</i>
Facts	-0.159	0.122	0.85	<i>0.192</i>
Percent FRPL	0.003	0.003	1.00	<i>0.244</i>

Notes. Reliability estimate for random level-1 coefficient is .301

The level of interest in a student's science course, similar to skills, is an experience that is predicted by achievement and identity covariates—there is no significant relationship between instructional/context variables and interest in their science class as shown in Table 4.6. There is also no relationship between interest in the science class and gender, race, parental education, and the student's educational expectations. Again, this may suggest that interest in a domain such as science is shaped over time by multiple experiences, and this type of interest is not as malleable to situational determinants. This type of interest, however, is different than situational interest, which as shown in chapters two and three of this dissertation, does vary by context and is an outcome that is correlated by contextual factors, including instruction.

Table 4.6
HGLM Predicting Interest of 2009 Science Course - Full model

<i>Level-1 (students)</i>				
Variable	Coefficient	s.e.	Odds Ratio	<i>p</i>
Male	0.085	0.091	1.08	<i>0.352</i>
Minority	-0.114	0.097	0.89	<i>0.243</i>
Student BA	0.055	0.114	1.06	<i>0.632</i>
Parent BA	-0.063	0.099	0.94	<i>0.523</i>
High Math Quintile	0.299	0.090	1.34	<i>0.001</i>
Science Identity	0.756	0.083	2.12	<i>0.000</i>
<i>Level-2 (Classroom/School)</i>				
Variable	Coefficient	s.e.	Odds Ratio	<i>p</i>
Engage	0.058	0.156	1.06	<i>0.710</i>
Relevance	0.022	0.116	1.02	<i>0.847</i>
Facts	-0.077	0.107	0.93	<i>0.472</i>
Percent FRPL	-0.001	0.003	0.99	<i>0.663</i>

Notes. Reliability estimate for random level-1 coefficient is .373

In the final model, experiences and characteristics from the base year are used to predict the student's aspiration of a career in STEM in 2012, from the first follow-up survey. Table 4.7 shows that male students are more likely than female students to report a STEM career, as well as students with a higher math ability and that view themselves as a science person. At level-2, students that had teachers who again used engaging instructional modes were marginally more likely to indicate a science career in 2012 ($p=.081$). This model has the only outcome where the percentage of students receiving free or reduced price lunch at the school has a significant influence, with students in schools that have higher rates of free or reduced price lunch with a lower likelihood of interest in a STEM career. However, with an odds ratio of .99, the magnitude of this difference is small.

Table 4.7
HGLM Predicting STEM Career in 2012 - Full model

<i>Level-1 (students)</i>				
Variable	Coefficient	s.e.	Odds Ratio	<i>p</i>
Male	0.454	0.119	1.57	0.000
Minority	-0.130	0.115	0.87	0.260
Student BA	0.194	0.124	1.21	0.118
High Math Quintile	0.497	0.125	1.64	0.000
Science Identity	0.518	0.117	1.68	0.000
<i>Level-2 (Classroom/School)</i>				
Variable	Coefficient	s.e.	Odds Ratio	<i>p</i>
Engage	0.22	0.126	1.25	0.081
Relevance	-0.030	0.092	0.97	0.743
Facts	-0.101	0.135	0.90	0.455
Percent FRPL	-0.007	0.002	0.99	0.003

Notes. Reliability estimate for random level-1 coefficient is .166

Discussion

The experiences students have in science, as well as outside of science in other academic settings or their everyday life, are diverse and are shaped by past experiences, current contexts and situations, and future goals and aspirations. Examining the relationship between these dynamic factors in complex and changing environments is a challenging research endeavor. This chapter more narrowly focused on exploring the experiences of ninth grade students in their science class and understanding the relationship between their background characteristics, instruction, and positive outcomes. Using the HSLs:09 dataset, which was specifically designed to capture these experiences in math and science, proved exceptionally beneficial in supporting the investigation of how experiences in ninth grade science vary students; trends in science course enrollment and variation and how instructional variables predict usefulness, skills, and interest in ninth grade science courses.

While there is quite a bit of variation in which courses students take during ninth grade, biology has the highest percentage of students enrolled. Course enrollment does not vary by gender, which is a positive finding for reducing gender barriers in STEM subjects, however, enrollment does have higher variation between races, which could indicate that students from traditionally underrepresented backgrounds in STEM experience differentiated access to courses while in high school, contributing to the leaky STEM pipeline. However, there were no significant negative relationships between race and the experiences of students in their science course as shown in the HGLMs, which suggests that if there were perhaps more parity in enrollment between races, that once students were in the course, they would benefit from the experience.

