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Factors that deepen or attenuate decline of science utility value during the middle school years

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ABSTRACT

Utility value is associated with positive learning outcomes in science 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 2600 middle-school students, we test the relationship of science classroom experiences (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 utility value also predict absence of decline. Overall, we find all five factors are associated with changes in utility value, but some have different relationships with growth vs. decline outcomes. These findings provide a more nuanced view of factors associated with utility value towards science (both in and out of the science classroom), as well as practical implications for educational practice.

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1. Introduction

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; Bryan, Glynn, & Kittleson, 2011; Gottfried, Fleming, & Gottfried, 2001; Maltese, Melki, & Wiebke, 2014; Sha, Schunn, Bathgate, & Ben-Eliyahu, 2015). 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., Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011; Osborne, Simon, & Collins, 2003).

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 (Bryan et al., 2011; Deci & Ryan, 1985; Hidi & Renninger, 2006; Krapp & Prenzel, 2011; Ryan & Deci, 2000; 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; George, 2006; Wigfield et al., 1997).

However, there is another factor within most theories of motivation that also drives actions and also often declines during middle school: utility value, or the importance one places on a topic (science, in this case) as it relates to one's future goals (e.g., valuing a science class because it is needed to become an engineer) (Eccles & Wigfield, 2002; Wigfield & Eccles, 2000). Utility value is particularly salient in science education due to the pivotal and structural role science plays as a gateway to many careers and opportunities. For example, 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., National Research Council, 2008).

From a motivational perspective, this type of value draws on learners' valuing a topic for the role it plays in supporting other

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learner goals (Eccles & Wigfield, 2002; Ryan & Deci, 2000; Wigfield & Eccles, 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, Chung, & 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 a topic is important despite not feeling personally interested in it nor well suited to succeed in it (Durik, Shechter, Noh, Rozek, & Harackiewicz, 2015; Wigfield & Eccles, 2000; Wigfield et al., 1997), such as a history major in university who thinks science is important for technological innovation in a country but has a belief that they would not be able to do well in science coursework and no curiosity about science topics.

Utility value has been related to positive outcomes in many academic domains. One of the most well-researched models considering the influence of utility value is that of Eccles et al. (1983) and Eccles and Wigfield (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 et al., 1983; Durik, Vida, & Eccles, 2006; Meece, Wigfield, & Eccles, 1990; Updegraff, Eccles, Barber, & O'Brien, 1996). For example, Eccles et al. (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, Bergin, and Whittaker (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.

1.1. What experiences enable growth vs. inhibit decline in values?

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 in science during the pivotal age of early adolescence. The factors that drive this utility value in science have not been fully explored, and are the focus of the current study, although we expect similar patterns for drivers of utility value in other academic areas. 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. 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., Bong, 2001; Bryan et al., 2011; Parker et al., 2012). Here we focus on the reverse relationship: What kinds of experiences drive changes in values? This question is generally applicable to all academic domains at all educational levels; we focus on the case of science in adolescence given the problematic declines in utility value in science during that time period.

1.2. Classroom experiences as drivers of utility value change

We consider two types of drivers of change. 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 (Ainley & Ainley, 2011; Fredricks, Blumenfeld, & Paris, 2004; Wang & Eccles, 2012), and while engagement has varied definitions and conceptualizations (Fredricks et al., 2004, 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, Miller, Crowson, Duke, & Akey, 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, we anticipate higher cognitive or affective engagement to prevent declines in science values (see Fig. 1).

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., Bandura, 1993; Britner & Pajares, 2006; Ryan & Deci, 2000; Schiefele, 2009). Beliefs in one's efficacy are also posited to feed back into the development of value towards a content area (Feather, 1982; Nagengast et al., 2011). As shown in Fig. 1, we anticipate this relationship to 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).

