EXAMINING MOTIVATIONAL SHIFTS IN MIDDLE SCHOOL: WHAT DEEPENS SCIENCE MOTIVATION AND WHAT ATTENUATES ITS DECLINE?

by

Meghan Elizabeth Bathgate

B.A. Psychology, Rhode Island College, 2006

B.A. Philosophy, Rhode Island College, 2006

M.A. Experimental Psychology, University of Massachusetts, Dartmouth, 2011

Submitted to the Graduate Faculty of the

Kenneth P. Dietrich School of Arts and Sciences in partial

fulfillment of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2016

UNIVERSITY OF PITTSBURGH

DIETRICH SCHOOL OF ARTS & SCIENCES

This dissertation was presented

by

Meghan Elizabeth Bathgate

It was defended on

August 1, 2016

and approved by

Ming-Te Wang, Associate Professor, Psychology

Timothy Nokes-Malach, Associate Professor, Psychology

Kevin Crowley, Professor, Learning Science & Policy

Dissertation Advisor: Christian D. Schunn, Professor, Psychology

EXAMINING MOTIVATIONAL SHIFTS IN MIDDLE SCHOOL: WHAT DEEPENS SCIENCE MOTIVATION AND WHAT ATTENUATES ITS DECLINE?

Meghan Elizabeth Bathgate, PhD

University of Pittsburgh, 2016

While motivational decline towards science is common during adolescence, this dissertation asks if there are beneficial science experiences that buffer against the loss of motivation and even promote its growth. The dissertation consists of two papers (Chapter 2 & 3) with additional analyses in Chapter 4 and a summary of findings in Chapter 5. The first paper examines whether classroom science experiences are differentially associated with motivational change and science content knowledge. Using self-reports from a sample of approximately 3,000 middle school students, this study investigates the influence of perceived science classroom experiences (student engagement & perceived success), on motivational change (fascination, values, competency belief) and content learning. Controlling for demographic information, school effects, and initial levels of motivation and content knowledge, we find that dimensions of engagement (affect, behavioral-cognitive) and perceived success are differentially associated with changes in particular motivational constructs and learning. The second paper examines one of these motivational outcomes (value) in more detail. Valuing science is associated with positive learning outcomes and is often used to motivate engagement in the sciences, but less is known about what influences its development and maintenance, particularly during the critical middle school years. Using multinomial regression applied to longitudinal data from approximately 2,600 middle-school students, I test the relationship of the perceived science experiences examined in Paper 1 (affective engagement, behavioral-cognitive engagement, &

perceived success) and optional formal and optional informal experiences to changes in science utility value. Furthermore, we address whether the same factors that predict growth in science value also predict absence of decline. Overall, we find that all five factors are associated with changes in value, but some have different relationships with growth vs. decline outcomes. Chapter 4 extends these findings to examine drivers of growth and decline for fascination and competency beliefs. Together, these findings provide a more nuanced view of the factors associated with science motivation and learning (both in and out of the science classroom), as well as the practical implications for educational practice.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

The celebration of this step in my life is shared with the people who have supported me in this journey. My loving husband, beautiful daughter, supportive parents, inspirational family members, my clever advisor, close colleagues, wonderful friends and immense grace and faith have all served as the foundation for this achievement.

1.0 INTRODUCTION

At a time of growing scientific exploration and ingenuity, there remains a persistent decline in learners' desire and ambition to pursue the sciences through their education (e.g., Osborne, Simon, & Collins, 2003). How can we enable learners to persist in their path towards science? How can we promote scientific literacy and engagement across the lifespan? These are the questions that drive my work and lay the foundation for this dissertation, which examines learners' experiences with science during the transitional time of adolescence. The scope of this dissertation includes two articles (Chapter 2 & 3), each addressing a set of research questions exploring the relationship among learners' science experiences and motivational change, along with additional analyses (Chapter 4) extending this work by examining additional outcomes.

The first article (Chapter 2) investigates middle school students' science classroom experiences (affective engagement, behavioral-cognitive engagement, & perceived success) and their relationship with changes in three motivational outcomes (fascination, values, competency beliefs) and one science content knowledge assessment. Specifically, this work asks: 1) Which aspects of motivational change are associated with student engagement and perceived success and 2) Are engagement and perceived success associated with content learning?

The second article drills down into one particular motivational outcome, *value*, to 1) further investigate the effects of classroom experiences in combination with learners' optional science experiences (both informal & formal), and 2) to explore the question of whether different factors are associated with qualitatively different types of motivational change. That is, are there different factors that enable motivational growth versus buffering against motivational loss? Motivational research generally conceptualizes motivational changes as symmetric across growth and decline. However, growth and decline outcomes are importantly different, and may be associated with different factors. As such, Chapter 3 examines whether experiential features within science (e.g., engagement, perceived success, optional science experiences) differentially influence patterns of value growth vs. value declines.

Chapter 4 extends Chapter 3 by following the same procedure (i.e., examining science experiences differential relationship on growth vs. decline), but using different motivational outcomes: fascination and competency beliefs. Finally, Chapter 5 provides a general review and summary of findings across Chapters 2—4.

The models used across Chapters 2—4 use many of the same variables and draw from the same data set (Activation Lab: Enables Success [ALES] 2014). However, because these articles are submitted to different journals with different audiences and requirements, there are slight differences in some of the phrasing. For example, engagement and perceived success variables are referred to as "perceived learning experiences" in Chapter 2 and "science learning experiences" in Chapter 3. The result sections clearly indicate these variables where appropriate.

2.0 KEY CHARACTERISTICS OF SCIENCE LERNAING EXPERIENCES: INFLUENCES OF ENGAGEMENT AND PERCEIVED SUCCESS ON SCIENCE MOTIVATION AND CONTENT LEARNING

The importance of educating upcoming generations in the sciences has been well argued (NRC, 2008; 2009), but the state of science education has shown to be lacking in a number of ways. From existing educational experience, many students are performing poorly and are losing a desire to persist in science (NRC, 2009; Schen & Tam, 2008). However, while the literature often points to a general decline in science motivation during adolescence (e.g., Osborne, Simon, & Collins, 2003), there is growing evidence that this decline is not uniform, but rather is influenced by experiential factors (Maltese, Melki, & Weibke, 2014; Vedder-Weiss & Fortus, 2011, 2012; Gottfried, Fleming, & Gottfried, 2001). As such, rather than focusing on motivational loss during middle school, we are interested in understanding the nature of students' experiences (e.g., levels and nature of engagement during a science class activity) that contribute to the growth of motivation, or at least buffer its decline. Further, we wish to understand whether the same experiences that improve one's learning of science content are associated with growth in motivation.

.

2.1 WHAT ARE THE MOTIVATIONAL PILLARS IN SCIENCE?

Before investigating factors that may attenuate science motivation during middle school, it is important to identify critical motivational outcomes. The motivational literature points to variety of theories, but most agree that we ideally desire learners who are intrigued by scientific concepts, see both the daily and long-term value of science and scientific practices, and feel capable of engaging in scientific practices and discussions. These concepts are captured in the following motivational constructs.

2.1.1 Intrinsic motivation: Fascination, interest, mastery, & curiosity

Intrinsic motivation towards a task arises from a learner's internal desire to engage with the task and underlying topic itself (Bathgate, Schunn, & Correnti, 2013; Bryan, Glynn, & Kittleson, 2011; Deci & Ryan, 1985; Ryan & Deci, 2000). Learners who are intrinsically motivated towards an activity, for example, are driven by their enjoyment of the activity itself, as opposed to being motivated by the consequences of that activity (e.g., getting a good grade on an activity). Interest is one example of this type of motivation. The role interest plays in driving behavior has gained increasing attention, as researchers and educators continue to demonstrate its association with persistence (Simpkins, Davis-Kean, & Eccles, 2006), choice (Sha, Schunn, & Bathgate, 2015), and learning (Zusho & Pintrich, 2003; Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011). Defined as both an emotional and cognitive factor, interest is thought to develop over time as learners reengage positively with particular content (Hidi & Renninger, 2006), such as science. When learners are interested in an area, particularly when that interest is at least somewhat developed and stable over time, they tend to persist and enjoy future activities related to that same content (Hidi & Renninger, 2006). For example, if a learner positively engages with science material that sparks her interest, the more likely she will seek out future science activities and have positive experiences with them.

In science, intrinsic motivation also involves curiosity in the workings of the natural world (Zimmerman, 2012; Jenkins & Pell, 2006; Baram-Tsabari & Yarden, 2007; Prokop, Prokop, & Tunnicliffe, 2007). Both interest and curiosity are usually found to coincide with a mastery approach (Hilpert, Stempien, van der Hoeven Kraft, & Husman, 2013; Cho & Summers, 2012), in which a learner desires to deeply understand a topic or discipline (Elliot, 1999; Elliot & McGregor, 2001; Ames, 1992). In general, a mastery approach is often thought to be intrinsically driven, where a learner is pursuing a knowledge or skill for its own reward as opposed to proving or demonstrating knowledge (referred to as a performance approach; Elliot & McGregor, 2001).

Interest, curiosity, and mastery goals each have each been associated with deeper learning and persistence (Hidi & Renninger, 2006; Silvia, 2006; Loewenstein, 1994; Elliot & McGregor, 1999; 2001; Richey, Nokes-Malach, & Wallace, 2014). Because of the similar effects on learning behaviors, their regular co-occurrence (Hilpert, et al., 2013) to the point of loading on a single underlying factor, interest, curiosity and mastery are conceptualized as components of the overarching construct of *Fascination* (Activation Lab Fascination Technical Report, 2014; http://www.activationlab.org/tools/). Collectively, Fascination then involves the interest and positive affect one has towards science, curiosity towards the natural world, and goals towards acquiring and mastering scientific skills and ideas.

2.1.2 Extrinsic motivation: Values

Often held in contrast to intrinsic motivation, extrinsic motivations arise from a desire to meet a secondary goal. In other words, an extrinsically motivated learner participates in an activity for the consequences of that activity (e.g., receiving a good grade or payment for completing a task), irrespective of the enjoyment he receives from participating. For example, a student may choose to enroll in a science camp because they need additional experience to apply for college, not because they enjoy the processes of science. Our conceptualization of value stems from Expectancy-Value Theory (Wigfield & Eccles, 2000)—specifically the concept of utility value—and represents both the personal and societal value one places on science. In the area of science specifically, extrinsic motivation reflects the value the learner places on science because of its utility in meeting personal goals (e.g., doing well in classes, understanding how the world works) or its utility to society (e.g., science is helpful to solving environmental problems).

2.1.3 Competency beliefs

Motivational theories such as Eccles and Wigfield's Expectancy-Value Theory (Eccles & Wigfield, 2002) and Bandura's work in efficacy beliefs (Bandura, 1993; 1997) make an important delineation between the (intrinsic or extrinsic) valuation of an area and learner perceptions of ability to perform well in that area (i.e., their competency beliefs). For example, a learner may be interested in a topic but feels they do not have the skills needed to do well within an activity about that topic (e.g., a student is interested in robotics but does not think they would do well participating in a robotics club). These competency beliefs have repercussions for whether a leaner chooses to participate in activities, as well as how well they perform within them (Beghetto, 2007; Britner & Pajares, 2006).

2.2 THE NATURE OF EXPERIENCES THAT INFLUENCE MOTIVATIONAL CHANGE AND CONTENT LEARNING

Learner's experiences within a science activity can influence how much science content is learned, as well their motivation to learn science. For example, a learner given too little support to complete a complex science activity may not be able to complete the activity well and leave that experience feeling discouraged. Perhaps with repeated experiences like this one, they conclude they are not good at science and become disinterested. Conversely, a learner given more support may have positive, successful experiences that then build a stronger sense of competence to develop a stable interest in science and expand their interest and knowledge.

Learners interact with science across a range of settings, including classroom science. Perceived science classroom experiences, that is one's self-reported emotional, behavioral, and cognitive experiences within a classroom, provide learners explicit feedback on achievement and repeated exposure to science content. There are certainly other factors that influence science motivation and learning (e.g., family values towards science, amount of informal science experiences); however, we focus on perceived science classroom experiences for three reasons. First, measuring learners' perceptions (as opposed to measuring type of activity, for example) provides insight into how learners experience a situation rather than assuming the type of activity is indicative of the experience itself. That is, it is the perception of these experiences that are expected to influence motivation and learning, rather than the type of activity itself. We recognize some activities may be more generally engaging, but the mechanism for motivational change lies within learners' perceptions of this experience. Secondly, while not every student has access to quality out-of-school science activities (e.g., camps, museums), all students take part in school science from middle school onwards. As such, understanding the influence of these experiences allows us to explore the mechanisms at work within them and leverage the positive influences of these activities (and suppress the negative) to impact many students. Finally, these experiences are malleable through a number of education policies (e.g., new curriculum guidelines or teacher professional development efforts). While one's family perception of science and demographic variables (gender, age) are associated with differences in science motivation and learning (Fan & Williams, 2010; Fan, et al., 2012; Grolnick & Slowiaczek, 1994; Archer, et al., 2012) and we do control for some parental and home variables (described in the Methods below), these variables are more stable and researchers and practitioners often have little or no direct influence on them.

We focus on two well-researched constructs, engagement and perceived success, each of which have been studied in isolation in relation to motivation or content learning in science, the outcomes of the current study.

2.2.1 Engagement

Engagement refers to the way an individual interacts with a particular task (or repeatedly in a domain across many such tasks) and is generally thought to consist of three dimensions: 1) affective engagement, how one feels (i.e., the emotional experience) during an activity or task, 2) behavioral engagement, what one actually does during an activity or task, and 3) cognitive engagement, the way one thinks (i.e., the type of cognitive processing utilized, such as degree of attention and making connections among ideas) during an activity or task (Fredricks, Blumenfeld, & Paris, 2004; Fredricks, et al., 2011). Overall, engagement has a robust connection with achievement, participation, and motivation in many educational areas and specifically in the sciences (Fredricks, Blumenfeld, & Paris, 2004; Wang & Eccles, 2012; Ainley & Ainley, 2011; Pekrun & Linnenbrink-Garcia, 2012; Stewart, 2008; Tytler & Osborne 2012). Specifically, affective (Steward, 2008), behavioral and cognitive (Wang and Eccles, 2012; Marks, 2000; Connell & Welborn, 1991) engagement each have empirical relationships with achievement in adolescence. Engagement has also been shown to relate to high-school students' academic motivation (e.g., self-efficacy) over time (e.g, Reeve & Lee, 2014).

Therefore, we expect there to be a relationship between the degree of engagement a learner experiences within an activity and larger changes in their motivation and learning over time in the current similarly aged sample. However, as the field learns more about engagement and how it functions, more questions are raised regarding the relationship and influence of the individual engagement dimensions on various outcomes, and the best way to measure engagement across diverse science learning activities. We address these open questions by examining the relative relationship of engagement dimensions on multiple motivational and learning outcomes using a measure targeted at students' reflection immediately following their experience.

2.2.2 Perceived success

In addition to a learner's immediate engagement in an activity, a learner also has a sense of how well they performed on a given task, often based on implicit or explicit feedback they receive during or following the activity. These perceived success experiences are hypothesized to relate to one's seeking similar experiences and, subsequently, more challenging experiences to develop their skills and have a history of being associated with achievement (e.g., Ryan & Deci, 2000; Bandura, 1993; Britner & Pajares, 2006; Schiefele, 2009). For example, a learner who feels as if they did well on an activity shows greater interest in similar activities in the future and may feel more capable of performing well on them (Pajares, 1997).

Both engagement and perceived success are malleable factors that can be supported by teacher, peer, or tool scaffolds (Wang & Holcome, 2010; Wang & Degol, 2014; Marks, 2000; Jang, Reeve, & Deci, 2010) and each of these elements (engagement and perceived success) are theorized to impact not only the immediate experience of a learner, but also build towards their broader motivations and learning within a domain (i.e., science). Therefore, we focus on these constructs as the main potential predictors of motivational change and learning gains in middle school science.

2.3 THE CURRENT STUDY

It is clear from the existing literature that the concepts described above have a strong history of empirical research; however, there remain critical open questions our current work will address. Specifically, while we know engagement and perceived success are associated with motivation and learning outcomes, we do not know their influence *across* motivational outcomes (i.e., do they have a similar impact for value vs. competency belief?) and their relative effects when examined concurrently (i.e., is each still influential when controlling for other?). By using a single data set with four outcomes (fascination, values, competency belief, and content knowledge) and measuring engagement and perceived success at the same time, we are able to describe the pattern of results across three types of motivation change[1] and content learning as well as control for any shared variance between engagement and perceived success.

In particular, the current study examines middle school students' self-reported experiences (engagement & perceptions of success) during their science classes and the influence of these factors on changes in their motivation (fascination, values, competency beliefs) and classroom content learning during the course of a school semester. Specifically, we ask the following research questions:

RQ 1: Which aspects of motivational change are associated with perceived classroom experiences of engagement and perceived success?

RQ 2: Are engagement and perceived success associated with content learning?

As part of addressing these questions, we also examine the internal structure and co-variation of engagement and perceived success in middle school classroom science. To foreshadow the results, it is possible that some aspects co-occur so highly in this kind of learning context that separation of all four aspects is not possible, which is itself an important finding.

---

[1] "Change" can be interpreted in multiple ways and is often interpreted as a delta score (i.e., Time 1 subtracted from Time 2 scores). However, since delta scores often have statistical artifacts, we use Post test motivational scores as our outcome, controlling for students' initial (Pre) motivation scores, to represent change in the current study.

2.4 METHOD

2.4.1 Participants

This data was taken from the Activation Lab: Enables Success (ALES) 2014 study. Approximately 3,000 middle school students (49% 6th grade, 51% 8th grade) provided at least some data in this study, although the sample size varies by analyses depending on the completion of particular instruments (e.g., some models include roughly 1,630 students) and these differences are noted where appropriate. These differences are largely due to absences across multiple data collection administrations (administration of all instruments took place across six days in total; see Procedure) and omission of demographic control variables (specially, highest parental education).

Six urban middle schools in Western Pennsylvania and five urban middle schools from the Northwest region of United States participated. The schools were recruited to represent a diverse range of types of science learning and socio-economic environments. In terms of type of science learning, schools varied in the extent to which they used a hands-on inquiry science curriculum or a textbook-focused science curriculum. Since teachers also have control over the use of learning resources, in fact the schools varied in a more continuous way (based on teacher-log self-report) from primarily using hands-on inquiry to primarily using textbook-focused science learning. Also, the particular content topic of science learning varied across schools, although the 6th graders most commonly studied topics related to weather or Earth Science and the 8th graders more commonly studied topics related to Biology or Ecology.