The multi-level models show different impacts for level-1 and level-2 variables depending on the outcome of interest. Overall, it was difficult to uncover relationships between instructional variables and student-level outcomes. However, the engaging instructional factor was marginally significant at predicting the usefulness of the science class as well as future aspirations in science. Student background characteristics were more predictive of the level of skills and interest the students reported in their class, though not along lines of gender and race, which as suggested above demonstrates improved environments in science for these students. Despite the prior research, which suggested that math achievement has a significant impact on the development and support of educational and career aspirations in science, when considering how students reflect on their current experiences, particularly the usefulness of science in their everyday life, this was not significant. Teachers can make their science instruction meaningful and useful for all students, regardless of their achievement level, gender, educational expectations, or parental educational level.

Limitations

Compared to analyzing engagement through optimal learning moments, this dataset was limited in its ability to provide more detail about the types of experiences that occur on a daily basis in their science classes. It is also possible that their reported experiences in science are more of an indication of their teacher and not their teacher's instruction as these two often can become one mechanism. It is also a limitation of secondary dataset analysis in general that the scope and type of variables are pre-determined and the researcher must utilize the questions and variables set by the overseeing agency. For example, this study would benefit from exploring how challenging the student felt their science class was given the findings of chapter three. However, the question asked about challenge on the questionnaire reads: "9th grader is taking their fall 2009 science class because he/she likes to be challenged," which unfortunately does not provide information on if they found the class difficult.

The generalizability of these analyses is limited by the large quantity of missing responses, both from students who were not enrolled in a science class and from the science teachers who did not provide a questionnaire. Although the appropriate weights were applied as suggested by the HSLS:09 technical documentation, the findings should be interpreted with caution knowing that there could be sample bias, particularly for the instructional variables.

Lastly, the outcomes analyzed in this chapter while beneficial to understanding the student's experience in high school, are limited in their ability to examine longitudinal impacts of science experiences because of the timing and release of the transcript data (which is expected in the summer of 2015). Future analyses will be able to test course-taking patterns, eleventh and twelfth grade science enrollment in Advanced Placement and/or International Baccalaureate courses, and some postsecondary information. Because of the timing of this

present study and the release of these data, the outcomes were limited to those available in the base year and first follow-up.

Implications

Given the demand to increase interest in science, technology, engineering, and mathematics throughout the educational system, the high school can serve as a critical part in supporting students' interest in STEM. As students develop future educational and occupational plans, experiences in their courses, particularly in STEM subjects, can shape, support and spur their interest in the types of majors and careers to pursue. This study identified mechanisms that influence experiences in science, finding that enrollment in science is diverse and that the experiences of students including the usefulness, interest, and skills is influenced by a combination of student background, achievement, and instructional factors.

Overall, this suggests that some parts of the experiences of students in science are malleable and can be directly influenced by science teachers and their instruction (such as instruction that emphasizes processes and skills, preparing students for future study in science and communicating ideas). Both the ESM and HSLs:09 data suggest that teachers can shape and influence the context of learning and provide engaging opportunities for students—however, this type of instruction should be implemented with a balanced approach—there is certainly content that needs to be presented in a fact-based lecture for example, but what this study highlights is that certain types instruction is correlated with positive learning outcomes. The ESM data in particular shows that when students are *enjoying* their task and find *importance* in what they are doing (regardless of what the activity is), this was related to having an optimal learning moment in science.

Improving STEM education is one policy lever utilized to strengthen the pipeline of talent from high schools into the STEM workforce. Even though not all students will be interested or enter a STEM workforce, these skills and concepts support the development of a well-educated science citizenry. While contributing to the research on the relationship between engaging experiences and instruction for researchers and policymakers, this research provides teachers with evidence on the experiences of students in their class, which has implications for their instruction and could potentially be a tool for how they emphasize certain instructional approaches in their classrooms. As requirements for the number and level of science classes increase and with the development and adoption of NGSS across states, understanding the experiences of students in high school and the role of teachers in fostering engagement is an important area to continue to research.

APPENDIX

Appendix

HSLs:09 Selected Teacher Questionnaire Items

* Think about the full duration of this [fall 2009 science] course. How much emphasis are you placing on each of the following objectives?