In terms of socio-economic variation, public school records show there is a wide range across schools in the proportion of students eligible for free/reduced lunch (24—92% receiving free/reduced lunch; *M* = 56%, *SD* = 24%) or from underrepresented minorities (36%-99% minority population; *M* = 56%, *SD* = 22%). These schools were recruited by contacting the 6th and 8th grade science teachers, who were compensated based on number of participating classes; almost all sciences teachers in these schools participated. The overall sample was evenly split on gender (50% female) with the following breakdown of ethnicity based on those students providing this information: 44% Caucasian, 29% African-American, 18% Hispanic/Latino, 10% Asian, 7% Native American/Pacific Islander, and 6% Indian/Middle-Eastern. These gender and ethnicity variables were described as part of the study (see Demographic control variables below).

2.4.2 Instruments

All measures (except the basic demographic variables) were developed with the use of student input. Specifically, cognitive interviews were conducted in which middle school students met 1:1 with a trained researcher (each scale was reviewed by 3—6 students using this process). Students were asked to read the item, reword it in their own words, respond to the item, and then provide reasons for their answer. Responses were audio-recorded and then carefully analyzed for match to the researcher intentions of each item. Using this method, we were able to validate that the students' perceptions corresponded with the construct being measured and, when necessary, make edits to item wording. All scales had also been iteratively improved through principal comments factor analyses and item response theory analyses to insure a single factor structure for each construct, adequate discrimination across the scale, and no differential discriminability by gender, age, or ethnicity.

2.4.2.1 Perceived learning experiences: Engagement

Conceptually, engagement reflects the degree of positive vs. negative behavioral, cognitive, and affective participation in a science learning activity. It involves the experience itself, and reflects influences of learner characteristics (e.g., abilities and attitudes), the activity (e.g., its difficulty and novelty), and various contextual aspects of the activity (e.g., interactions with other learners or support from adults). We developed these scales by reviewing a number of existing engagement surveys (such as those reviewed by Fredricks et al., 2011) and adapted them to be: 1) science specific, 2) clearly related to a specific form of engagement (affect, behavioral, or cognitive) within a particular experience, 3) at an appropriate reading level for lower ability middle school students, and 4) relate to a broad number of possible science experiences. An important feature of this measure, and a major reason for its development in place of the use of an existing measure, is the reference to a single activity a student just completed. Many scales focus on a larger or more general scope (e.g., academic or school engagement without a set timeframe) (e.g., High School Survey of Student Engagement, Motivation and Engagement Scale; School Engagement Measure). However, students experience a range of activities within a given context, each of which may be differentially engaging, and it is unclear how they should respond across these varied activities (see Wang & Degol, 2014 for a discussion on the multilevel conception of engagement). Further, reflections about extended time periods are at risk of becoming measures of general attitudes and beliefs rather than direct summaries of experiences. Therefore, we designed a scale to be used following single activities. The eight-item engagement measure was developed through the use of cognitive interviews described above. Conceptually, the scale includes three affective, two behavioral, and three cognitive items (See Table 1 for items). Additionally, although the current study only involves school-based activities, this scale is designed to also work across a range of other science learning activities (e.g., museum activity, science camp). Most importantly here, the items address engagement broadly enough to be used across the diverse set of possible science-related tasks that occur in science classrooms. Exploratory factor analyses below describe the properties of the empirically-determined factors used in subsequent analyses.

2.4.2.2 Perceived learning experiences: Perceived Success

Conceptually, perceived success captures the learner's sense of success in a particular science learning activity. Like engagement, the construct is focused on the experience itself, with possible contributions from the learner, the activity, and the contextual aspects of the activity. Perceived success items were also developed using cognitive interviews and pilot data collection. The final scale consists of six items (See Table 1) that ask about students' beliefs in how well they did on an activity they just completed. Since learners may be influenced by both absolute and relative different standards of success, our measure taps into both kinds of perceptions. Four items asked about students' *absolute* perceived success; that is, whether they felt successful by their own standards (e.g., I felt I was very successful). Two items asked about students' perceptions of *relative* success; that is, perception of success in relationship to peers' performance (e.g., I was more successful than everyone else). Exploratory factor analyses below describe the psychometric properties of this measure.

2.4.2.3 Motivational variables

Each of our three motivational variables (fascination, values, competency beliefs) described below have undergone extensive empirical validation (using cognitive interviews, exploratory and confirmatory factor analyses, as well as item response theory analyses) and each scale has been shown to make up its own single factor structure with good item fit across student ability/levels of motivation, and good internal reliability (Cronbach's alphas all >.8). Response options are purposely varied to encourage respondents to process each item carefully, and IRT analyses validate the treatment of the scales as interval scales. For specific item information please see the technical reports (http://www.activationlab.org/tools/). Conceptually, the scales represent more stable self characterizations of the learner across time and place, in contrast to engagement and perceived success, which represent subjective experiences during a specific activity in a specific moment in time. Each of the three motivation scales consists of eight items on a four-point Likert scale, each of which is averaged into a mean score in our analyses.

The *Fascination* measure (8 items) captures the intrinsic attachment to science content and activities (Hidi & Renninger, 2006; Wigfield & Eccles, 2000; Ryan & Deci, 2000; Lowenstein, 1994; Jirout & Klahr, 2012; Elliot & McGregor, 2001; Ames, 1992). Conceptually, it involves subdimensions of emotional attachment (e.g., In general, when I work on science I: love it, like it, don't like it, hate it), mastery goals (e.g., I want to know everything about science: YES!, yes, no, NO!), and persistent curiosity (e.g., After a really interesting science experience is over, I look for more information about it: YES!, yes, no, NO!).

The *Values* measure (8 items) captures the extrinsic drive towards science learning (Ryan & Deci, 2000; Wigfield & Eccles, 2000). Conceptually, it includes valuing science for personal benefits (e.g., Knowing science helps me understand how the world works: All the time, most of the time, sometimes, never) and for the benefit of society (e.g., Science makes the world a better place to live: YES!, yes, no, NO!).

Finally, the *Competency Belief* measure (8 items) captures student expectations for successful participation in diverse forms of science learning (Bandura, 1993; 1997; Beghetto, 2007; Britner & Pajares, 2006). It includes students' beliefs about their ability to do well on both in and out-of-school specific science activities (e.g., I can do the activities I get in class: all the time, most of the time, half the time, rarely; If I went to a science museum, I could figure out what is being shown in: all areas, most areas, a few areas, none of it) and perceived mastery of skills involved in completing science learning activities (e.g., I think I'm very good at coming up with questions about science).

2.4.2.4 Science content learning

To match the experimental context, our content learning measures were developed to test knowledge taught over the course of the semester. Because different teachers covered different content (especially across grades and regions, but also somewhat across schools within regions), items were selected to correspond to the content taught by the teacher. These measures were developed by selecting items from released state test items and research-based item banks (e.g., American Association for the Advancement of Science, Trends in International Mathematics and Science Study, Misconceptions-Oriented Standards-Based Assessment Resources for Teachers) and were all multiple choice items mostly measuring students' conceptual knowledge. Z-scores are used to address differential difficulty across test forms.

2.4.2.5 Demographic control variables

Students were asked their *gender* and *ethnicity* (asking participants to check all that apply from a longer list). Ethnicity was then recoded to a binary variable (minority, non-minority), with minority being coded if any of the checked options included one of the traditionally under-represented minorities in STEM (i.e., all but Caucasian and Asian). A binary variable of *grade* (6^{th}/8^{th}) was also recorded.

We also include two variables relating to students' home experiences that are expected to influence results in a meaningful way: *Home resources* and *highest parental education*. Since home environments vary in their access to learning materials (e.g., dictionaries, science books) and parental education has a long-established relationship to achievement outcomes, both are included in our analyses. However, since these variables are relatively stable and not as readily influenced as classroom learning experiences, we include them as control variables.

Home resources were measured via survey by asking students to select the frequency of availability of seven resources located in their home (e.g., Are these things available for use in your home? Study or homework area: Always, most of the time, rarely, never). The scale has an acceptable Cronbach's alpha of .73. Highest parental education was collected by asking students each of their parent's highest education history (the coding and options were as follows: 1 = did not graduate from high school, 2 = graduated from high school, 3 = went to college but did not graduate, 4 = graduated from college, 5 = went to more school after college [master's degree, Ph.D., M.D., etc.]). We then selected the highest education of either parent to use in our analyses. For example, if one parent graduated high school (2) and the other graduated college (4), the coding for the parent graduating college would be used.

2.4.3 Procedure

All measures were collected during the students' science class at various time points during the year (as described below; see Figure 1) using paper surveys distributed by the researchers, with students bubbling responses in pencil directly onto the surveys. Students were told their individual responses would not be shown to their teacher and would not affect their grade.

2.4.3.1 Motivational variables

Fascination, values, and competency belief measures were collected at the start of the fall semester to control for students' starting levels of motivation (Pre) and were collected again at the end of the fall semester (Post), approximately four months later.

2.4.3.2 Science content learning

Students were given the content knowledge test at the start of the school year. This pre-knowledge measure was used to control for any entering knowledge from prior classwork and informal learning sources. Students were then given the same measure at the close of the semester to capture their content learning over the course of the semester. As a reminder, the included items varied across teachers because different teachers taught very different content. Test-specific z-scores were used to equate difficulty across the different test items included on each test form.

2.4.3.3 Demographic variables

Gender and ethnicity were collected at the beginning of the school year, but following the administration of the motivational surveys to avoid any stereotype threat on these other measures that may occur by first answering demographic questions that invoke identities with negative science stereotypes (i.e., female or under-represented minorities).

2.4.3.4 Engagement

Students completed both the engagement and perceived success measure immediately following two different science lessons separated from each other by at least a month but also separated by at least two weeks from the pre and post data collections. The particular days we sampled purposely avoided testing days and focused on typical class activities, but were also influenced by complexities of scheduling so many classes for data collection. Particular activities varied greatly and included both hands-on and lecture structures as well as variation in teacher-directed versus student or group driven work. The purpose of such variety is to improve the generalizability of the findings and to insure variation in engagement and perceived success.

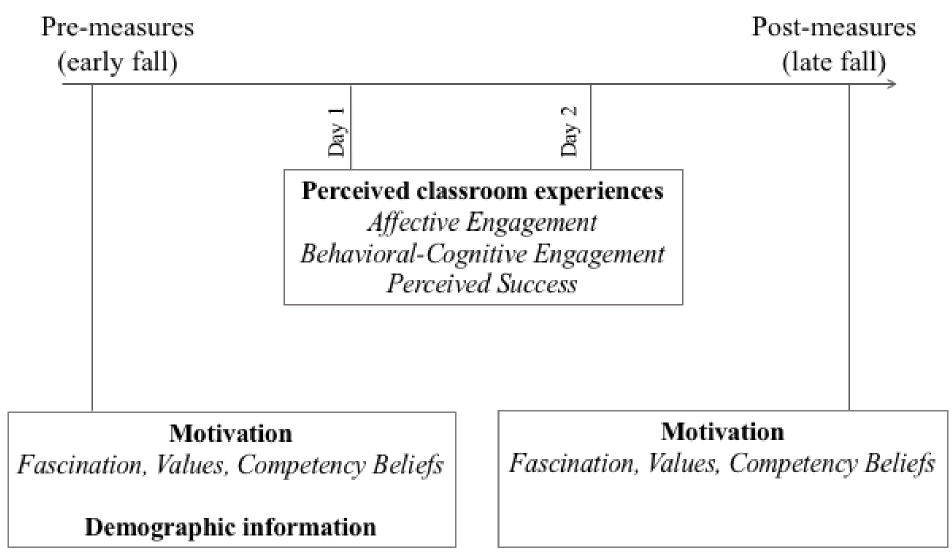

Figure 1. Time line of data collection

2.4.4 Data analysis

We first briefly describe an exploratory factor analyses used to test the structure of the engagement and perceived success scales. Next, we explore the Pre-Post changes in students' means for our outcomes and predictors, as well as describe the correlations among our variables. We subsequently answer each of our research questions using mixed-level modeling. This approach is selected to account for the nested structure of the data (i.e., students are nested within schools/teachers) that may vary systematically. Details for these analyses are included in each subsection for clarity.

2.5 RESULTS

2.5.1 Instrument structure of engagement and perceived success

Given our central focus on perceived classroom learning experiences, we examined the structure of the engagement and perceived success measures to explore dimensionality within each and discriminant validity between them. Since the two different days of administration came from the same range of science activity types, splitting the results this way represents a simple replication test of the analysis patterns as students become familiar with the scale.

Exploratory factor analyses (EFA) with a Varimax rotation were run on data from each day of administration independently to ask whether engagement is separable from perceptions of success. In other words, are students able to separate engagement from whether or not they perceive themselves successful (and vice versa)? This analysis also provides evidence of the dimensionality of engagement; namely, whether the three forms of engagement are empirically distinct in these kinds of learning contexts.

The EFAs yields a three-factor solution (based on Eigen-values above 1) across both days of administration. Most items load on only one factor at above .3, and no items load on a secondary factor at or above .4. All but one item (discussed below) load on the primary factor at above .6. All perceived success variables—and no engagement variables—load on factor 1 consistently (36% and 35% of variance was explained by day, respectively).

Factor 2 includes affect items E1-E4. While E4 was initially conceptualized by the research team as a cognitive item, students responded to it more like an affective engagement item. In retrospect, E4 could be conceptualized as one's sense of flow, which has been previously related to emotional experience of an activity (Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003; Csiszentmihalyi, 1990).

The third factor includes both behavioral and cognitive engagement items together (E5-E8). This same 2-factor structure of engagement was replicated through an EFA with perceived success items removed. The two cognitive variables (E5 & E6) have some evidence of double-loading across factors, suggesting that cognitive engagement may regularly co-occur to some degree with affect, at least as measured here in this context. Nonetheless, at both time points, each variable loads fits best on the behavioral-cognitive factor, and thus was kept within its a priori conceptual category.

Additionally, perceived success items were included in a follow-up EFA with engagement items removed and showed a single-factor solution with factor loadings from .64-.78 for the first administration and a two-factor solution for the second administration (absolute items on one dimension and relative items on the second dimension). However, when items from the second administration were constrained to a single-factor EFA, items were appropriately fitting, with loadings from .67-.80.

Table 1. Engagement and perceived success items

	Category	Final Subcategory	Item
E01	Engagement	Affect	I felt bored (r)
E02	Engagement	Affect	I felt happy
E03	Engagement	Affect	I felt excited
E04	Engagement	Affect	Time went by quickly
E05	Engagement	Behavioral-Cognitive	I was daydreaming a lot (r)
E06	Engagement	Behavioral-Cognitive	I was focused on the things we were learning most of the time
E07	Engagement	Behavioral-Cognitive	I was busy doing other tasks (r)
E08	Engagement	Behavioral-Cognitive	I talked to others about stuff not related to what we were learning (r)
PS01	Perceived Success	Absolute	I did a good job
PS02	Perceived Success	Absolute	It was easy for me
PS03	Perceived Success	Absolute	I felt I was very successful
PS04	Perceived Success	Absolute	I did everything well
PS05	Perceived Success	Relative	I did a better job than the others
PS06	Perceived Success	Relative	I was more successful than everyone else

Note: The engagement and perceived success items all shared the prompt: “During this activity.” Due to scheduling logistics, two teachers did not participate in the second engagement administration. Sample size each day is between 2,563—2,234.

Overall, the EFAs revealed a consistent and coherent set of results: one perceived success factor and two engagement factors (affective & behavioral-cognitive). While behavioral and cognitive engagement are conceptually distinct, students' responses to behavioral and cognitive items are sufficiently correlated to load on a single factor, making them not distinct from each other empirically, at least not in the kinds of in-class science learning activities that were examined in this study. Based on these results, we move forward with a one factor characterization of perceived success (as an average of those items) and a two-factor characterization of engagement (affective engagement as the average of items E1-E4 and behavioral-cognitive engagement as the average of E5-E8).

Overall variable means and reliabilities for engagement (affective & behavioral-cognitive) and perceived success were similar across the two days (shown in Table 2). A combined average across the two days of administration was computed for affective engagement, behavioral-cognitive engagement, and perceived success, respectively, as a (noisy) estimate of typical science classroom experiences over the semester for each student for use in the regression results. The correlations in scores between days are moderate (*r*s = .52, .56, and .49 for affective engagement, behavioral cognitive engagement, and perceived success, respectively), supporting the use of the mean across two days as an estimate of typical engagement and perceived success levels for each learner over this time period.

Table 2. Means, standard deviations, and Cronbach alphas for predictor and outcome variables across administration days

	Day 1			Day 2			Combined		
	M	*SD*	*a*	*M*	*SD*	*a*	*M*	*SD*	*a*
Affect Eng.	2.7	0.72	.80	2.7	0.70	.79	2.7	0.66	.84
Beh-Cog Eng.	3.0	0.64	.72	3.0	0.61	.71	3.0	0.58	.80
Perc. Success	2.9	0.57	.83	2.9	0.58	.83	2.9	0.53	.86

Note: Day 1 N = ~2,700; Day 2 N = ~2,600; Combined = ~3,000.

2.5.2 Overall pre-post changes in the motivational and learning variables

At the mean level, students are moderately motivated towards science at both pre and post, with means around 2.7 on the 4-point scales (See Table 3). There are also statistically significant differences from pre to post testing across all three types of motivation (Fascination: $t(2,356) = -10.18$, $p < .001$; Values: $t(2,353) = -2.26$, $p = .024$; Competency Beliefs: $t(2,340) = 3.80$, $p < .001$). However, practically speaking, these differences are very small, nudging the mean score approximately 0.1 on a four-point scale. Furthermore, while average shift was is small, there were significant individual variations occurring with some students showing meaningful growth and other showing meaningful declines. Table 3 shows the interquartile range of students' pre-post changes in each type of motivation, revealing important variations of change occurring across students. Many students are declining by over 0.5 standard deviations on each scale in just four months; at the same time, many other students are increasing by over 0.5 standard deviation units in that same short period.

Therefore, the purpose of our primary analyses is not to examine what leads to the small mean decline in motivation (or, in the case of competency belief, a small mean increase), but rather to examine whether differences in engagement and perceived success during science class accounts for some of this large individual variation in motivational changes. For example, does a student's engagement and perceived success in class buffer against this frequently discussed (small) overall downward trend?

Table 3. Descriptive data and change data for motivation and learning outcomes

	Pre			Post			*Change*
	M	*SD*	*a*	*M*	*SD*	*a*	*Interquartile range*
Motivation Outcomes							
Fascination	2.7	0.6	.86	2.6	0.6	.86	[-0.4,0.3]
Values	2.6	0.5	.83	2.6	0.5	.83	[-0.3,0.3]
Competency Belief	2.8	0.6	.84	2.8	0.6	.83	[-0.3,0.3]
Learning Outcome							
Content Learning	7.3	3.2	.60	49.1	20.8	.70 [t]	[28.9-56.7]

Note: Based on students with both Pre and Post data (N = ~2,300).

[t] A weighted theta was used as a measure of reliability for content learning, as it is a better measure for dichotomous scales and can be weighted for the sample size associated with each content test.

Before addressing our central research questions, we first examined the correlation structure among all our predictor variables to show first-order correlational relationships between predictors and outcomes, and also to screen for potential multicollinearity problems in the predictors or redundancies in the outcomes. In terms of the relationships among the predictor variables (Table 4 upper-left gray box), the correlations among engagement (both affective and behavioral-cognitive) and perceived success are moderate. This relationship is theoretically expected (i.e., low perceived success can come from low behavioral-cognitive engagement or cause low affective engagement). However, the correlations are sufficiently low that the multiple-regressions should not suffer from severe multi-collinearity. At the same time, the predictors are sufficiently correlated that first-order correlations between predictors and outcomes may simply reflect indirect rather than direct connections.

Moving to the relationship among the outcome variables (lower-right gray box), we see the strongest correlations are among fascination, values, and competency beliefs. The strength and direction of these relationships are typical of previous motivational research examining these variables. Despite the moderate to moderately-high correlation, there remains enough variation for each outcome to be potentially driven by a unique set of factors (or, perhaps, driven by the same factors to varying degrees). Prior knowledge of the class content has relatively low overlap with the motivational variables.

Finally, the relationship among the predictor variables and the outcome variables (upper-right white box) tend to be low to moderate and have varying strength depending on the particular predictor-outcome pairings. For example, fascination is most strongly associated with affective engagement and has a lower and roughly equal relationship with behavioral-cognitive engagement and perceived success. Values shows a similar pattern in relationship to the predictors as fascination, but with a slightly lower correlation with affective engagement. Competency beliefs is most strongly associated with perceived success, and learning is roughly equally related with each predictor, showing the lowest correlations. Multiple regressions are needed to examine whether indeed every predictor is actually associated with every outcome, or whether many of the connections are actually mediated.

Table 4. Pearson correlations among predictor variables, among outcomes variables, and between predictors and outcomes

	Beh-Cog. Eng.	Perc. Succ.	Fasc.	Values	Comp. Bel.	Post Content Knowl.
Affective Eng	.54***	.41***	.42***	.33***	.27***	.08***
Behavioral-Cognitive Eng		.40***	.26***	.22***	.24***	.13***
Perceived Success			.21***	.20***	.33***	.10***
Fascination				.70***	.56***	.15***
Values					.55***	.20***
Competence Beliefs						.27***

***$p \leq .001$

2.5.3 Which aspects of motivational change are associated with perceived classroom experiences of engagement and perceived success?

2.5.3.1 Changes in fascination

Three linear mixed models were run with post-fascination average as the outcome (See Table 5) using RStudio software. First, a fully unconditional model was run to assess the amount of school-level (level 2) variance in fascination. The second model (Baseline Control) adds in first-level fixed effects variables and includes pre fascination averages to control for students' initial motivational levels and demographic control variables (gender [male/female], ethnicity [minority/non-minority], grade [6th/8th]). The third model (final) adds affective engagement, behavioral-cognitive engagement, and perceived success first-level fixed effects variables. It is important to note that over this four-month period, fascination levels (and indeed all three examined motivations) are relatively stable, even though some students are showing significant growth or decline. Thus, the various measured experiences can only have moderate predictive power for post fascination.

The fully unconditional model shows that the random effects of school do account for significant amount of variance in post-fascination (i.e., there is some systematic variation in students' fascination by school) indicating the need to use mixed-linear modeling for this data: X^2 (1, N = 2,676) = 7.17, p = .007. However, this variance is .01%. Model 2 and Model 3 consistently improve in fit (see R^2 and AIC indices in Table 5) as our additional variables are added.

Affective engagement is consistently and most strongly associated with changes in fasciation, followed by perceived success. Behavioral-cognitive engagement shows no relationship with changes in fascination.

Control variables are also associated with changes. Specifically, males and 8th grader each show greater increases in fascination compared to females and 6th graders, respectively. Home resources also show an effect in the baseline model, but this effect becomes non-significant once the perceived classroom experiences are accounted for.

Table 5. Fixed variable standardized coefficients associated with changes in fascination

	Model 1 Unconditional	Model 2 Baseline control	Model 3 Final
(Intercept, unstandardized)	2.57***	2.48***	2.46***
Level-1 Control variables			
Pre-Fascination		.62***	.54***
Male		.05**	.05**
Minority		-.01	<.01
8th Grade		.08***	.09***
Home Resources		.05*	.03
Highest Parent Education		.03	.02
Level-1 Perceived classroom experiences			
Affective Eng.			.19***
Behavioral-Cognitive Eng.			<.01
Perceived Success			.07***
R^2	.01	.41	.46
AIC	4671.31	2065.42	1900.77

***$p \leq .001$, **$p \leq .01$, *$p \leq .05$. $N_{school} = 11$, $N_{student}$ for fully unconditional model: 2,676, $N_{student}$ for baseline control model = 1,673, $N_{student}$ for final model = 1,635.

2.5.3.2 Changes in values

The same three models previously described (fully unconditional, baseline, final) were run with the post-values variable as the outcome. Similar to the fascination outcome, school-level variance in the fully unconditional model accounts for only 1% of the variance. This effect is significant for the fully unconditional model (X^2 [1, N = 2,673] = 6.51, p = .01), but becomes non-significant after including the control variables in Model 2 and 3. Model 2 and Model 3 consistently improve the model fit (see R^2 and AIC indices in Table 6) as our level-two variables are added. Looking at the standardized coefficients in the final model, affective engagement is most predictive of changes in values, followed by perceived success, but no relationship with behavioral-cognitive engagement.

Gender and grade are also predictive of changes in values, with a similar pattern of that seen in fascination (i.e., males and 8th graders each show increases in values compared to females and 6th graders, respectively). Home resources and highest parental education also show a relationship. That is, increases in each are associated with significant increases in values. However, home resources have only a marginal relationship once perceived classroom experiences are included in Model 3.

Table 6. Fixed variable standardized coefficients associated with changes in values

	Model 1 Unconditional	Model 2 Baseline control	Model 3 Final
(Intercept, unstandardized)	2.62***	2.57***	2.55***
Level-1 Control variables			
Pre-Values		.58***	.52***
Male		.08***	.07***
Minority		-.01	-.01
Grade		.04*	.07***
Home Resources		.05**	.04+
Highest Parent Education		.06**	.06**
Level-1 Perceived classroom experiences			
Affective Eng.			.12***
Behavioral-Cognitive Eng.			.04
Perceived Success			.07***
R^2	.01	.37	.40
AIC	4165.06	1830.44	1733.18

***$p \leq .001$, **$p \leq .01$, *$p \leq .05$. + ≤.10. $N_{school} = 11$, $N_{school} = 11$, $N_{student}$ for fully unconditional model: 2,673, $N_{student}$ for baseline control model = 1,673; $N_{student}$ for final model = 1,635.

2.5.3.3 Changes in competency beliefs

The same three models were run with post-competency beliefs as the outcome. The fully unconditional model shows school-association accounts for 6% of the variance (X^2 [1, N = 2,662] = 112, $p < .001$), but this effect becomes non-significant with the inclusion of control variables in

Models 2 and 3. Model 2 and Model 3 consistently improve the model fit (see R^2 and AIC indices in Table 7) as our level-two variables are added. Looking at the standardized coefficients in the final model in Table 7 shows perceived success is the strongest predictor of changes in competency beliefs, with some additional role of affective engagement. Behavioral-cognitive engagement shows no relationship to change.

All control variables are associated with changes in competency beliefs. Similar to values, males and eighth graders each show a positive gain compared to their counterparts. Home resources and highest parental education have similarly sized positive relationships with post-competency beliefs. However, for competency belief changes, minority status is also a predictive of change: minority students show a larger decrease in competency beliefs compared to non-minority peers.

Table 7. Fixed variable standardized coefficients associated with changes in competency beliefs

	Model 1	Model 2	Model 3
	Unconditional	Baseline control	Final
(Intercept, unstandardized)	2.83***	2.84***	2.83***
Level-1 Control variables			
Pre-Competency Beliefs		.58***	.50***
Male		.05**	.05**
Minority		-.05*	-.05**
Grade		.05*	.05**
Home Resources		.09***	.08***
Highest Parent Education		.08***	.08***
Level-1 Perceived classroom experiences			
Affective Eng.			.06**
Behavioral-Cognitive Eng.			.02
Perceived Success			.19***
R^2	.06	.44	.49
AIC	4287.72	1742.52	1599.13

****$p \leq .001$, **$p \leq .01$, *$p \leq .05$. $N_{school} = 11$; $N_{student}$ for fully unconditional model: 2,662, $N_{student}$ for baseline control model = 1,667, $N_{student}$ for final model = 1,629.

2.5.4 Are engagement and perceived success associated with content learning?

Using the same three models run with post-test as the outcome, the fully unconditional model shows school association accounting for about 24% of the variance. (X^2 [1, N = 2,673] = 549, p

< .001), indicating the need for mixed-level modeling. However, this contribution was reduced to 13% once background control variables were included in the model[2]. Model 2 improves the model fit, as does Model 3, although only slightly (see R^2 and AIC indices in Table 8). Looking at the standardized coefficients in the final model. Table 8 shows the coefficients for the baseline and final model. Again, the baseline model consists of pre-test content scores and demographics. The full model adds engagement and perceived success variables.

The pattern of results in this final model is markedly different than the previous three motivational outcomes. Here, only behavioral-cognitive engagement is positively associated with post-test scores. Perceived success shows no significant relationship and affective engagement shows a significant negative relationship with post-test scores. This change in effect demonstrates the importance of considering related experiential variables simultaneously.

With the exception of gender, all control variables show some relationship with learning. Minority status is negatively associated with learning gains whereas the remaining variables are positively associated. Parental education has the largest relationship of any variable in the model (with the exception of the pre-test scores) and this relationship is maintained even once perceived classroom experiences are included in the model.

---

[2] Classroom variance across the 105 classes was also explored and accounted for 4% of variance in fascination (X^2 [1, N = 2,676] = 35.4, p < .001), 3% of variance values (X^2 [1, N = 2,673] = 21.4, p < .001), 7% of variance in competency beliefs, and 17% of variance in content knowledge. However, this variance was largely reduced once control variables were included and the decision to use the school-level variance was made due to the large effect of school-level variance in content learning.

Table 8. Fixed variable standardized coefficients associated with changes in content knowledge

	Model 1 Unconditional	Model 2 Baseline control	Model 3 Final
(Intercept, unstandardized)	49.33***	51.91***	51.91***
Level-1 Control variables			
Pre-Test score		.47***	.47***
Male		-.01	-.01
Minority		-.09***	-.09***
Grade		.04*	.04*
Home Resources		.05*	.04*
Highest Parent Education		.12***	.12***
Level-1 Perceived classroom experiences			
Affective Eng.			-.05*
Behavioral-Cognitive Eng.			.05*
Perceived Success			.03
R^2	.24	.44	.44
AIC	23240.28	14413.65	14130.67

***$p \leq .001$, **$p \leq .01$, *$p \leq .05$. $N_{school} = 11$, $N_{student}$ for fully unconditional model: 2,669, $N_{student}$ for background model = 1,731, $N_{student}$ for final model = 1,697.

2.5.5 Summary of results across motivation & learning outcomes

To understand the patterns across our four outcomes, Table 9 shows the strength of the independent contributions each variable had to each respective outcome (based on the final model). Most saliently, changes in motivational variables are predicted by affective engagement and perceived success but not behavioral-cognitive engagement. That is, the emotional experience one has with classroom science activities and one's perception of how well they completed those activities contributes to growth/decline in one's motivation towards science. The largest relationship is found between affective engagement and fascination. Similar (and relatively small) relationships are found among perceived success for both fascination and values. However, competency beliefs are most strongly predicted by perceived success, much more strongly than perceived success predicts fascination or values. In other words, how behaviorally-cognitively engaged a student is does not change their beliefs about their ability in science and even students' affective engagement has a comparatively small impact on competency beliefs.

For science content learning, both behavioral-cognitive and affective engagement predicted learning growth in opposing directions (controlling for pre-test scores) and perceived success had no relationship. In other words, only productive behaviors and thought processes (behavioral-cognitive engagement) have a positive relationship with content learning and one's affective engagement in class is associated with decreases in content learning. There is no evidence here that the perceptions of success directly impact one's content learning.

Table 9. Summary of effects across four outcome variables based on final model

	Fascination	Values	Competency Belief	Content Learning
Demographic control variables				
Male	+	+	+	ns
Underrepresented minority	ns	ns	–	–
Grade	+	+	+	ns
Home Resources	ns	+	+	+
Highest Parent Ed.	ns	+	+	+
Experience variables				
Affect Eng.	++	+	+	–
Beh-Cog Eng.	ns	ns	ns	+
Perceived Success	+	+	++	ns

"++" = Strong positive effect (significant coefficient > .15), "+"=positive effect (significant coefficient < .15), "–" = negative effect (significant coefficient < .15), ns = not statistically significant

The pattern of effects of the demographic control variables also adds depth to these results. Gender showed a consistent effect across all motivational outcomes with boys being associated with relatively higher motivation. But there were no gender differences in learning. In other words, boys are more motivated in science, but perform no differently than girls. By contrast, having a minority status was associated with reductions in both competency beliefs and amount of content learning. 8^{th} graders showed greater growth (or perhaps less loss) in motivation. Home resources showed a small relationship with all outcomes, except fascination. That is, increases in student access to productive home resources is associated with more values, competency beliefs, and learning, even once initial scores are controlled for. However, access to resources at home does not have a relationship with students' fascination. Parental education also shows a relationship to all outcomes except fascination. However, parental education has relationships to competency beliefs and learning that are worth noting. It is the strongest predictor to learning (with the exception of pre-test) and, in both cases, has a stronger relationship than minority and gender.

It is important to note that the demographic effects were almost entirely stable even when we added engagement and perceived success variables; that is, the demographic effects cannot be explained by the way students perceive their activity experiences during class. Other out-of-school factors, like informal experiences or societal stereotypes, are likely relevant. At the same time, this disconnect highlights that the association of engagement and perceived success with changes in motivation and learning cannot be attributed to third variable correlations through these demographic variables.

2.6 DISCUSSION

What is the character of perceived science classroom experiences that drive changes in motivation for science and science content learning? In simple correlational terms, all aspects of the experience are correlated with all changes, as was previously found in the literature (e.g., Fredricks, Blumenfeld, & Paris, 2004; Ainley & Ainley, 2011; Pekrun & Linnenbrink-Garcia, 2012; Wang & Holcome, 2010; Wang & Eccles, 2012; Connell & Wellborn, 1991). However, the current findings demonstrate the importance of considering related experiential variables simultaneously: very different features of the experiences are associated with motivational changes vs. science content learning, and different features matter for different motivational changes.

Before discussing each of the observed relationships in terms of prior findings and theories, we begin with a brief comment regarding causality. Clearly, as an observational study using regression techniques, no strong claims regarding causality can be made. However, the cases in which no significant association was found by the regression analyses does rule out some causal connections, or at least suggest they are at best quite small or limited to narrow contexts. Further, the regressions looked at change over time, and thus reverse causal relationships are ruled out (e.g., growth in fascination at the end of the semester cannot have caused high levels of affective engagement earlier in the semester). Finally, the use of multiple regressions that control for a number of plausible confounded factors does reduce concerns about associations caused by third variables.

2.6.1 Experiences that change science motivation

Overall, the relative levels of affective engagement and perceived success are associated with changes in all three motivational variables; in no case did behavioral-cognitive engagement significantly account for any motivational outcome. Further, affective engagement is most strongly associated with changes in fascination, and perceived success with changes in competency beliefs.

The two strong connections—affective engagement with fascination and perceived success with competency beliefs—can be thought of in similar ways: as an internalization or stabilization of situational experience to a stable set of attitudes and beliefs. For example, the growth in fascination is consistent with the work on interest by Hidi and Renninger (2006), who theorized a developmental sequence from situational interest (more temporal, relying on environmental support) to individual interest (more stable, personally driven). Our work provides quantitative empirical support for their theory, which has previously been assessed primarily through qualitative data. Further, it goes beyond their work to show that the affective elements of the experience (rather than the cognitive or behavioral elements of the experience), along with perceptions of success, are what contribute to the development of a more stable individual interest.

Turning to the growth in competency beliefs, our work builds on seminal theorizing by Bandura (1993, 1997), also showing that these beliefs build from attributions of success in various experiences. Interestingly, we also show that growth in competency beliefs is associated with affective engagement, but not behavioral-cognitive engagement. In other words, students become more confident in their competencies when the experience is pleasant rather than involving cognitive or behavioral effort. This may stem from differential attributions regarding the two kinds. On the one hand, the experience of high vs. low affective engagement might change the perceptions of effort required to complete the tasks (i.e., time going quickly with high affective engagement and time going slowly with low affective engagement), which then is internalized as signals of competence. On the other hand, the experience of cognitive-behavioral engagement may not indicate competence at all because off-task cognition and behavior does not allow the learner to judge competence in the counterfactual case of them having attended.

Changes in values are not strongly associated with any particular experience measure, but two experiential factors are significant predictors. The observed association with perceived success is consistent with Self Determination Theory, whose supporting research finds that when learners feel more successful in domain activities, they tend to value that area more (Ryan & Dei, 1985; Deci & Ryan, 2000). Although the association of changes in values with affective engagement is theoretically consistent (e.g., Deci & Ryan, 2000; Renninger & Bachrach, 2015), our findings are unique in that we examine learners' affect during a particular science activity and their subsequent values of science (controlling for initial values), whereas many studies have focused on the opposite relationship (values predicting affective engagement), have measured values related to the activity context rather than the activity itself (e.g., value of peer support), or have subsumed value within emotional engagement (e.g., Finn, 1993). By examining affective engagement directly from science experiences and relating them to changes in values of science, we can better understand how learners' more fine-grained experiences relate to larger motivational shifts within the same content area.