Increasing students' interest in science

No emphasis

Minimal Emphasis

Moderate Emphasis

Heavy Emphasis

Teaching students basic science concepts

No emphasis

Minimal Emphasis

Moderate Emphasis

Heavy Emphasis

Teaching students important terms and facts of science

No emphasis

Minimal Emphasis

Moderate Emphasis

Heavy Emphasis

Teaching students science process or inquiry skills

No emphasis

Minimal Emphasis

Moderate Emphasis

Heavy Emphasis

Preparing students for further study in science

No emphasis

Minimal Emphasis

Moderate Emphasis

Heavy Emphasis

Teaching students to evaluate arguments based on scientific evidence

No emphasis

Minimal Emphasis

Moderate Emphasis

Heavy Emphasis

Teaching students how to communicate ideas in science effectively

No emphasis

Minimal Emphasis

Moderate Emphasis

Heavy Emphasis

Teaching students about the applications of science in business and industry

No emphasis

Minimal Emphasis

Moderate Emphasis

Heavy Emphasis

Teaching students about the relationship between science, technology, and society

No emphasis

Minimal Emphasis

Moderate Emphasis

Heavy Emphasis

Teaching students about the history and nature of science

No emphasis

Minimal Emphasis

Moderate Emphasis

Heavy Emphasis

Preparing students for standardized tests

No emphasis

Minimal Emphasis

Moderate Emphasis

Heavy Emphasis

U.S. Department of Education
National Center for Education Statistics

High School Longitudinal Study of 2009
OMB No: 1850-0852

REFERENCES

REFERENCES

- Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior*. Englewood Cliffs, NJ: Prentice-Hall.
- Christenson, S., Reschly, A., & Wylie, C. (2012). *Handbook of research on student engagement*. New York: Springer.
- Csikszentmihalyi, M., & Schneider, B. (2000) *Becoming adult*. New York: Basic Books.
- Easton, L. B. (2008). *Engaging the disengaged: How schools can help struggling students succeed*. Thousand Oaks, CA: Corwin Press.
- Elmore, R. F. and Others (1990). *Restructuring schools: The next generation of educational reform*. San Francisco: Jossey-Bass.
- Gamoran, A. (1987). The stratification of high school learning opportunities. *Sociology of Education*, 60(3), 61–77.
- Hallinan, M. & Kubitschek, W. (1999). Curriculum differentiation and high school achievement. *Social Psychology of Education*, 3(1–2), 41–62.
- Hanushek, E.A., Jamison, D.T., Jamison, E.A., & Woessmann, L. (2008). Education and economic growth: It's not just going to school but learning that matters. *Education Next*, 8(2), 62-70.
- Klem, A.M. & Connell, J. (2004). Relationships matter: Linking teacher support to student engagement and achievement. *Journal of School Health*, 74(7), 262-273.
- Marks, H.M. (2000). Student engagement in instructional activity: Patterns in the elementary, middle, and high school years. *American Educational Research Journal*, 37(1), 153-184.
- Muro, M., Rothwell, J., Andes, S., Fikri, K., & Kulkarni, S. (2015). *American's advanced industries: What they are, where they are, and why they matter*. Washington DC: Brookings Institution Press.
- National Academies. (2012). 3 Dimension 1: Scientific and engineering practices. *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.
- National Center for Education Statistics. (2013). *High School Longitudinal Study of 2009 (First Follow-Up)* [Public-use Data File]. Washington DC: Department of Education.

- National Research Council. (2004). *Engaging schools: Fostering high school student's motivation to learn*. Committee on Increasing High School Students' Engagement and Motivation to Learn. Board on Children, Youth, and Families, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.
- OECD. (2007). PISA 2006: Science competencies for tomorrow's world – Volume 1- Analysis. Paris, France: OECD Publishing.
- OECD. (2013). PISA 2012 results: What students know and can do: Student performance in mathematics, reading and science (Volume I). Paris, France: OECD Publishing.
- Osborne, J.F., & Collins, S. (2000). *Pupils' and parents' views of the school science curriculum*. London: King's College.
- Osborne, J.F. (2002). The challenge for science education for the twenty-first century. Pontifical Academy of Sciences, *Scripta Varia 104*, Vatican City.
- Osborne, J., Simon, S. & Collins, S. (2003). Attitude towards science: a review of the literature and its implications. *International Journal of Science Education*, 25(9), 1049–1079.
- Osborne, J., & Dillon, J. (2008). Science education in Europe: Critical reflections. London: The Nuffield Foundation.
- Shernoff, D., Csikszentmihalyi, M., Schneider, B., & Shernoff, E. (2003). Student engagement in high school classrooms from the perspective of flow theory. *School Psychology Quarterly*, 18(2), 158-176.
- Wang, X. (2013). Why students choose STEM majors: Motivation, high school learning, and postsecondary context of support. *American Educational research Journal*, 50(5), 1081-1121.