Unlike affective engagement, behavioral-cognitive engagement shows no significant association with any motivational change. In other words, engaging (or not) in the thoughts and behaviors productive for science class activities are not associated with increases (or decreases) in motivation. For example, it is possible for a student to be behaviorally and cognitively engaged in class, but not have those experiences influence their overall science interest. This finding has been posited in the interest literature, (Renninger & Bachrach, 2015) and may reflect the myriad of reasons one engages beyond interest in a topic or activity (e.g., desire to get a good grade, performance goals). In other words, students may make other attributions than interest to the cause of their staying on-task. Further, the type of science learning activities may be important here; if the activities are highly scripted or involving very closed-ended tasks, students may not be given opportunities to deepen their interests from completing these activities (Chi, 2008; Marks, 2000).

2.6.2 Experiences that drive science content learning

Content learning gains show a different pattern from the motivational variables. Unlike for the motivational shifts, content learning is associated with behavioral-cognitive engagement. That is, the more behavioral and cognitive engaged a learner is in their science class, the greater their learning. This connection was expected, given that a learner needs to attend appropriately to the content being taught (e.g., think about that content, complete the activities around that content) to effectively learn it. Prior literature and review articles on behavioral and cognitive engagement have also demonstrated the importance of such on-task behaviors and effective attention and effort to academic achievement and learning (Finn, 1989; 1993; Connell & Wellborn, 1991; Fredricks, Blumenfeld, & Paris, 2004; Wang & Eccles, 2012; Marks, 2000).

More interesting and novel is the finding that one's affective experiences in science classes are negatively associated with learning gains. This negative relationship is counterintuitive and there may be multiple reasons for this finding. For example, perhaps students who find the content more affectively engaging are less familiar with it, or high positive emotional experiences in class leads to students attending to the wrong information (i.e., superficially or only what they are most excited by). Our current data cannot directly explain these effects and further investigation and replication across more administrations is needed to better understand this relationship and why it occurs. However, it does appear that multicollinearity among our predictor variables (particularly between affective engagement and behavioral-cognitive engagement) is not an issue here. VIF statistics were all acceptable and the correlation between the two forms of engagement was only moderate. This finding emphasizes the need for research using finer-grained measurement of affective experiences to model their influence on motivations and academic achievement (Linnenbrink-Garcia & Pekrun, 2011; Wang & Degol, 2014).

Another interesting aspect to the current findings is the lack of relationship of perceived success in supporting content learning. That is, believing one's self as successful in science class activities did not result in higher learning. Explaining this effect is beyond the current data and may be due to multiple factors. Perhaps students in this age and context are relatively inaccurate at their reflections on how they performed, as they are still coming to understand the scope of what they know vs. what they do not know. Or perhaps there is misalignment between the activities completed in class and the content being tested in the exam. That is, if the activities the students did prior to the perceived success survey did not closely align with the content test, their perceptions of success may not be a good indicator of learning. Future research will have to examine this relationship in greater detail to examine what underlies it and, in turn, how to best address it.

2.6.3 Educational implications

The current study highlights the aspects of the experience that are most important to target in order to achieve particular changes. For example, if content learning is the primary goal, behavioral-cognitive engagement is the primary lever to target. Both behavioral-cognitive engagement and perceived success can be supported by setting clear objectives with an explicit path as to how to reach them (e.g., Connell & Wellborn, 1991; Fredricks, Blumenfeld, Friedel, & Paris, 2002). Having tasks that require clear learning behaviors and directs attention to particular features associated with learning objectives can encourage learners' cognitive-behavioral engagement. Additionally, learners likely feel the most success when an activity meets—and slightly extends—their current ability (Vygotsky, 1980). Providing encouraging feedback and creating an environment in which learners feel safe to "fail" and allowing them opportunities to practice new skills is also posited to benefit engagement.

Similarly, if specific motivational changes are the primary goal, then this research points to particular experience categories to target. For example, encouraging affective engagement can influence changes in fascination and values. Selecting activities that are more student-centered (e.g., hands-on, authentic science practices, group/student-directed) and help learners find the relevance of an activity to their own lives can generate more positive experiences, which influence more stable motivations, particularly in those learners with lowered expectations of success (Hulleman & Harackiewicz, 2009; Renninger & Bachrach, 2015; Chin & Osborne, 2008; Marks, 2000). However, these approaches are not an uncomplicated solution, as different approaches are most effective at different at levels of initial motivation. For example, learners with lower interest are influenced by different factors (e.g., novelty) and may need more support to engage and see opportunities for engagement than learners with higher interest (Durik & Harackiewicz, 2007; Renninger, 2010; Renninger & Bachrach, 2015). Educators desiring to best meet the needs of their learners should consider the initial motivations and expectations of their learners and how their activity content and procedures could best connect to learners' lives.

The high co-occurrence of cognitive and behavioral engagement is also important. Teachers are given relatively little access to student cognition in the class overall. Here we find that, at least in middle school science, when students are behaviorally on-task there is a good chance they are also cognitively on-task as well. However, we do note that future research may need to consider cognitive engagement in a more fine-grained and task-specific way that the current survey instrument was able to do in order to better understand the generality of that behavioral-cognition co-occurrence (Greene, 2015).

2.6.4 Future directions

2.6.4.1 Engagement structure

We showed a clear separation between affective engagement and behavioral-cognitive engagement in our data set, as well has a lack of separation of behavioral and cognitive engagement. However, there are limitations to generalizing this finding. First, we expect situational context to affect the degree of this separation and, in fact, the two-factor structure may not be found across all experiences (i.e., there may be activities that more cleanly separate cognitive from behavioral engagement). Middle school science classrooms clearly vary from other science experiences, such as out-of-school activities (e.g., museums, camps) and less structured activities (e.g., free-choice activities). Behavioral engagement within a typical school classroom may be particularly narrow and connected to cognitive engagement. Perhaps activities that allow learners to engage in more diverse behavioral and cognitive ways may demonstrate a stronger split between behavioral and cognitive engagement. For example, a child in a science museum may interact with a particular display in different behavioral ways (e.g., playing with the objects in a display, reading the associated explanations provided by museum signs, speaking with a museum educator). These activities could relate to cognitive engagement in less predictable ways (e.g., the child is playing with the objects and making no connection to the larger content to be learned or perhaps they are tying it all together). Similarly, students completing highly routinized data collection could be behaviorally engaged but not cognitively engaged. Engagement measured across a greater variety of contexts is needed to better understand how these dimensions function under different constraints and opportunities (Azevedo, 2015; Sinatra, Heddy, & Lombardi, 2015).

Second, our measure of cognitive and behavioral engagement did not include all ways in which students might cognitively or behaviorally engage in a science learning tasks. To be generalizable across tasks, we focused on a few indicators of each. Prior work, has explored a much larger set of indicators (Sha, Schunn, Bathgate, 2012). But, they also produced a single behavioral-cognitive engagement factor, and further their psychometric properties were not as robust as the items that were included in our final measure. Here a more focused study of cognitive and behavioral engagement in fixed tasks may be useful so that very detailed task-specific measures can be deployed.

2.6.4.2 Temporal stability of engagement differences

We only measured engagement and perceived success twice following science classes. This methodological decision is a relatively "rough" slice of a students' experience and, thus, an incomplete understanding of each student's typical experience in class. More frequent sampling over a longer period of time would provide a more robust pictures of their engagement, which may be more strongly associated with changes in motivation and learning.

2.6.4.3 Malleability

We have emphasized experiential variables that are malleable to some extent. Next steps should be taken to understand the character of the context in which these experiences occur and their relationship with engagement (Sinatra, Heddy, Lombardi, 2015; Azevedo, 2015). In other words, what features of science learning experiences lead to greater affective and behavioral-cognitive engagement, respectively? Understanding these relationships will require both qualitative and quantitative work and produce practical application to educational practices (Renninger & Bachrach, 2015; Ryu & Lombardi, 2015).

2.6.4.4 Demographic effects

Although not the focus of this article, there are relationships among minority, gender, home resources, and parental education with motivational and learning outcomes. These patterns are reflected in the previous literature examining these effects (e.g., Wang & Eccles, 2012; Bembenutty, 2007; Jones, Howe, & Rua, 2000; Reilly, Neumann, & Andrews, 2015) and deserve further investigation to understanding the cultural effects that are giving rise to these differences. However, it is notable that home resources and parental education had a larger role in competency belief outcomes than minority or gender, both of which have previous relationships to such outcomes. Additionally, highest parental education had the largest relationship with content learning (controlling for pre-test)—higher than minority status and any of the classroom experience variables. This finding warrants additional exploration to examine the possible mechanisms for these effects.

3.0 FACTORS THAT DEEPEN OR ATTENUATE DECLINE OF SCIENCE UTILITY VALUE DURING THE MIDDLE SCHOOL YEARS

Research examining motivational shifts in middle school, particularly shifts in motivation for science, is growing (e.g., Ainley & Ainley, 2011; Azevedo, 2015; Bathgate, Schunn, & Correnti, 2014; Sha, Schunn, Bathgate, & Ben-Eliyahu, 2015; Bryan, Glynn, & Kittleson, 2011; Gottfried, Fleming, & Gottfried, 2001; Maltese, Melki, & Wiebke, 2014). This increased attention stems in part from a recognition by educators, researchers, and policy makers of the increasingly important role science plays in equipping our society with the ability to reason through the complex societal challenges and the changing nature of career opportunities. This increased attention also stems from the relatively poor performance and persistence in the sciences (e.g., Osborne, Simon, & Collins, 2003; Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011).

A common research and intervention focus involves science interest (i.e., building or maintaining an intrinsic attachment to science content). Interest, particularly intrinsic interest, has been found to play an important role in persistence, engagement, and learning (Hidi & Renninger, 2006; Bryan et al., 2011; Deci & Ryan, 1985; Ryan & Deci, 2000; Krapp & Prenzel, 2011; Wigfield & Cambria, 2010). Another common focus involves learners' self efficacy beliefs towards science (i.e., learners' perception of their ability to successfully engage in or complete science activities). Self-efficacy also has been found to drive persistence, engagement, and learning (Bandura, 1993, 1997; Beghetto, 2007; Britner & Pajares, 2006). Both interest and self-efficacy for science decline in many students, particularly during the middle school years (e.g., Eccles, Wigfield, Harold, & Blumenfeld, 1993; Wigfield et al., 1997; George, 2006).

However, there is another factor within most theories of motivation that also drives actions and also often declines during middle school: utility value. Science is a foundation for diverse health careers and much of the policy language used to promote science education draws on the importance of science in addressing societal goals (e.g., science is important because it helps nations be competitive on the global economic scale; we need scientists to help address challenging societal issues) (e.g., NRC, 2008). From a motivational perspective, this type of value draws on learners' valuing a topic for the role it plays in supporting other learner goals (Eccles & Wigfield, 2002; Wigfield & Eccles, 2000; Ryan & Deci, 2000) rather than interest in the topic *per se*. In science, this conceptualization of utility value is multifaceted and includes the importance placed on the knowledge of science (i.e., the content), the reasoning involved in science, the role science plays in one's personal life (e.g., to meet a personal educational goal, such as getting into college) and the larger perceptions of science (e.g., science helps solve challenges facing society) (Eccles & Wigfield, 2002; Hill & Tyson, 2009; Moore, Bathgate, Schunn, & Cannady, 2013). Although often correlated with self-efficacy beliefs and interest (e.g., Eccles et al., 1993), utility value is not necessary tied to those forms of motivation. For example, individuals can think science is important despite not feeling personally interested in science nor well suited to succeed in it.

This type of value has been related to positive outcomes both in and out of the science domain. One of the most well-researched models considering the influence of utility value is that of Eccles and colleagues (1983; 2002), which posits that utility value influences performance or "achievement-related choices" towards a task, even when considering learners' efficacy beliefs or contextual constraints of the learning environment (e.g., peer support). This relationship has been empirically demonstrated across multiple studies (e.g., Eccles, 1983; Updegraff et al., 1996; Durik et al., 2006; Meece et al., 1990). For example, Eccles (1983) showed that middle school and high school students' utility value towards a task, in this case math, was associated with an increased desire to pursue math, even when other related variables were included in the model (e.g., gender, expectancies for success, social contexts). Meece et al. (1990) similarly showed that students' perceived importance of math was associated with intentions to take additional math courses, even to a greater degree than how they perceived their expectations for success in math.

Utility value has also shown relationships with performance based outcomes. For example, Bong (2001) found that college students' value towards their course was associated with increases with their midterm grades. Relationships between utility value and positive outcomes have also been found within science. Cole et al. (2008) used structural equation modeling to understand the role of students' science interest and value (i.e., usefulness & importance) and found that students' valuing of science predicted their studying effort, which in turn predicted their science grade. These results held even when controlling for students' interest, college readiness scores, and gender. Cole et al. also examined the same model across other domains (English, Math, Social Studies) and found similar effects of value's relationship to study effort and grade. In this school learning context, interest was not predictive of students' reported study effort (with the exception of a negative relationship in the domain of English), which emphasizes the need to separately consider utility value and interest.

Given the established importance of utility value in learning behaviors, questions about the drivers both for growth and for decline of utility are raised, especially during the pivotal age of early adolescence. The factors that drive this utility value in science in particular have not been fully explored, and are the focus of the current study. In addition, motivational research more generally has tended to conceptualize motivational changes as monolithic and symmetric in causes across growth and decline. Pragmatically and conceptually, growth and decline outcomes are importantly different, and they may be driven by different factors, with some factors enabling motivational growth and others causing or inhibiting motivational decline. This paper examines whether critical experiential factors equally influence patterns of motivational growth vs. decline.

Some prior evidence suggests different factors drive motivational improvements versus preventing declines. For example, Schultz et al. (2011) examined minority students' science experiences and goal orientations and found that participating in undergraduate research prevented dysfunctional attitudes often associated with poor performance, but had no effect on improving attitudes. However, no prior study has specifically examined whether different experiences influence growth vs. decline of a given motivational factor.

3.1.1 What experiences enable growth vs. inhibit decline in valuing science?

As noted above, many researchers have focused on whether valuing science drives learning experiences, such as choice to participate and type of engagement during learning (e.g., Bryan et al., 2011; Bong, 2001; Parker et al., 2012; Bathgate & Schunn, In Press). Here we focus on the reverse relationship: What kinds of experiences drive changes in values? First, we include school science class experiences because this science learning context is broadly shared and often cited as a cause of declining motivation (e.g., Vedder-Weiss & Fortus, 2011; 2012). Since the presence of these experiences is universal, we focus on their character. In particular, since it is how learners perceive experiences that impacts their motivations, we examine perceptions of the learners' science learning experiences (versus objective characterizations of the learning environment, which are only indirectly associated with motivational change). We consider several different dimensions of perceived experiences, which are reviewed next. Second, we include common optional science learning experiences outside the classroom. Because those highly varied in nature and location that makes measurement more difficult, we examine their relative frequency rather than more fine-grained measures of the learner experience in those optional science learning settings.

A critical aspect of experience is students' *engagement* during science learning. Engagement is routinely associated with outcomes such as learning and continued participation (Fredricks, Blumenfeld & Paris, 2004; Wang & Eccles, 2012; Ainley & Ainley, 2011), and while engagement has varied definitions and conceptualizations (Fredricks, Blumenfeld, & Paris, 2004; Fredricks et al., 2011), most research points to three major forms: Affective, behavioral, and cognitive. Affective engagement refers to the emotional experience a learner has towards a given activity, such as the enjoyment s/he receives. Behavioral engagement refers to the common actions a learner may take during an activity, such as asking a question. Cognitive engagement refers to the attention and thought processes related to an activity (e.g., degree of focus on the activity; making connections with other ideas).

Previous work has demonstrated utility value's effects on cognitive engagement (Greene et al, 2004; Johnson & Sinatra, 2013). By contrast, our work explores how engagement is related to growth or decline in utility value. Since engagement provides the learner with opportunities to connect more deeply with the content, we anticipate a relationship between learners' engagement in science class and changes in their utility value towards science. For example, being cognitively engaged may help learners connect the ideas being learned in their science class to other areas of their lives. Additionally, it is theorized that students' values can develop from positive affect experiences with an area (Eccles & Wigfield, 2002). As such, learners' affective engagement may also relate to growth in utility value. Alternatively, having low engagement experiences in science class may lead learners to attribute lower value to science by attributing their lack of engagement to low value of the topic. Thus, higher cognitive or affective engagement may prevent declines in science values.

In addition to experiencing some degree of engagement during science activities, learners also take away a perception of how well they performed on an activity based on sources such as their self-reflection and any feedback they may receive (e.g., social comparison, verbal feedback, comparing current performance with past performance, grade). Since performance in science is relatively low in the US, particularly in middle and high school (Shen & Tam, 2008; NRC, 2008; 2009), students often struggle with the difficult concepts in science. Supports and scaffolds can be introduced into the instruction to allows students to experience success. *Perceived success experiences* are associated with seeking similar and increasingly challenging experiences, which build a sense of mastery and intrinsic interest towards a domain, as well as contribute to one's overall sense of ability (e.g., Ryan & Deci, 2000; Bandura, 1993; Britner & Pajares, 2006; Schiefele, 2009). Beliefs in one's efficacy are also posited to feed back into the development of value towards a content area (Nagengast et al., 2011; Feather, 1982) This relationship may lead to both growth of value (e.g., by showing an area of relative success to other classes) and decline of science value (e.g., by showing an area of relative weakness).

In addition to engaging and building perceptions of success in class, during the school year learners can further their science learning through participating in commonly available *optional science experiences* outside the science classroom. These optional experience include both formal (i.e., school-related) activities, such as an after-school science club, and informal activities, such as a family museum trip, summer camp experience, or exploring in one's yard/neighborhood. These types of experiences often differ from typical classroom science in that they are generally voluntary, connected to particular topic interests, more personal, and generally open-ended and collaborative (Falk & Dierking, 2000); all features that offer a complimentary and unique contribution towards experiencing science. The more informal activities may be especially strong in being attached to personal topic interests and open-ended. Participating in optional science experiences outside of the classroom is associated with a range of positive outcomes and experiences, including increased interest (Sha, Schunn, & Bathgate, 2015), knowledge and scientific literacy (Crowley & Jacobs, 2002; Feldman & Pirog, 2011), continued science participation (Simpkins et al., 2006), and has received increasing attention as a rich resource for improving science learning (National Science Board, 2007).

We anticipate these optional experiences to relate to changes in learners' science value for a few reasons. Specifically, these additional opportunities to participate in science affords learners greater breadth of science content beyond what may be covered in their typical science classes. Seeing diverse forms of science in different contexts may provide additional avenues for learners to see how science relates to their lives and their existing set of values, it might expose more recent applications from emerging science areas rather than the older science content taught in middle school science, and it might highlight various careers and hobbies associated with science rather than emphasizing content knowledge. Additionally, involvement in optional experiences often includes social influences from peers and adults, which has been shown to contribute to one's persistence and motivation in science (Fouad et al., 2010; Archer et al., 2012; Alexander, Johnson & Kelley, 2012; Ryan & Patrick, 2001). Thus, these optional science experiences are anticipated to deepen science value. However, given that students who participate in such optional experiences may already have at least moderately high science values coupled with the common negative experiences of in-school science, the effect of these experiences may actually be to buffer declines in science value during the middle school years.

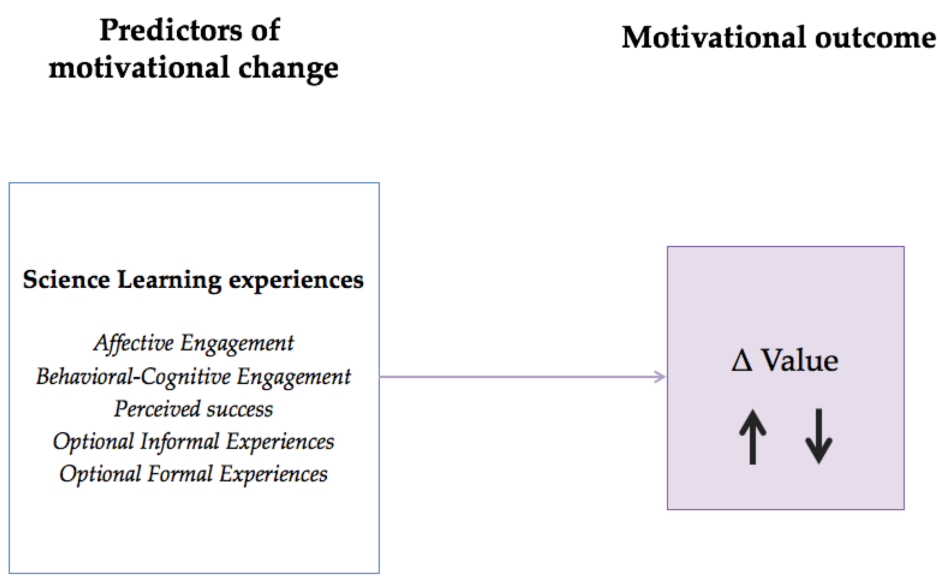

Figure 2. Conceptual model science learning experiences predicting changes in science value.

3.1.2 Current study

The current study examines the impact different science learning experiences on motivational change towards science during middle school. Specifically, the data are parsed into distinct conceptual and empirical groups descriptive of the change in science value they experience during a semester: growth, maintain, decline. The overarching research question is: *What are the experiential features that predict growth, decline, or maintenance of science values in middle school?*

3.2 METHOD

3.2.1 Data set

The dataset includes ~2,600 6th and 8th grade students (49% 6th grade)[3] who completed the pre and post assessments as part of the Activation Lab: Enables Success (ALES) 2014 study. These data were collected during the fall of 2014 at six urban middle schools in Western Pennsylvania and five urban middle schools in the Bay Area of the United States. Schools were recruited by contacting middle school science teachers at in-service events, and teachers were offered compensation which varied according to the number of participating classes. From teachers who agreed to participate, schools were selected to span a range of diverse socio-economic backgrounds as well as types science learning experiences. Specifically, there was a large range in the percentage of students eligible for the free/reduced lunch (24%–92%; *M* = 56%, *SD* = 24%) and ethnic minorities underrepresented in science (36%–99%, *M*=56%, *SD* = 22%). The overall sample was composed of equal gender (50% female) with the following

[3] As with most longitudinal datasets, sample size varies somewhat by analyses. Sample size are noted within each analysis.

ethnicities represented: 44% Caucasian, 29% African-American, 18% Hispanic/Latino, 10% Asian, 7% Native American/Pacific Islander, and 6% Indian/Middle-Eastern[4].

In terms of learning experiences included in science instruction, schools varied in the degree of inquiry-based vs. textbook-focused instruction, as well as the topics covered in science class. However, the 6th graders commonly studied topics associated with weather or Earth Science, whereas the 8th graders most commonly studied topics associated with Biology or Ecology.

Finding similar patterns in motivation across such diverse science learning contexts supports the generality of the predictor variables examined here (i.e., that they are not determined by particular optional science learning experiences available in one region or by particular science curricula).

3.2.2 Measures & procedure

Student perspectives were incorporated in the development of the Values, Engagement, and Perceived Success scales through the use of cognitive interviews. During these interviews, a handful of middle school students met one-on-one with a member of the research team and were asked to read aloud each item, reword the item in their own words, respond to the item, and provide an explanation for their response. In this way, the validity of the measure was verified (i.e., that each item conceptually reflects what it intends to measure) and any necessary edits were made based on student feedback. The remaining measures did not undergo this procedure

---

[4] Students can have multiple ethnicities, so the total is greater than 100%.

(Optional Science Experiences, Home Resources, Family Support) because they were fact-based (e.g., asking whether students have done particular activities such as attended a science camp).

Each of these measures has been further validated empirically through the use of exploratory and confirmatory factor analyses (EFA & CFA), showing a single factor structure (except where noted) with good reliability (specific Cronbach alphas are provided for each scale below). Item-response theory analyses were also used to confirm items covered a wide range of student levels as well verifying that they provided good item and scale fit. Further information can be found in the Activation Lab Technical Reports (Activation Lab: http://www.activationlab.org/tools/).

3.2.2.1 Science values

The eight-item value measure includes items reflecting students' values towards science for both self (e.g., Knowing science helps me understand how the world works: All the time, most of the time, sometimes, never) and society (e.g., Science makes the world a better place to live: YES!, yes, no, NO!; a = .83 for both administrations). This measure was given once at the start of the school year (Time 1) and again at the end of the fall semester (Time 2). See Figure 2 for procedural timeline.

3.2.2.2 Science learning experiences: Affective and behavioral-cognitive engagement

Conceptually, the Engagement measure consists of Affective, Behavioral, and Cognitive forms. However, use of EFA and CFA across multiple data sets using this measure has empirically shown a two-factor structure to this instrument: 1) Affective Engagement and 2) Behavioral-Cognitive engagement (Sha, Schunn, & Bathgate, 2012; Bathgate & Schunn, in review). In other words, affective items make up a separate factor, whereas both behavioral and cognitive items load together on a second combined factor. Therefore, separate scale scores are created for Affect and Behavioral-Cognitive Engagement. Four affective items ask about students' emotional engagement (e.g., During this activity, I felt excited: YES!, yes, no, NO!) and four behavioral-cognitive items ask about particular behaviors or thought processes a student engages in during an activity (e.g., During this activity, I was busy doing other tasks: YES!, yes, no, NO! [reversed]; During this activity, I was focused on the things we were learning most of the time: YES!, yes, no, NO!). Engagement and Perceived Success measures (described directly below) were administered together immediately after two science classes throughout the fall semester based on teachers' availability. Both affect and behavioral-cognitive items had good reliability across administrations (affect: $\alpha = .80$, $\alpha = .79$ across the two days; behavioral-cognitive: from $\alpha = .72$ to $\alpha = .71$). For each student, a mean across the two days was computed for each kind of Engagement.

3.2.2.3 Science learning experiences: Perceived success

The six-item perceived success measure asks students' perception of how well they felt they did during an activity in absolute (e.g., During this activity, I did everything well: YES!, yes, no, NO!) and relative terms (e.g., During this activity, I was more successful than everyone else: YES!, yes, no, NO!). EFAs showed a single factor structure with good reliability across administrations ($\alpha = .83$ for both days). For each student, a mean across the two days was computed.

3.2.2.4 Optional formal and informal experiences

Information about the formal (i.e., school-based) and informal (i.e., outside of school) activities students engaged in throughout the fall semester was gathered via a 12-item scale at the end of the fall semester (two items were removed due to poor fit, resulting in the ten used here). Items asked the frequency with which students did various science-related activities, such as visiting a museum, spending time exploring nature/objects, and talking to others about science (e.g., Have you ever done any of the following? Gone to a science camp: More than once, once, never). Items separated into two factors: Informal Experiences (6 items, α = .74) and Formal Experiences (4 items, α = .74). These two factors will be examined as separate predictors in the models.

3.2.2.5 Demographic controls

Binary variables are used to control for gender, grade, and ethnicity (separated into minority & non-minority). Gender and ethnicity variables were collected at the end of the data administration to limit effects of stereotype threat. Grade information was collected from the teacher during survey administration.

A richly resourced home environment that includes access to learning materials, such as dictionaries, websites, and calculators serves not only to provide learners access to these materials, but also to demonstrate the value of these materials by their existing in their family home (Pomerantz et al., 2007). As such, we want to control for these existing home resources. Since this variable is likely long-standing and not driving particular experiences, we include it as a control variable. For this measure, students provided the frequency of availability of seven particular resources at home, such as a study area, Internet connectivity, and books about science (e.g., Are these things available for use in your home? Study or homework area: Always, most of the time, rarely, never). The seven-item scale has a Cronbach's alpha of .73.

Finally, students provided their perceptions of the degree to which they felt their leaning is supported by family members in their home through a five-item measure (α = .78), including perceptions of whether learning was valued in their home (e.g., My learning in school is important to someone in my family: YES!, yes, no, NO!) and whether adults were available to help teach or guide learning (e.g., Someone in my family is interested in teaching me things: YES!, yes, no, NO!). These five items were averaged to form a family support control variable.

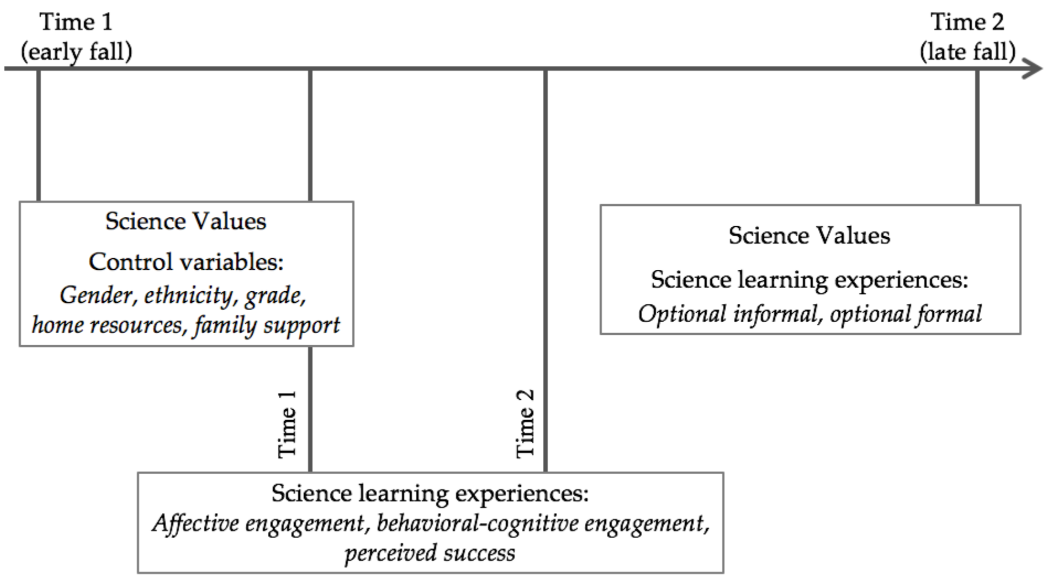

Figure 3. Fall data collection timeline

3.3 RESULTS

3.3.1 Data cleaning & screening

We begin with an assessment of correlational structure among the predictors. If the predictor variables are too highly correlated, then it is not possible to tease apart their individual effects.

However, the correlations among the predictor variables are all low to moderate (see Table 10). Further, the regression analyses revealed acceptable VIF statistics (i.e., multicollinearity is not a concern).

Next, we address distribution issues because they could have a large effect on regression analyses, especially on change scores. First, no extreme outliers (defined as being further from the mean than 3 times the interquartile range) were found in the data (Tukey, 1977). Second, we addressed ceiling or floor effects on the measures for particular students that could limit the possibility of additional change. For example, if a student has a Time 1 Values mean near the maximum possible, their scores can only decrease at Time 2, which could potentially lead to misleading results for students with very extreme scores on either end of the scale. To address this issue, students with a mean Values score greater than two standard deviations above or below the mean are not included in the following analyses. This exclusion step resulted in a relatively small loss of data (about 4%).

Table 10. Means, standard deviations, and intercorrelations of predictor variables

	Values	Affect. Eng.	Beh-cog. Eng.	Perc. Success	Opt. Informal	Opt. Formal
M	2.6	2.7	3.0	2.9	2.4	1.8
SD	0.5	0.7	0.6	0.5	0.7	0.8
Correlations						
Values Time 1		.32	.23	.20	.31	.13
Affect Eng.			.54	.41	.23	.11
Beh-cog Eng.				.40	.13	-*.03*
Perc. Success					.16	.10
Opt. Informal						.50

Note. All correlations were statistically significant at $p < .01$ with the exception of formal experiences with behavioral-cognitive engagement, which was $p = .07$.

3.3.2 Which factors impact changes in science value in middle school?

Since the data have a nested structure (students are nested within schools), a hierarchical linear regression model (HLM) was conducted to examine the contribution of school-level variance in explaining changes in Values (i.e., how much does school membership account for changes in Values?). In the fully unconditional model, school membership accounted for ~3% of the changes, but this contribution decreased to ~1% once the control variables (e.g., ethnicity) were added. Since school-level data contributes so little variance, we proceed with the simplified regression analyses, which more straightforward to interpret, familiar to most readers, and appropriate for the data.

To first examine what predicts overall amount of change in Values of time, multiple-regressions were run with Students' Time 1 Values average included in the first step of the regression. For Model 0, the baseline model, each predictor was included individually (controlling for Time 1 Values and control variables). Without considering the potential for confounding experience variables, all predictors were significantly associated with changes in Values.[5]

For Model 1, all three science classroom experiences (Affective Engagement, Behavioral Engagement, Perceived Success) were included in the second step of the regression, followed by the control variables. Model 2 omits the classroom experiences and instead includes the two optional science experiences in the second step (along with the control variables). Model 3 includes all the variables in one model (initial Values in step one of the regression, the remaining variables in the second step). The contrast of Model 3 results with Model 1 and 2 results reveals that it is important to consider the influences of informal learning experiences to appropriately estimate the influences of school experiences (see Table 11). In addition, there is little substantial shift in Betas (especially in terms of which relationships are significant), showing the results are not produced by overfitting the data or statistical suppression effects.

We see both types of Engagement, Perceived Success, and both types of Optional Experiences significantly contribute to changes in motivation (holding other variables constant); however, the strength of the relationships varies. Optional Experiences are associated with the greatest increases in Values, followed by Affective Engagement, and with Behavioral-Cognitive

[5] Because we are using standardized variables, the absolute size of the weights is not particularly meaningful, nor are the betas between classroom experiences and optional experiences directly comparable because of the differences in scales and sampling methods (i.e., sparse sampling of in-class experiences).

Engagement and Perceived Success showing small, but still significant, relationships. In other words, participating in optional learning experiences, both formal and informal, is independently associated with increases in valuing science. The positive emotional experience students have in the classroom also relates to increases in Values over time. Finally, the ways students direct their behavior and thoughts towards their science classroom work, and their perceptions of how well they completed this work, are associated with increases in the degree they value science.

Table 11. Standardized betas for single-factor regressions, and for multiple regression models for Values (Time 2) outcome, controlling for home resources, gender, grade, and ethnicity

	Model 0	**Model 1**	**Model 2**	**Model 3**
Predictor	**Single factor**	**Classroom experiences**	**Optional experiences**	**Final Model**
Time 1 Values	.54***	.49***	.48***	.45***
Affective Eng.	.15***	.11***	-	.07**
Beh-cog Eng.	.11***	.03	-	.06*
Perceived Success	.11***	.07***	-	.05*
Optional Informal	.24***	-	.18***	.16***
Optional Formal	.20***	-	.12***	.13***
Adjusted R^2, Step 2		35%	38%	39%

*$p < .05$, **$p < .01$, ***$p < .001$

Note: The overall models for each regression were significant at the $p < .001$ level for each step. Adjusted R^2: Model 1, Step 1 = .31; Model 2, Step 1 = .31; Model 3, Step 1 = .30. Adjusted R-squares for the regressions run in Model 0 ranged from 30%–37%.

These regression results provide estimates of the overall effects of each predictor on Values changes during middle school, but potentially masks asymmetrical relationship with growth vs. declines.

3.3.3 Generating categories of change: Growth, maintain, decline

The next set of analyses separately consider growth and decline relationships by empirically categorizing Values changes into three categories (growth, maintain, decline). A half standard deviation (half SD = 0.23) above or below the mean change in Values (M = -0.02) was used as the cut point to create the three categories: Grow (growth by more than 0.22), Decline (decline by more than .24), Maintain (the remaining students). This selection provided suitable power to each category, as well as creating pragmatically meaningful change outcomes. Table 12 shows the descriptive statistics for the predictor variables by change category. The Time 1 Values means are far from floor or ceiling. That is, the Decline group were far from the maximum and thus could have also gained, and the Grow group were far from the minimum and thus could have dropped. Additionally, there is roughly similar variation on all predictors and subgroups, so there is no issue of restricted range within a group that may limit predictiveness.

Table 12. Means and standard deviations for each predictor by Values change category

	Grow		Maintain		Decline	
	M	*SD*	*M*	*SD*	*M*	*SD*
Time 1 Values	2.5	0.6	2.7	0.5	2.8	0.6
Affective Eng.	2.7	0.7	2.7	0.6	2.7	0.6
Beh-cog Eng.	3.0	0.6	3.0	0.5	3.0	0.6
Perceived Success	3.0	0.5	2.9	0.5	2.9	0.5
Optional Informal*	2.5	0.7	2.3	0.7	2.2	0.7
Optional Formal*	1.9	0.8	1.7	0.7	1.6	0.7
Total N (% of total)	*701 (30%)*		*1,094 (46%)*		*559 (24%)*	

*All scales are 4-point scales with the exception of optional experiences, which are on a 3-point scale.