CHAPTER 5: CONCLUSION

The primary goal of this study was to understand what contributes to student experiences in high school science classes using a mixed-dataset approach. Examining data from two different sources provided a unique perspective on students' learning experiences and the contexts in which it develops. Engagement was operationalized across the chapters using features of flow theory to evaluate how the challenge, skill, interest, importance and value in science classes vary across students and settings. The multiple analytic approaches motivated by a singular conceptual framework provides information about the students and the instruction they experienced, which contributes to how teachers can plan and implement their teaching in science.

After the overall framework and organization for this dissertation was presented in chapter one, the first part of this study in chapter two explored and validated the construct of optimal learning moments using in the ESM data. Several different measures of engagement were reviewed and tested to uncover variation in optimal learning moments, as well as relationships between the situational and cross-situational measures of engagement in science. Chapter three analyzed the same ESM dataset in more detail by examining how optimal learning moments varied across students and their environments, including the instruction of their science teachers. In chapter four, the HSLs dataset is used to analyze experiences in science based on the findings from chapters two and three. Specifically, the questions of how engagement influences experiences in ninth grade science are investigated, including: students' perception of the class' usefulness for everyday life, their skills in the course, their level of interest in the course, and the students' interest in pursuing a career in STEM in the first follow-up.

Summary of Findings

In chapter two, relationships between different measures of engagement were tested, and the findings suggest that multiple measures of engagement can help capture the multidimensionality of optimal learning experiences. Examining the variation of, and the relationship between both situational and cross-situational measures of engagement proved useful in establishing the measures employed in the study, while uncovering how the different measures influenced each other. Comparison of using raw scores and Z-scores for the ESM affective measures supported the use of standardizing measures of optimal learning by capturing deviation for each student's mean level, although both appear to be valid constructs of engagement. This study also contributes to measuring optimal experiences in relationship to other states associated with being in flow, including persistence, time flying by, and concentration, which provided further evidence on the engagement measure used in chapter three.

Throughout the chapters, there were some themes that were repeated across the studies, while some of the findings were varied from one chapter to the next. Gender, for example, was a consistent source of variation across the studies in this dissertation. The first set of analyses examining how optimal learning moments varied across students found that males experience more optimal learning moments than female students, however, this gap did narrow in science classes. Gender was not a significant predictor of being in an optimal learning moment in science when conditioning on enjoyment, importance, and persistence in the moment (level-1), and science attitudes of the student (level-2). There were also no gender differences in science course-taking in ninth grade, but there were gender differences in students' interest in pursuing a career in STEM, after conditioning on their experiences in ninth grade science. Males in both the base-year and first follow-up report higher levels of career aspirations in STEM, which

highlights that despite similar reported experiences in high school, the gap in aspirations persists. Future research could explore additional influences on this outcome and how the gap between male and female students changes throughout high school and in to college.

Another finding present in both chapters three and four is that in order to enable more optimal learning experiences, students in science need to find relevance and value in what they are learning and understand how it is applicable to their lives, regardless of whether or not they intend to pursue a career in a STEM field. The importance of the activity during science was a significant predictor of being in an optimal learning moment as well as enjoyment—indicating that a learning environment should not only create value in the content, but also make learning exciting and enjoyable. Extending this finding into chapter four and the types of instruction that might create higher value or usefulness of the science class, evidence suggests that instruction that emphasizes increasing interest, using process skills, preparing students for future study in science, evaluating evidence, and communicating their ideas contributes to students finding higher usefulness for their science class.

Limitations

While each chapter summarized its own study limitations, there are some additional limitations to the overall design of this dissertation. The ESM sample was limited to four schools and teachers that had indicated interest in participating in this study of engagement, and one of the schools was specifically using their professional development to support teachers in increasing student engagement. Thus, the generalizability of findings is limited and results should be interpreted with consideration for the small sample of students and teachers. Despite the small sample of schools and teachers, the schools did vary in location and size, ranging from a smaller rural school to a larger urban school, which does provide some variation at the school

level. Using the HSLs:09 did provide a larger national sample, however, because of the missing teacher data, these findings should also be interpreted conservatively. Even with these sampling concerns across the studies, finding consistent results about engagement using the two different datasets and analytic approaches does provide evidence as to sources of variation and what contributes to learning experiences for students.