3.3.4 Which factors predict changes in value during middle school?

A multinomial linear regression was run to examine which variables contribute to particular directions of change in Values. In other words, which factors influence students' growth or decrease in Values during middle school? Table 13 shows variables in the model and their respective impacts, accounting for control variables. As the name suggests, multinomial regression analyses allows multiple distinct categories (e.g., growth, maintenance, decline) to be predicted in the same model. One category is set as the reference group against which the other categories are compared. In this instance, students in the maintenance group serve as the reference group. e^B (the exponent of the beta) represents the odds ratio for each predictor variable. In other words, these columns show the quantitative effect an increase/decrease in a predictor variable has on a students' likelihood of being classified in the growth/decline category relative to the maintenance category. For the growth column, the e^B represents the degree to which a unit change in a predictor variable changes the likelihood of a student being in the maintenance category, holding all other variables in the model constant. Lower numbers represent greater likelihood of being categorized in the reference group (maintenance category); numbers close to or above 1 represent an increased likelihood of being categorized in the growth group (i.e., a predictor deepen one's Values). For the decline column, e^B represents the degree to which a unit change in a predictor variable changes the likelihood of students being in the maintenance group relative to the decline group. In this case, higher numbers represent an attenuation of motivational loss (i.e., increase the likelihood of being in the maintenance vs. the decline group[6]).

As a concrete example, Table 13 shows that for every unit increase in Affective Engagement, a student is 25% (1.25 times) more likely to be classified in the maintenance category as opposed to the decline category (holding all other variables constant). However, changes in Affective Engagement do not increase the likelihood of students being classified in the growth category, relative to the maintain category. In other words, increases in Affective Engagement are associated with an attenuation of decreases in Values, but not associated with a deepening of Values. That is, positive emotional classroom experiences can buffer against losing science value, but it does not necessarily increase science values.

Overall, the variables predicting changes in Values show more differences than similarities in predicting growth versus decline groups. In fact, there was only one common

---

[6] A 1/x transformation was applied to the Decline e^B output for each predictor in order to make the e^B magnitudes more easily comparable across the growth and decline categories.

significant predictor: More Optional Informal Experiences lead to a decrease in falling into the decline category (i.e., it attenuates a loss of Values) and an increased likelihood of falling into the growth category (i.e., it deepens Values). For the growth group, Optional Formal Experiences and Perceived Success (marginally) in science also increase the likelihood of falling into the growth category. For students declining in Values, both Affective and Behavioral-Cognitive Engagement also had a supportive impact, buffering against the likelihood of falling into the decline category.

However, not all of the predictors' effects are significantly different from each other by category. That is, a predictor may or may not have a significantly different impact on growth than it does on decline. To formally test the differences in size of e^B between growth and decline groups for each predictor variable, we used an approach provided by Cumming (2009) and Finch and Cummings, 2009. This approach examines the degree of overlap in the confidence intervals for each e^B as calculated using a bias corrected bootstrap technique (1,000 re-samples). If the confidence intervals for across the two groups overlap by less than 50%, the two e^B are considered significantly different from each other; varying the size of the confidence interval produced more precise p-values regarding differences. In this case, two variables show significant differences in the strength of relationships for their effect on growth vs. decline categorization: Affective Engagement and Optional Formal Experiences. In other words, having positive emotional classroom experiences has a significantly different relationship to growth than it does to decline categorization (in addition to appearing to be qualitatively different). Optional Formal Experiences shows the opposite effect, having a significantly different relationship to deepening science Values relative to its effect on buffering against decline (in addition to appearing to be qualitatively different).

Since the analysis of differences in predictive strength has reduced power, trend-level differences were also examined. The patterns for Behavioral-Cognitive Engagement and Optional Informal Experiences were trending towards significance ($p < .20$), suggesting greater effects of each on attenuating decline than supporting growth. Only Perceived Success showed no hint of a distinctive relationship between growth or decline in Values.

Table 13. Multinomial logistic regression results for directional changes in science Values from Time 1 to Time 2

Predictor	Enable Growth e^B	Prevent Decline e^B	Statistical significance of difference between effect on Growth vs. Decline
Affective Eng.	1.00	1.27**	*
Beh-Cog Eng.	1.01	1.22**	*t*
Perceived Success	1.12+	1.09	
Optional Informal	1.23**	1.47***	*t*
Optional Formal	1.44***	1.02	*

$^t p < .20$, $+p < .08$, $*p < .05$, $**p < .01$, $***p < .001$

Note: Nagelkerke pseudo $R^2 = .26$

3.3.5 Continuous versus categorical change

Table 14 shows the impact of each predictor across continuous change, enabling growth, and preventing decline outcomes. For the growth columns, positive predictors are those that deepen motivation (i.e., increase the likelihood of a student being in the growth group relative to maintenance) and for the decline column, positive predictors are those that attenuate the loss of motivation (i.e., increase the likelihood of a student being in the maintenance group relative to the decline group).

For the multiple linear regression, we see all variables significantly predicting changes in Values. However, these effects are not consistent in their influence on patterns of growth vs. decline. In four instances, there are trends where a predictor significantly influences one pattern and not the other: both types of Engagement, Perceived Success, and Optional Formal Experiences. In the cases of Affective Engagement and Optional Formal Experiences, the effect of these variables is statistically different across categories. The only completely consistent results were for the predictiveness of Optional Informal Experiences.

Table 14. Patterns of impact of all variables for growth and decline groups (relative to maintenance group) for science Values

	Multiple Regression Method		
Predictor	*Linear*	*Multinomial*	
	All	*Enable Growth*	*Prevent Decline*
Affective Eng.	***		**
Beh-Cog Eng.	**		**
Perceived Success	*	+	
Optional Informal	***	**	***
Optional Formal	***	***	

+*p* < .08, **p* < .05, ***p* < .01, ****p* < .001

Notes: Time 1 (for multinomial regressions) and control variables (for both) are included in the models but are not shown in the table. Thick borders indicate significant difference in the influence of a variable across growth and decline categories and the dotted border indicates trend level differences at *p* < .10.

3.4 DISCUSSION

3.4.1 Which factors predict changes in value during middle school?

Looking across the analyses of the relationship between various aspects of science learning experiences and changes in utility value towards science, our results show that factors previously found to be associated with other science motivational variables (e.g., interest) (e.g., Renninger & Bachrach, 2015; Linnenbrink & Pintich, 2003; Ainley, 2012) are all found to be actively associated with changes utility value towards science, albeit in varied ways. These results further contribute to the motivation and science education literatures by examining these experience factors simultaneously in the model to show they each contribute above and beyond the other, even though many of the experience factors are correlated with one another. Thus, it is unlikely that relationships to changes in values are indirect / mediated relationships (e.g., perceived success producing higher affective engagement which in turn alone leads to changes in values). It should also be noted that these analyses are correlational in nature and additional design and research is needed to draw causal claims on these relationships.

More concretely, these finding suggest that having a multi-faceted learning environment that encourages both emotional and behavioral-cognitive engagement is especially supportive for the child; having high levels of only one or the other form of engagement does not provide large effects on coming to appreciate the value of science, although supporting either is beneficial. Similarly, learners' perceptions of success are contributing additional variance beyond engagement effects. Although perceived success and engagement are moderately correlated, the correlations are sufficiently modest that learners often are emotionally or cognitively-behaviorally engaged without feeling successful in their experience (and vice versa); but having both engagement and perceived success appear to lead to growth in values. In addition to showing that multiple dimensions of classroom experiences each contribute to changes in valuing science, the current data shows that optional science experiences also play an important role beyond just the classroom experiences: participating in optional informal and formal science experiences each offer a unique positive relationship with utility value, even after accounting for differences in classroom experiences. Or considered from the perspective of optional science learning and its likely connection to other home factors, differences in classroom experiences were associated with changes in value even after controlling for differences in optional formal and informal learning experiences.

3.4.2 Do different factors matter for growth vs. decline of value?

A further contribution of this study is the novel investigation of whether factors are differentially related to the growth of utility value and the prevention of its loss during middle school. These types of asymmetric contributions cannot be investigated using the more traditional linear regression approach. Comparing the results of the category regressions (multinomial linear regressions) with the results of the linear regressions shows several notable differences (See Table 14). Each significant linear regression predictor also had a corresponding multinomial regression predictor for either growth or decline, but often not for both growth and decline. For example, in the linear regression, participating in optional formal experiences is strongly associated with growth in Values; however, if we examine the multinomial regression, we see that this effect is not uniform, but is dependent on the direction of change (i.e., formal experiences deepen Values, but does not buffer against decline).

These patterns give us insight into the nature of the relationship of each of these factors with changes in utility value. For example, we have evidence that both types of Engagement are associated with a prevention of declining utility value, but not with enabling growth. Why do we see these varied relationships with engagement? We offer a possible mechanistic explanation of these effects. Many learners enter middle school with an openness towards science (i.e., they are not disinterested or disengaged with it), but subsequently experience classroom learning that is lackluster: the classroom structure is overly teacher-centered and scripted, often devoid of application or authentic experiences, and promotes more rote memorization practices (e.g., Chi, 2009; Lemke, 1990). These common teaching practices likely undermine (or at least not promote) the utility value of science, leading towards decline. However, not all students have a negative experience, and how students experience these classroom activities (i.e., their affective and behavioral-cognitive engagement) may serve as a preventative measure against this decline. This explanation would account for why the effect of engagement is only found in the decline vs. maintenance comparison. Additional research will be needed to further test this explanation.

Perceived Success shows only a small relationship with growth in utility value (relative to maintain), suggesting it is not strongly associated with these categorical changes in utility value in a distinct way. However, when used in a linear regression, Perceived Success did account for increases in value. One possible explanation for this weaker relationship (in both the linear regression and the logistic regression) is that perceived success has an indirect relationship with utility value through changes in interest or changes in competency beliefs. For example, as a student perceives themselves as repeatedly successful in science activities, they may find themselves more interested in the content being taught and, in turn, find a sense of value of science in their lives. There is some evidence for the connection of interest and value through prior work establishing the co-existence of these motivations (e.g., Bathgate, Schunn, & Correnti, 2014) and the theoretical link between them (Eccles et al., 1983; Wigfield & Eccles, 2000).

Optional Informal experiences is the most consistently predictive factor, associated with both increased likelihood of utility value growth and attenuation of decline. That is, additional informal experiences are consistently beneficial, which is reflected in the benefit of informal experiences in much of the literature (e.g., Maltese et al., 2014; Dabney et al., 2012). One possible explanation for growth effects is that informal experiences provide learners with a range of science content and activities that provide diversity of science content and provide examples of the application of how science can be applied to their lives, which in turn, relate to changes in their utility value. In terms of preventing decline, learners whose classroom teaching is relatively poor (e.g., little active learning, presented poorly) are afforded a counterpoint through these informal experiences that often vary from classroom teaching in content, setting, structure, and format. That is, these experiences may buffer against the loss of value under these poorer circumstances.

By contrast, Optional Formal experiences are not associated with maintenance of utility value (relative to decline), but have a relatively strong relationship with growth (relative to maintain). Why do we only see the benefit of Optional Formal experiences only for growth in utility value? A tentative explanation involves the consistency of the school setting with the formal optional experiences: Learners who are already having a negative formal science experiences may not have opportunities benefit from experiencing additional activities within that same setting (e.g., with potentially the same teachers and peers), whereas students who are already having a positive school science experience may benefit from additional activities within that environment. This pattern of effects is different from the more consistent benefits of Optional Informal experiences because those experiences are not connected to school science learning resources. Further research is needed to follow-up on these hypothesized explanations.

Another aspect needing additional results relates to the frequency rather than quality of the optional experience data. The content, activities, and structure of these kinds of environments among informal spaces is highly varied (Dierking & Falk, 2003; Renninger, 2007), and it is likely that the relative benefits of the optional experiences will vary across programs. However, because of this large variation, precisely measuring the type and quality of these experiences across a large and varied data set is difficult. This challenge is accentuated by the current methodological constraint of retroactively asking students about the quality of these optional experiences via a survey administered in their science classes rather than having the opportunity to measure experiences as they occurred. Nonetheless, despite the strong potential of moderating effects of the degree of engagement and perceived success within these optional learning experiences, the current study did find large effects for just the simple amounts of participation in optional formal and informal experiences.

3.4.3 Practical implications and future directions

Thinking about changes in motivation in terms of growth and decline creates pragmatic opportunities to differentiate intervention by context. Educators may be able to characterize their students (or subsets of their students) as those who need to grow vs. those who need to be supported against waning values. By focusing on different forms of engagement, perceived success, and optional science experiences, there is the opportunity to selectively focus on promoting growth and maintenance of utility value. For example, directing learners towards optional informal experiences may help them choose to participate in additional experiences that afford opportunities for the practical application of science. Additionally, selecting activities that afford student input (e.g., discussions; student-centered activities), are topically related to broadly interesting content, and are relatable to students' daily lives (i.e., shows application to real-life problems) have been found to support students' engagement (Smart & Marshall, 2013; Jang, 2008; Chin & Osborne, 2009; Hulleman et al., 2010). Finally, by allowing learners multiple opportunities to practice a skill or to demonstrate knowledge (as opposed to the more typical single test per unit structure) creates a setting that supports learners' perceptions of success. We provide evidence that each of these factors is related to changes in utility value towards science and is, subsequently, a possible area for intervention.

4.0 FACTORS THAT DEEPEN OR ATTENUATE DECLINE OF SCIENCE FASCINATION AND COMPETENCY BELIEFS DURING THE MIDDLE SCHOOL YEARS

Chapter 3 examined the relationship of classroom and optional science experiences with directional change in values. However, the additional motivational outcomes examined in Chapter 2 (fascination & competency beliefs) were not included in that article. Chapter 4 now takes up those analyses to answer whether are there different factors that support growth vs. decline in fascination and competency beliefs, respectively. The three motivational variables examined throughout the dissertation (values, fascination, competency belief) are semi-independent. That is, they are both theoretically and empirically related, but contribute independently towards outcomes (e.g., Sha, Schunn, Bathgate, & Ben-Eliyahu, 2015) and, as Chapter 2 shows, they can be driven by different inputs. Replicating and extending the analyses in Chapter 3 with fascination and competency beliefs affords a view into the potentially different relationship of predictors with change categories both within and among the motivational outcomes. It provides insight into what drives changes in different types of motivation, as well as whether these drivers consistently have a differential effect for enabling growth and preventing decline.

4.1 METHOD

The data set and procedure described in Chapter 3 (Sections 3.2) are identical to these analyses.

4.2 RESULTS

4.2.1 Data screening

The same data screening procedures as described in Section 3.3.1 are used here. Since Chapter 3 shows the means, standard deviations, and intercorrelations among all most predictor variables, Table 15 shows only the information not previously accounted for relating to these variables (i.e., new information pertaining to both fascination and competency beliefs).

Table 15. Means, standard deviations, and intercorrelations of predictor variables

	Fasc.	Comp. Bel.	Affect. Eng.	Beh-cog. Eng.	Perc. Success	Opt. Informal	Opt. Formal
	M	*SD*	*Correlations*				
Fascination Time 1	*2.7*	*.52*	.35	.25	.19	.16	.33
Competency Beliefs Time 1	*2.8*	*.54*	.23	.22	.32	.09	.28

Note. All correlations were statistically significant at $p < .01$.

4.2.2 Which factors impact changes in science fascination and competency beliefs in middle school?

The same model building described in Section 3.3.2 was conducted here with Time-2 fascination and competency beliefs as independent outcomes. Looking at the results in Table 16, Model 0 shows that each predictor has a significant relationship with both outcomes (independently) when run individually along with Time-1 scores and control variables. In relation to both outcomes, Model 1 shows only affective engagement and perceived success are related to changes in these motivations. Model 2 shows optional experiences relating to changes to both fascination and competency beliefs, with informal experiences having the larger relationship in both cases. Model 3 represents the final model for each outcome. For fascination, all variables except behavioral-cognitive engagement, were related to increases in motivation. Optional informal experiences had the biggest relationship. That is, having more informal science experiences is associated with increases in science fascination. Affective engagement has a relatively strong relationship, as well, which is sensible: Positive emotional experiences in science classes are associated with greater science fascination. Perceived success and optional formal experiences show smaller, but significant relationships. Although behavioral-cognitive engagement is statistically related to increases in fasciation when run independently, this relationship drops out when affective engagement and perceived success are introduced to the regression. This change highlights the theoretical importance of measuring these co-occurring forms of perceived classroom experiences simultaneously. For example, if affective engagement and perceived success were not measured and included in the model, changes in fascination may have been attributed to behavioral-cognitive engagement.

Model 3 for competency beliefs shows a notably different relationship with these variables. First, we see affective engagement not having a relationship with changes in competency beliefs once all variables are included in the model. That is, more positive emotions during science classroom activities are not related to changes in students' beliefs in their science ability. However, behavioral-cognitive does show a small but significant relationship with these changes. Perceived success and informal experiences show the strongest relationship with changes in competency beliefs and, interestingly, are of equal degree. This equality is notable, as the theoretical connection between perceptions of success in science activities and increases in one's competency beliefs is strong and, while there is some expectation of informal experiences contributing to changes in competency beliefs, the finding that these experiences are associated with the changes in competency beliefs to the same degree of perceived success is important both theoretically and practically (See Section 5.1.1). Finally, formal experiences show a small statistical relationship to changes in competency beliefs, as well, reinforcing the importance of participation in optional science experiences and overall science motivation.

Similar to exploration of values in Chapter 3, we next explore whether there are asymmetrical relationships with these outcomes by type of change (growth, maintain, decline).

Table 16. Standardized betas for single-factor regressions, and for multiple regression models for fascination (Time 2) and competency beliefs (Time 2) as independent outcomes

Predictor	**Model 0** Single factor	**Model 1** Classroom experiences	**Model 2** Optional experiences	**Model 3** Final Model
Fascination				
Time 1 Fasc.	.57***	.50***	.49***	.43***
Affective Eng.	.23***	.20***	-	.18***
Beh-cog Eng.	.12***	<.001	-	.02
Perceived Success	.14***	.08***	-	.05**
Optional Informal	.29***	-	.25***	.24***
Optional Formal	.18***	-	.08***	.07***
Adjusted R^2, Step 2		40%	42%	46%
Competency Beliefs				
Time 1 Comp Bel	.57***	.49***	.51***	.45***
Affective Eng.	.10***	.11***	-	<.01
Beh-cog Eng.	.11***	.03	-	.04*
Perceived Success	.21***	.07***	-	.18***
Optional Informal	.21***	-	.19***	.18***
Optional Formal	.13***	-	.05*	.04*
Adjusted R^2, Step 2		45%	45%	49%

*$p < .05$, ***$p < .001$

Note: These models control for home resources, gender, grade, and ethnicity. The overall models for each regression were significant at the $p < .001$ level for each step. Adjusted R^2 for fascination models: Model 1-3, Step 1=.33-.34. Adjusted R-squares for the regressions run in Model 0 ranged from 33%–42%. Adjusted R^2 for competency beliefs models: Model 1-3 Step 1=.39. Adjusted R-squares for the regressions run in Model 0 ranged from 39%–45%.

4.2.3 Generating categories of change: Growth, maintain, decline

We used a half standard deviation (half SD fascination = 0.25; competency beliefs = 0.24) above or below the mean change (fascination M = -0.11; competency belief M = 0.04) as the cut point to create the three categories. For fascination: Grow (growth by more than 0.15), Decline (decline by more than -0.36), Maintain (the remaining students). For competency beliefs: Grow (growth by more than 0.27), Decline (decline by more -0.20), Maintain (the remaining students). See Table 17 for means and standard deviations. As with the analysis in Chapter 3, this selection provided enough power to each category while creating pragmatically meaningful change outcomes. Table 18 shows the students falling within each category.

Table 17. Means and standard deviations for each predictor by change category

	Grow		Maintain		Decline	
	M	*SD*	*M*	*SD*	*M*	*SD*
Fascination						
Time 1 Fascination	2.4	0.5	2.7	0.5	3.0	0.5
Affective Eng.	2.8	0.6	2.7	0.6	2.7	0.6
Beh-cog Eng.	3.0	0.6	3.0	0.5	3.0	0.6
Perceived Success	3.0	0.5	3.0	0.5	2.9	0.5
Optional Informal*	2.5	0.7	2.3	0.7	2.3	0.7
Optional Formal*	1.9	0.8	1.7	0.7	1.7	0.7
Competency Beliefs						
Time 1 Competency Beliefs	2.5	0.6	2.7	0.5	2.8	0.5
Affective Eng.	2.7	0.7	2.7	0.6	2.7	0.6
Beh-cog Eng.	3.0	0.6	3.0	0.6	2.9	0.6
Perceived Success	3.0	0.5	3.0	0.5	2.9	0.5
Optional Informal	2.5	0.7	2.4	0.7	2.3	0.7
Optional Formal	1.9	0.8	1.7	0.7	1.7	0.7

*All scales are 4-point scales with the exception of optional experiences, which are on a 3-point scale.

Table 18. Percentage of students in each change category

	Grow	Maintain	Decline
Total N (% of total)	584 (21%)	968 (43%)	709 (31%)
Total N (% of total)	701 (30%)	1,094 (46%)	559 (24%)

4.2.4 Which factors predict changes in fascination and competency beliefs during middle school?

The same multinomial logistic regression described in section 3.3.4 was used here, except with Time-2 fascination or Time-2 competency beliefs as the outcome. The results for fascination are shown in Table 19. All variables are associated with at least a trend level relationship with one of the change categories. Optional informal experiences shows a relatively large and consistent relationship, in that a unit increase in affective engagement is associated with a 66% increased likelihood of students' fascination growing (opposed to maintain) and a 44% increased likelihood of maintaining fascination (relative to decline). Affective engagement shows a similar relationship for both growth and prevention of decline. That is, for every unit increase in affective engagement, a student is 33% more likely to be classified in the growth category as opposed to the maintenance category and 44% more likely to fall into the maintenance group compared to the decline group (holding all other variables constant). In other words, increases in affective engagement are associated with a deepening of science fascination for the growth (vs. maintenance) students and an attenuation of fascination loss for the decline (vs. maintenance) students.

Optional informal shows a significant relationship, but only to enabling growth (relative to maintain). That is, a unit increase in optional formal is associated with 24% increased likelihood of growth vs. maintenance of fascination. Perceived success shows a smaller, but significant relationship to preventing decline and a trend level relationship with enabling growth in fascination. Behavioral-cognitive engagement shows the weakest relationship, with only a trend level significant towards preventing decline.

Using the same technique described in section 3.3.4, we found marginal differences in the relationship some variables have across categories of change. Specifically, optional formal experiences have a slightly different relationship with enabling growth vs. preventing decline. Behavioral-cognitive engagement has a marginally different relationship between the categories, but since it is not strongly associated with the categorical outcomes, this finding is not very informative beyond suggesting a very slight relationship.

Table 19. Multinomial logistic regression results for directional changes in science Fascination from Time 1 to Time 2

Predictor	Enable Growth e^B	Prevent Decline e^B	Statistical significance of difference between effect on Growth vs. Decline
Affective Eng.	1.33***	1.44***	
Beh-Cog Eng.	.92	1.12^t	+
Perceived Success	1.12^t	1.15*	
Optional Informal	1.66***	1.47***	
Optional Formal	1.24**	1.04	+

${}^t p < .20$, $+p < .08$, $*p < .05$, $**p < .01$, $***p < .001$

Note: Nagelkerke pseudo R^2 =.32

Table 20 shows the outcomes for changes in competency beliefs using the same approach. Here, we again see the benefit of participating in more frequent optional informal experiences: For every unit increase in optional informal experiences, there is a 59% increased likelihood of growth (relative to maintain) and a 28% increased likelihood of maintenance (relative to decline). This relationship is the only to show any evidence of statistically different relationship among the change categories. Perceived success shows a similarly sized relationship across change categories (45% & 46%, respectively). However, behavioral-cognitive engagement is only associated with significant changes in preventing decline. That is, a unit increase in behavioral-cognitive engagement is associated with a 21% increased likelihood of maintaining competency beliefs relative to decline. Finally, affective engagement and optional formal show a small trend towards enabling growth (relative to maintain), but these relationships are quite small.

Table 20. Multinomial logistic regression results for directional changes in science competency beliefs from Time 1 to Time 2

Predictor	**Enable Growth** e^B	**Prevent Decline** e^B	**Statistical significance of difference between effect on Growth vs. Decline**
Affective Eng.	.90 ^{t}	1.01	
Beh-Cog Eng.	1.02	1.21**	
Perceived Success	1.45***	1.46***	
Optional Informal	1.59***	1.28***	^{t}
Optional Formal	1.13 ^{t}	1.10	

Note: Nagelkerke pseudo R^2 =.27

$^t p < .20$, $+p < .08$, $*p < .05$, $**p < .01$, $***p < .001$

4.2.5 Continuous versus categorical change

Tables 21 and 22 show the impact of each predictor across continuous change (Model 3 of Table 2), enabling growth, and preventing decline outcomes. For the enabling growth columns, positive predictors deepen motivation and, for the decline column, positive predictors are those that attenuate the loss of motivation.

For the multiple linear regression, we see slightly different variations between fascination (Table 21) and Competency Beliefs (Table 22). The most notable difference is the type of engagement that is associated with changes in fascination (affective) vs. competence belief (behavioral-cognitive). Aside from this difference, all other relationships vary only in degree of strength.

In examining the multinomial analyses, there are some variables associated with only one type of change (e.g., behavioral-cognitive engagement in preventing decline of competency beliefs). Unlike the analyses on values in Chapter 3, we do not see any strong statistical evidence for these variables being differentially associated with growth vs. decline (relative to maintain). However, there are the marginal differences in behavioral-cognitive and optional informal experiences with fascination and optional informal experiences with competency beliefs.

Table 21. Patterns of impact of all variables for growth and decline groups (relative to maintenance group) for science fascination.

	Multiple Regression Method		
Predictor	*Linear*	*Multinomial*	
	All	*Enable Growth*	*Prevent Decline*
Affective Eng.	***	***	**
Beh-Cog Eng.			*t*
Perceived Success	**	*t*	*
Optional Informal	***	***	***
Optional Formal	***	**	

$^{t}p < .20$, $*p < .05$, $**p < .01$, $***p < .001$

Notes: Time 1 (for multinomial regressions) and control variables (for both) are included in the models but are not shown in the table. The dotted border indicates trend level differences at $p < .10$.

Table 22. Patterns of impact of all variables for growth and decline groups (relative to maintenance group) for science competency beliefs

	Multiple Regression Method		
Predictor	*Linear*	*Multinomial*	
	All	*Enable Growth*	*Prevent Decline*
Affective Eng.		*t*	
Beh-Cog Eng.	*		**
Perceived Success	***	***	***
Optional Informal	***	***	***
Optional Formal	*	*t*	

$^{t}p < .20$, $*p < .05$, $**p < .01$, $***p < .001$

Notes: Time 1 (for multinomial regressions) and control variables (for both) are included in the models but are not shown in the table. The dotted border indicates trend level differences at $p < .10$.

4.3 DISCUSSION

Overall, we see the importance of both perceived classroom experiences and optional science experiences on changes in fascination and competency beliefs (a more detailed description of the theoretical and practical relationship of these variables with fascination and competency beliefs can be found in Chapter 2). While there is some evidence that optional informal and behavioral-cognitive engagement are associated with only one type of change (enabling growth and preventing decline, respectively) there were only marginally differences in the relationships variables had with enabling growth and preventing decline.

One of the of the most notable findings is the strong relationship of optional informal activities and fascination and competency beliefs—particularly competency beliefs, where the relationship is as strong as perceived success. This finding suggests that not only does supporting students' feelings of success enable increases to their more general sense of science ability, but that providing opportunities for varied and frequent science experiences outside of school aids in the growth of students' competency beliefs and prevents its decline. Perhaps being exposed to more ways of participating in science and by being given opportunities to face and overcome new challenges provides students with familiarity with science activities (which in turn help them to feel more capable since they have faced the challenge—or at least some part of it—before) and with a greater perceptions of success extending beyond the classroom context.

5.0 GENERAL DISCUSSION AND CONCLUSIONS

5.1.1 Patterns across drivers of motivational change in middle school

Table 23 presents findings across the findings in Chapter 3 and 4 to show three main ideas: 1) patterns among predictor variables within a particular outcome, 2) patterns of predictor variables across different types of motivation, and 3) differential relationships of the predictors with the motivational outcomes depending on type of change (e.g., enabling growth vs. prevent decline). To accentuate the overall patterns across the findings, the "+" in Table 23 indicates a statistically significant relationship (p-value above .05) but is not indicative of strength of relationship beyond that.

Across the analyses there are a number of patterns worth mentioning. First, we see that value has the most sensitivity to directional change. That is, the predictors have the greatest evidence of differential relationships with enabling growth and preventing decline in relation to valuing science. There are two clear cases where the relationships differ across change categories (affective engagement & optional formal experiences) and two additional places with marginal significance (behavioral-cognitive engagement & optional informal). Changes in fascination and competency beliefs show only marginally different relationships with predictors. These results suggest that changes in motivational variables are not all differentially driven, but that the relationships depend both on the predictor and motivational outcome being examined. These findings also uniquely demonstrate the power finer-grained experiential variables (i.e., classroom activity level) provide for understanding engagement in relation to the development of science motivation in middle school; an approach not generally taken when measuring engagement (Wang & Degol, 2014; Greene, 2015; Fredricks et al, 2011).

Looking at the individual predictors next, we see that optional informal experiences are consistently beneficial for increasing motivation. The message is clear: more frequent and varied informal experiences lead to increases in science fascination, value, and competency beliefs. This relationship supports the literature's description of the role informal science learning has on student motivation (Dierking et al, 2003; NRC, 2009; Renninger, 2007; Dabney et al, 2012) and extends it by examining how informal science participation is related to distinct outcomes (i.e., growth, decline) in a relatively large set of students. This finding certainly needs to be explored further to better understand the mechanism(s) of this effect. What are the possible mechanisms for this effect? What occurs in these experiences that produces these motivational changes and are there elements of these experiences that could be brought into classroom experiences to help support science motivation? Future work should carefully address these questions using a wide range of informal science experiences.

Optional formal experiences are also beneficial to all three types of motivation, but show some evidence that these experiences have a stronger relationship with enabling growth as opposed to preventing decline (e.g., in relationship to fascination and values). As discussed in Chapter 4, perhaps the reason for this unequal relationship lies in the consistency of the school context in which formal experiences take place. That is, if students are already having a poor school science experience, having additional experiences within that context would not prevent motivational decline.

Next, there is some evidence that behavioral-cognitive engagement may matter more for preventing decline than enabling growth (e.g., in relationship to values and competency beliefs). This finding reflects the negative relationship between behavioral engagement and at-risk academic behaviors (e.g., absences, discipline issues) found in previous work (e.g., Finn, 1993), but the absence of relationship between behavioral-cognitive engagement and motivational growth is less clear. Perhaps students who are at risk of declining motivation can keep themselves from sliding if they keep their attention and behaviors on classroom activities. By doing so, students likely perform better, leading to buffering against the loss of competency beliefs. Additionally, this engagement may help them better understand the application of science, which can lead to a buffer from the loss of science value. Interestingly, being behaviorally and cognitively engaged does not enable growth or prevent decline of fascination. That is, paying attention and participating in productive behaviors in science class does not lead to increases (or prevent loss) in science fascination. This pattern accentuates the uniqueness among the motivational outcomes by showing they can be driven by different factors and experienced differently by students.

Affective engagement and perceived success show a less consistent pattern across all outcomes, but they are consistent in their own way. Affective engagement is more related to fascination and values. However, perceived success has a consistent overall relationship with each outcome—particularly competency beliefs—but shows little variation in its relationship to growth vs. decline. This finding supports the theoretical and empirical evidence around competency beliefs and its role in supporting motivation (Eccles & Wigfield, 2002; Pajaras, 1997; Linnenbrink & Pintrich, 2003) and knowing that its benefit for particular outcomes is not dependent on directional growth emphasizes a more global approach for including competence building activities within student experiences.

Table 23. Patterns and direction of impact of all variables for growth and decline groups (relative to maintenance group) across each outcome variable.

Predictor	**Value**			**Fascination**			**Competency Belief**		
	All	*Enable Growth*	*Prevent Decline*	*All*	*Enable Growth*	*Prevent Decline*	*All*	*Enable Growth*	*Prevent Decline*
Affective Eng.	+		+	+	+	+			
Beh-cog Eng.	+		+				+		+
Perceived Success	+			+		+	+	+	+
Optional Informal	+	+	+	+	+	+	+	+	+
Optional Formal	+	+		+	+		+		

+ $p < .05$

Notes: Time 1 predictors are removed from this table. Trend effects (p-values between .05 and .20) of predictors are not included. Thick borders indicate significant difference in the influence of a variable across growth and decline categories and the dotted border indicates marginal level differences at $p < .10$.

5.1.2 Drivers of content learning in middle school

Chapter 2 addresses the relationship of perceived classroom experiences on content learning and shows only behavioral-cognitive engagement to positively relate to learning. Unsurprisingly, paying attention and taking part in productive classroom behaviors support learning. This is supported by previous literature on academic engagement and disengagement (Finn, 1993; Fredricks, Blumenfeld, & Paris, 2004, Wang & Eccles, 2012). However, the effect of home resources and higher parental education are notable. While these variables themselves are less malleable than classroom experience, they do provide insight into ways to better support content learning that may be actionable. That is, it is not having a better resourced home or having parents with higher education that is the mechanism for learning gains. Rather, it is how the child interacts with these resources and parents. For example, it may be that the more educated parents' emphasis on science or academics in general, or their modeling of academic behaviors that the child adopts, or the knowledge of the more educated parent to help address a student's curriculum related question, or that a student knows where to go to access a particular resource. By uncovering the mechanism, researchers and practitioners may be able to leverage them within formal and informal places.

5.1.3 Addressing discrepancies among findings

Across the chapters, there were three differences in regard to which predictors positively predict motivation. Specifically, 1) behavioral-cognitive engagement does not show a relationship with values (Chapter 2) but does when optional science experiences are included (Chapter 3), 2) similarly, behavioral-cognitive engagement does not show a relationship with competency beliefs (Chapter 2), but does when optional experiences are included (Chapter 4), and 3) affective engagement is positively related to competency beliefs (Chapter 2), but not when optional experiences are included (Chapter 4).

The changes in these relationships are notable, but hard to directly compare since the models vary in multiple ways, such as the use of mixed-level modeling, the inclusion of different demographic variables (highest parental education, family support), and the addition of optional experiences in Chapter 4. Since our variables are somewhat correlated, these changes may account for the discrepancies. Additionally, the beta size of behavioral-cognitive engagement in Chapter 2 in relationship to values is similar to that of gender and grade, although it is not strong enough to reach significance. Additional work can be done with the Act Lab data sets, which is currently growing to include additional time points with new samples that can be used to replicate these particular findings.

5.1.4 Future directions

The current analyses use two time points from the Act Lab data set, which leaves some question as to the longer-range longitudinal trajectory of these motivational changes and learning gains. Incoming data that includes motivational and content knowledge across five time points over two years on these students will help to not only replicate many of the analyses here, but also extend them using additional modeling techniques (e.g., growth curve modeling). This type of data, collected with such frequency, is rare in science education and can contribute to a theoretical understanding of what drives science motivation and learning in adolescence, as well as a practical description of the drivers (e.g., informal experiences) that yield the highest leverage for a particular goal (e.g., valuing of science).

BIBLIOGRAPHY

Ainley, M., & Ainley, J. (2011). Student engagement with science in early adolescence: The contribution of enjoyment to students' continuing interest in learning about science. *Contemporary Educational Psychologist*, *36*, 4-12.

Ainley, M. (2012). Students' interest and engagement in classroom activities. In *Handbook of research on student engagement* (pp. 283-302). Springer US.

Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of educational psychology*, *84*(3), 261.

Alexander, J. M., Johnson, K. E., & Kelley, K. (2012). Longitudinal analysis of the relations between opportunities to learn about science and the development of interests related to science. *Science Education*, *96*(5), 763–786.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., WIllis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. American Educational Research Journal, 49(5), 881 – 908.

Azevedo, R. (2015). Defining and measuring engagement and learning in science: Conceptual, theoretical, methodological, and analytical issues. *Educational Psychologist*, *50*(1), 84-94.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist*, *28*(2), 117-148.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. Macmillan.

Baram-Tsabari, A., & Yarden, A. (2008). Girls' biology, boys' physics: Evidence from free-choice science learning settings. *Research in Science & Technological Education, 26*(1), 75-92.