There were certainly measures across both studies that provided similar details about student learning experiences in science, however, the items used were not the same in both studies for the students or their teachers. For example, using the HSLs:09 teacher survey instrument to collect data about instruction from the teachers in the ESM study would have allowed for a better alignment of items across the samples and improved this student's ability to measure the in-the-moment experiences of students given specific instructional approaches by the teacher. While instruments in the ESM study were still constructed using previously validated items, these questions came from international questionnaires because the ESM study was part of a larger international research project, thus the HSLs:09 items were not used. Research done after the completion of this dissertation was able to collect additional data from the teachers to address the weaknesses of more fully capturing the learning environments, and future analyses will be able to utilize these improvements to the overall design of the research project.

Policy Implications

There is no question that improving learning environments and providing students more opportunities to be engaged motivates the research and policies undertaken to enhance the educational experiences for students. However, there is no one-size-fits-all approach or a magic bullet that can accomplish these broad goals, and determining what is good teaching also remains

a top priority with countless studies using a diverse set of approaches and perspectives to undertaking this task. For example, the Measures of Effective Teaching (MET) project was a two-year study that included over 3,000 teachers in seven large districts across the country, and employed teacher surveys, student surveys of the teacher, achievement measures, and 360-degree video cameras that captured every angle of the classroom instruction. The goal of the MET project was to determine which classroom measures were highly associated with high levels of student achievement, including student engagement and the role of teachers in delivering engaging instruction (MET, 2010). Preliminary findings from the MET project showed that there is a positive correlation between highly-rated teachers and improved student achievement (MET, 2012). The MET project is an example of how the exhaustive field of engagement literature can be considered when evaluating teaching and learning.

This dissertation also contributes to how technology can be used in education research. Measuring engagement using innovative smartphone technology not only lessened the burden of cleaning and preparing the ESM data compared to previous paper-and-pencil methods, but this research also informs how new technologies can be used for measuring the individual experience, or other types of data collection using smartphones more broadly for education research. Because of the increased use and assimilation of smartphones in daily lives, technology, such as the app used in this study, Paco, is well-positioned to streamline the ability of capturing several different types of data and using a diverse set of time frames (e.g. collecting daily, weekly, or even at the end of every learning unit in school). Anecdotally, the use of smartphones for data collection or other innovative uses in research may have particular value in reaching students, schools, families and other community members in urban or rural low-income communities due to the role of smartphones in being a primary source of accessing information.

According to the most recent Pew Research Center Study (2013), 78% of teens now have a cell phone, and almost half of these devices are smartphones. This is a rapidly increasing amount, up 14 percentage points from just 2 years ago. The report highlights that accessing the internet on a phone is common among today's adolescents, and there is a growing opportunity to capitalize on this as a lower-cost and effective way of obtaining data compared to paper-and-pencil and even computer-based surveys.

Finally, there are also implications beyond the science classroom. While all subjects could benefit from teachers connecting learning to something that the student cares about, which can increase interest and understanding—this is of particular value across science, technology, engineering and mathematics, which are areas that the students might not otherwise experience in their daily lives. There are opportunities to strengthen the students' understanding of concepts and practices when connections can be integrated across the STEM disciplines (Honey, Pearson, & Schweingruber, 2014). This includes the adoption and implementation of the standards, such as the Common Core State Standards in mathematics, the NGSS, and the Standards for Technological Practice, which have been designed specifically to be integrated with one another. Using instructional approaches that utilize project-based learning for example, which emphasize student-led learning and provide a balance of challenge and skill, can also help shape improved learning environments in STEM. This is not to say that all instruction should be integrated all the time or should always use project-based learning (this is unrealistic given teacher preparation, time, and resources constraints), however, using these principles when it can create stronger connections for students, deepen their understanding of the content, and develop relevance for their own lives can lead to engaging learning experiences and students that will be better prepared for their educational and occupational futures.

REFERENCES

REFERENCES

- Honey, M., Pearson, G., & Schweingruber, H. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. Washington DC: National Academies Press.
- Madden, M., Lehnart, A., Duggan, M., Cortesi, S. & Gasser, U. (2013). *Teens and technology 2013*. Pew Research Center. Retrieved from:
http://www.pewinternet.org/files/oldmedia/Files/Reports/2013/PIP_TeensandTechnology2013.pdf
- Measures of Effective Teacher Project (MET). (2010). *Learning about teaching: Initial findings from the measures of effective teaching project*. Seattle, WA: Bill and Melinda Gates Foundation.
- Measures of Effective Teacher Project (MET). (2012). *Gathering feedback for teaching: research paper*. Seattle, WA: Bill and Melinda Gates Foundation.