Bathgate, M.E., & Schunn, S.D. (In Press). Disentangling intensity from breadth of science interest. *Instructional Science.*

Bathgate, M.E., Schunn, C.D., & Correnti, R. (2013). Children's motivation towards science across contexts, manner of interaction, and topic. *Science Education, 98*(2), 189-215.

Beghetto, R. (2007). Factors associated with middle and secondary students' perceived science competence. *Journal of Research in Science Teaching*, *44*(6), 800–814.

Bembenutty, H. (2007). Self-regulation of learning and academic delay of gratification: Gender and ethnic differences among college students. *Journal of Advanced Academics, 18*(4), 586-616.

Bong, M. (2001). Role of self-efficacy and task-value in predicting college students' course performance and future enrollment intentions. *Contemporary Educational Psychology, 26*(4), 553–570.

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching*, *43*(5), 485-499.

Bryan, R. R., Glynn, S. M., & Kittleson, J. M. (2011). Motivation, achievement, and advanced placement intent of high school students learning science. *Science Education*, *95*(6), 1049–1065.

Chi, M. T. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science*, *1*(1), 73-105.

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

Cho, M. H., & Summers, J. (2012). Factor validity of the Motivated Strategies for Learning Questionnaire (MSLQ) in asynchronous online learning environments. *Journal of Interactive Learning Research*, *23*(1), 5-28.

Cole, J. S., Bergin, D. A., & Whittaker, T. A. (2008). Predicting student achievement for low stakes tests with effort and task value. *Contemporary Educational Psychology*, *33*(4), 609-624.

Connell, J. P., & Wellborn, J. G. (1991). Competence, autonomy, and relatedness: a motivational analysis of self-system processes. In M.R. Gunnar and L.A. Sroufe (Eds.), *Self-processes and development: Minnesota symposium on child psychology* (Vol. 23). Chicago: University of Chicago Press.

Crowley, K., & Jacobs, M. (2002). Islands of expertise and the development of family scientific literacy. In G. Leinhardt, K. Crowley, and K. Knutson (Eds.), Learning conversations in museums. Mahwah, NJ: Lawrence Erlbaum Associates.

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience.* New York: Harper-Perennial.

Cumming, G. (2009). Inference by eye: Reading the overlap of independent confidence intervals. *Statistics in Medicine*, *28*, 205-220.

Dabney, K. P., Tai, R. H., Almarode, J. T., Miller-Friedmann, J. L., Sonnert, G., Sadler, P. M., et al. (2012). Out-of-school time science activities and their association with career interest in STEM. *International Journal of Science Education*,*2*(1), 63-79.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum.

Dierking, L. D., Falk, J. H., Rennie, L., Anderson, D., & Ellenbogen, K. (2003). Policy statement of the "informal science education" ad hoc committee. *Journal of Research in Science Teaching*, *40*(2), 108-111.

Durik, A. M., & Harackiewicz, J. M. (2007). Different strokes for different folks: How personal interest moderates the effects of situational factors on task interest. *Journal of Educational Psychology*, *99*, 597-610.

Durik, A. M., Vida, M., & Eccles, J. S. (2006). Task values and ability beliefs as predictors of high school literacy choices: A developmental analysis. *Journal of Educational Psychology*, *98*(2), 382.

Eccles J. S., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J. L., & Midgley, C. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Ed.), *Achievement and achievement motivation* (pp. 75–146). San Francisco, CA: W. H. Freeman

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology*, *53*(1), 109-132.

Eccles, J. S., Wigfield, A., Harold, R. D., & Blumenfeld, P. (1993). Age and gender differences in children's self-and task perceptions during elementary school. *Child development*, *64*(3), 830-847.

Elliot, A., & McGregor, H. (2001). A 2 X 2 achievement goal framework. *Journal of Personality and Social Psychology*, 80, 501–509.

Elliot, A. J. (1999). Approach and avoidance motivation and achievement goals. *Educational Psychologist*, *34*, 169–189.

Falk, J.H. & Dierking, L.D. (2000). *Learning from museums: Visitor experiences and the making of meaning.* Altamira Press: Chicago.

Fan, W., & Williams, C. M. (2010). The effects of parental involvement on students' academic self-efficacy, engagement and intrinsic motivation. *Educational Psychology*, *30*(1), 53.

Fan, W., Williams, C. M., & Wolters, C. A. (2012). Parental Involvement in Predicting School Motivation: Similar and Differential Effects Across Ethnic Groups. *The Journal of Educational Research, 105*(1), 21.

Feather, N. T. (1982). Expectancy-value approaches: Present status and future directions. In N. T. Feather (Ed.), *Expectations and actions: Expectancy-value models in psychology* (pp. 395–420). Hillsdale, NJ: Erlbaum.

Feldman, A. & Pirog, K. (2011). Authentic science research in elementary school after-school science clubs. *Journal of Science Educational Technology*, 20, 494–507.

Finch, S., & Cumming, G. (2009). Putting research in context: Understanding confidence intervals from one or more studies. *Journal of Pediatric Psychology, 34,* 903-916.

Finn, J. D. (1993). *School engagement and students at risk* (NCES 93470). National Center for Education Statistics. Retrieved from http://nces.ed.gov/pubs93/93470.pdf.

Finn, J. D. (1989). Withdrawing from school. *Review of Educational Research, 59,* 117–142.

Fouad, N. A., Hackett, G., Smith, P. L., Kantamneni, N., Fitzpatrick, M., Haag, S., & Spencer, D. (2010). Barriers and supports for continuing in mathematics and science: Gender and educational level differences. *Journal of Vocational Behavior*, *77*(3), 361-373.

Fredricks, J., Blumenfeld, P., & Paris, A. (2004). School Engagement: Potential of the Concept, State of the Evidence. *Review of Educational Research*, *74*(1), 59–109.

Fredricks, J., McColskey, W., Meli, J., Mordica, J., Montrosse, B., & Mooney, K. (2011). *Measuring student engagement in upper elementary through high school: a description of 21 instruments.* (Issues & Answers Report, REL 2011–No. 098). Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Southeast. Retrieved from http://ies.ed.gov/ncee/edlabs

George, R. (2006). A cross-domain analysis of change in students' attitudes toward science and attitudes about the utility of science. *International Journal of Science Education*, *28*(6), 571-589.

Glynn, S. M., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science motivation questionnaire II: Validation with science majors and nonscience majors. *Journal of Research in Science Teaching, 48*(10), 1159–1176.

Gottfried, A. E., Fleming, J. S., & Gottfried, A. W. (2001). Continuity of academic intrinsic motivation from childhood through late adolescence: A longitudinal study. *Journal of Educational Psychology*, *93*, 3-13.

Greene, B. A. (2015). Measuring cognitive engagement with self-report scales: Reflections from over 20 years of research. *Educational Psychologist*, *50*(1), 14-30.

Greene, B. A., Miller, R. B., Crowson, H. M., Duke, B. L., & Akey, K. L. (2004). Predicting high school students' cognitive engagement and achievement: Contributions of classroom perceptions and motivation. *Contemporary educational psychology*, *29*(4), 462-482.

Grolnick, W. S., & Slowiaczek, M. L. (1994). Parents’ involvement in children’s schooling: A multidimensional conceptualization and motivational model. *Child Development, 65*(1), 237–252.

Hidi, S., & Renninger, K.A. (2006). The four-phase model of interest development. *Educational Psychologist*, 41(2), 111 – 127.

Hill, N. E., & Tyson, D. F. (2009). Parental involvement in middle school: a meta-analytic assessment of the strategies that promote achievement. *Developmental psychology*, *45*(3), 740.

Hilpert, J. C., Stempien, J., van der Hoeven Kraft, K. J., & Husman, J. (2013). Evidence for the latent factor structure of the MSLQ: A new conceptualization of an established questionnaire. *SAGE Open, 3*(4), 1-10.

Hulleman, C. S., Godes, O., Hendricks, B. L., & Harackiewicz, J. M. (2010). Enhancing interest and performance with a utility value intervention. *Journal of Educational Psychology, 102*(4), 880-895. doi: 10.1037/a0019506

Hulleman, C. S., & Harackiewicz, J. M. (2009). Promoting interest and performance in high school science classes. *Science, 326,* 1410 –1412.

Jang, H. (2008). Supporting students' motivation, engagement, and learning during an uninteresting activity. *Journal of Educational Psychology*, *100*(4), 798.

Jang, H., Reeve, J., & Deci, E. L. (2010). Engaging students in learning activities: It is not autonomy support or structure, but autonomy support and structure. *Journal of Educational Psychology, 102,* 588-600.

Jenkins, E. W., & Pell, R. G. (2006). *The relevance of science education project (ROSE) in England: A summary of findings.* Leeds: Centre for Studies in Science and Mathematics Education, University of Leeds.

Jirout, J., & Klahr, D. (2012). Children’s scientific curiosity: In search of an operational definition of an elusive concept. *Developmental Review, 32*(2), 125-160. doi: 10.1016/j.dr.2012.04.002

Johnson, M. L., & Sinatra, G. M. (2013). Use of task-value instructional inductions for facilitating engagement and conceptual change. *Contemporary Educational Psychology*, *38*(1), 51-63.

Jones, M. G., Howe, A., & Rua, M. J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education*, *84*(2), 180-192.

Krapp, A., & Prenzel, M. (2011). Research on interest in science: Theories, methods, and findings. *International Journal of Science Education*, *33*(1), 27-50.

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

Linnenbrink, E. A., & Pekrun, R. (2011). Students’ emotions and academic engagement: Introduction to the special issue. *Contemporary Educational Psychology, 36*, 1-3.

Linnenbrink, E. A., & Pintrich, P. R. (2003). The role of self-efficacy beliefs in student engagement and learning in the classroom. *Reading &Writing Quarterly*, *19*(2), 119-137.

Loewenstein, G. (1994). The psychology of curiosity: A review and reinterpretation. *Psychological Bulletin, 116*(1), 75–98.

Maltese, A. V., Melki, C. S., Wiebke, H. (2014). The nature of experiences responsible for the

generation and maintenance of interest in STEM. *Science Education, 98*(6), 937962.
Marks, H. M. (2000). Student engagement in instructional activity: Patterns in the elementary, middle, and high school years. *American Educational Research Journal, 37*, 153–184.
Meece, J. L., Wigfield, A., & Eccles, J. S. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of educational psychology*, *82*(1), 60.
Moore, D. W., Bathgate, M. E., Chung, J., & Cannady, M. A. (2013). Measuring and evaluating science learning activation. Dimensions, November/December 2013.
Nagengast, B., Marsh, H. W., Scalas, L. F., Xu, M. K., Hau, K. T., & Trautwein, U. (2011). Who took the “x” out of expectancy-value theory? A psychological mystery, a substantive-methodological synergy, and a cross-national generalization. Psychological Science, 22(8), 1058-1066.
National Research Council. (2009). *Learning science in informal environments: people, places, and pursuits* (P. Bell, B. Lewenstein, A. W. Shouse, & M. A. Feder Eds.). Washington, DC: The National Academies Press.
National Research Council. (2008). *Research on future skill demands: A workshop summary*. Washington, DC: The National Academies Press.
National Science Board (2007). National action plan for addressing the critical needs of the U.S. Science, Technology, Engineering, and Mathematics education system. http://www.nsf.gov/nsb/documents/2007/stem_action.pdf
Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049 – 1079.
Paiares, F. (1997). Current directions in self-efficacy research. In M. L. Maehr & P. R. Pintrich (Eds.), Advances in motivation and achievement (pp. 1-49). Greenwith, CT: JAI Press.
Parker, P. D., Schoon, I., Tsai, Y-M., Nagy, G., Trautwein, U., & Eccles, J. S. (2012). Achievement, agency, gender, and socioeconomic background as predictors of postschool choices: A multicontext study. Developmental Psychology, 48(6), 1629–1642.
Pekrun, R., & Linnenbrink-Garcia, L. (2012). Academic emotions and student engagement. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 259-292). New York: Springer.
Pomerantz, E. M., Moorman, E. A., & Litwack, S. D. (2007). The how, whom, and why of parents’ involvement in children’s academic lives: More is not always better. Review of Educational Research, 77(3), 373–410.
Prokop, P., Prokop, M., & Tunnicliffe, S.D. (2007). Is biology boring? Student attitudes towards biology. *Educational Research, 42*(1), 36-42.
Reeve, J., & Lee, W. (2014). Students’ classroom engagement produces longitudinal changes in classroom motivation. *Journal of Educational Psychology, 106*(2), 527.
Reilly, D., Neumann, D.L., & Andrews, G. (2015). Sex differences in mathematics and science achievement: A meta-analysis of national assessment of educational progress assessments. *Journal of Educational Psychology, 107*(3), 645.
Renninger, K. A. (2010). Working with and cultivating interest, self-efficacy, and self-regulation. In D. Preiss & R. Sternberg (Eds.), *Innovations in educational psychology: Perspectives on learning, teaching and human development* (pp. 158-195). New York: Springer.

Renninger, K. A. (2007). Interest and motivation in informal science learning. *Commissioned Paper for Learning Science in Informal Environments Committee. Washington DC: Board on Science Education, The National Academies*.

Renninger, A., & Backrach, J.E. (2015). Studying triggers for interest and engagement using observational methods. *Educational Psychologist, 50*(1), 58-69.

Richey, J. E., Nokes-Malach, T. J., & Wallace, A. (2014). Achievement goals, observed behaviors, and performance: Testing a mediation model in a college classroom. *COGSCI 2014: The Annual Meeting of the Cognitive Science Society*.

Ryan, R.M., & Deci, E.L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology,* 25(1), 54-67.

Ryan, A. M., & Patrick, H. (2001). The classroom social environment and changes in adolescents' motivation and engagement during middle school. *American Educational Research Journal*, *38*(2), 437-460.

Ryu, S., & Lombardi, D. (2015). Coding classroom interactions for collective and individual engagement. *Educational Psychologist*, *50*(1), 70-83.

Schiefele, U. (2009). Situational and individual interest. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of motivation at school* (pp. 197–222). New York, NY: Routledge.

Schultz, P. W., Hernandez, P. R., Woodcock, A., Estrada, M., Chance, R. C., Aguilar, M., & Serpe, R. T. (2011). Patching the pipeline: Reducing educational disparities in the sciences through minority training programs. Educational Evaluation and Policy Analysis, 33, 95-114. doi: 10.3102/0162373710392371

Sha, L., Schunn, C., & Bathgate, M. (2015). Measuring choice to participate in optional science learning experiences during early adolescence. *Journal of Research in Science Teaching*, *52*(5), 686–709. http://doi.org/10.1002/tea.21210

Sha, L., Schunn, C.D., & Bathgate, M.E. (April, 2012). Activated science learners as self-regulated agents. Poster presented in structured symposium: *Activating Young Science Learners: Igniting Persistent Engagement in Science and Inquiry* at the American Education Research Association (AERA) annual conference, April, 2012.

Sha, L., Schunn, C., Bathgate, M., & Ben-Eliyahu, A. (2015). Families support their children's success in science learning by influencing interest and self-efficacy. *Journal of Research in Science Teaching.* DOI: 10.1002/tea.21251

Shen, C., & Tam, H. P. (2008). The paradoxical relationship between student achievement and self-perception: A cross-national analysis based on three waves of TIMSS data. *Educational Research and Evaluation, 14*, 87–100.

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

Silvia, P. J. (2006). *Exploring the psychology of interest.* New York: Oxford University Press.

Simpkins, S.D., Davis-Kean, P.E., & Eccles, J.S. (2006). Math and science motivation: A longitudinal examination of the links between choices and beliefs. *Developmental Psychology, 42*(1), 70-83.

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

Smart, J. B., & Marshall, J. C. (2013). Interactions between classroom discourse, teacher questioning, and student cognitive engagement in middle school science. *Journal of Science Teacher Education*, *24*(2), 249-267.

Tukey, J.W. (1977). *Exploratory Data Analysis.* Reading, PA: Addison-Wesley.
Tytler, R., & Osborne, J. (2012). Student attitudes and aspirations towards science. In B. J. Fraser, K. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 597–625). New York, NY: Springer International.
Updegraff, K. A., Eccles, J. S., Barber, B. L., & O'Brien, K. M. (1996). Course enrollment as self-regulatory behavior: Who takes optional high school math courses? *Learning and Individual Differences, 8*, 239-259.
Vedder-Weiss, D., & Fortus, D. (2012). Adolescents' declining motivation to learn science: A follow-up study. *Journal of Research in Science Teaching, 49*(9), 1057–1095.
Vedder-Weiss, D., & Fortus, D. (2011). Adolescents' declining motivation to learn science: Inevitable or not? *Journal of Research in Science Teaching*, *48,* 199–216. doi: 10.1002/tea.20398
Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*. Harvard university press.
Wang, M. T. & Degol, J. (2014). Staying engaged: Knowledge and research needs in student engagement. *Child Development Perspectives, 8*(3), 137-143.
Wang, M. T., & Eccles, J. S. (2012). Adolescent behavioral, emotional, and cognitive engagement trajectories in school and their differential relations to educational success. *Journal of Research on Adolescence*, *22*(1), 31-39.
Wang, M. T., & Holcombe, R. (2010). Adolescents' perceptions of school environment, engagement, and academic achievement in middle school. *American Educational Research Journal*, *47*(3), 633-662.
Wigfield, A., & Cambria, J. (2010). Students' achievement values, goal orientations, and interest: Definitions, development, and relations to achievement outcomes. *Developmental Review*, *30*(1), 1-35.
Wigfield, A., & Eccles, J. S. (2000). Expectancy–Value Theory of Achievement Motivation. *Contemporary Educational Psychology*, *25*(1), 68–81. http://doi.org/10.1006/ceps.1999.1015
Wigfield, A., Eccles, J. S., Yoon, K. S., Harold, R. D., Arbreton, A. J., Freedman-Doan, C., & Blumenfeld, P. C. (1997). Change in children's competence beliefs and subjective task values across the elementary school years: A 3-year study. *Journal of educational psychology*, *89*(3), 451.
Zimmerman, H. (2012). Participating in science at home: Recognition work and learning in biology. *Journal of Research in Science Teaching, 49*(5), 597-630. doi: 10.1002/tea.21014
Zusho, A., Pintrich, P. R., & Coppola, B. (2003). Skill and will: The role of motivation and cognition in the learning of college chemistry. *International Journal of Science Education*, *25*(9), 1081-1094.