1.3. Optional learning experiences as drivers of utility value change

In addition to engaging and building perceptions of success during required class activities, during the school year learners can further their science learning through participating in commonly available *optional science experiences*. 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, a weekend 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 (Lin & Schunn, 2017; Sha, Schunn, & Bathgate, 2015), knowledge and scientific literacy (Crowley & Jacobs, 2002; Feldman & Pirog, 2011), continued science participation (Simpkins, Davis-Kean, & Eccles, 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 (i.e., deepening growth and attenuating decline) 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

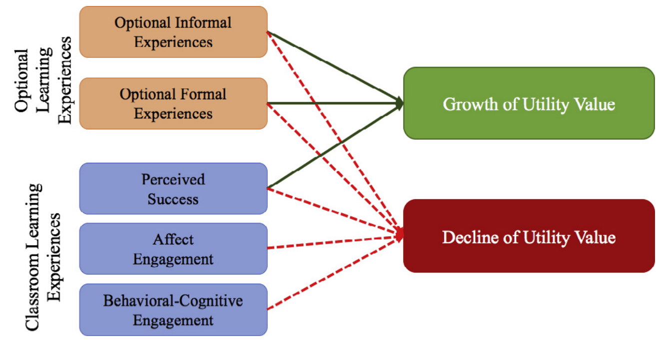

Fig. 1. Predicted model of learning experiences supporting growth (solid lines) or preventing declines (dotted lines) in utility value.

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 (Alexander, Johnson, & Kelley, 2012; Archer et al., 2012; Fouad et al., 2010; 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 (see Fig. 1).

1.4. Current study

The current study examines the impact different science learning experiences have on motivational change towards science during middle school. While previous work has investigated the importance of utility value in many academic domains, our study investigates factors that shape its development, using the case of science utility value changes as a model. Additionally, 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) to allow us to examine the differential relationship different learning experiences have with these types of changes. Based on the prior literature, we expect each science experience variable to relate to changes in utility value overall, but the strength of the unique contributions of each experience variable is an open question. Further, we expect some experience factors to enable growth in utility value whereas other experience factors to prevent declines in utility value. Specifically, we ask: (1) To what extent do classroom and optional science experiences relate to changes in utility value? And (2) Are classroom and optional science experiences differentially related to different types of shifts in utility value (growth, maintain, decline)?

2. Method

2.1. Dataset

The dataset includes ~2600 6th and 8th grade students (49% 6th grade)[1] who completed the pre and post assessments. 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

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

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 ethnicities represented: 44% Caucasian, 29% African-American, 18% Hispanic/Latino, 10% Asian, 7% Native American/Pacific Islander, and 6% Indian/Middle-Eastern.[2]

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).

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, 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. This process was done with 3–6 middle school students per scale construct (e.g., values, engagement). 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 (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 (IRT) 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/).

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!; $a = 0.83$ for both administrations). The YES! To NO! scale has been used in previous work validating these measures for use with middle school students (Sha et al., 2015). In the cognitive interviews used in the development of these scales, students preferred and had an easier time interpreting the YES!-NO! scale compared to the scales typically used in adult research: strongly agree to strongly disagree. Further, IRT analyses revealed sensible ordering and spacing in response patterns across the scale options. This measure was given once at the start of the school year (time 1; August-early September) and again at the end of the fall semester (time 2; late December-early January), in line with teachers' availability and scheduling constraints with a large, multi-site data collection effort. See Fig. 2 for procedural timeline.

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 (Bathgate & Schunn, submitted for publication; Sha, Schunn, & Bathgate, 2012). 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, approximately one month apart. Both affect and behavioral-cognitive items had good reliability across administrations (affect: $\alpha = 0.80$, $\alpha = 0.79$ across the two days), behavioral-cognitive: from $\alpha = 0.72$ to $\alpha = 0.71$). For each student, a mean across the two days was computed for each kind of Engagement.

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!). It was given at the same time as the engagement survey, at the end of class on two days approximately one month apart. EFAs showed a single factor structure with good reliability across administrations ($\alpha = 0.83$ for both days). For each student, a mean across the two days was computed.

2.2.4. Optional formal and informal science 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, $\alpha = 0.74$) and formal experiences (4 items, $\alpha = 0.74$). These two factors will be examined as separate predictors in the models.

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

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

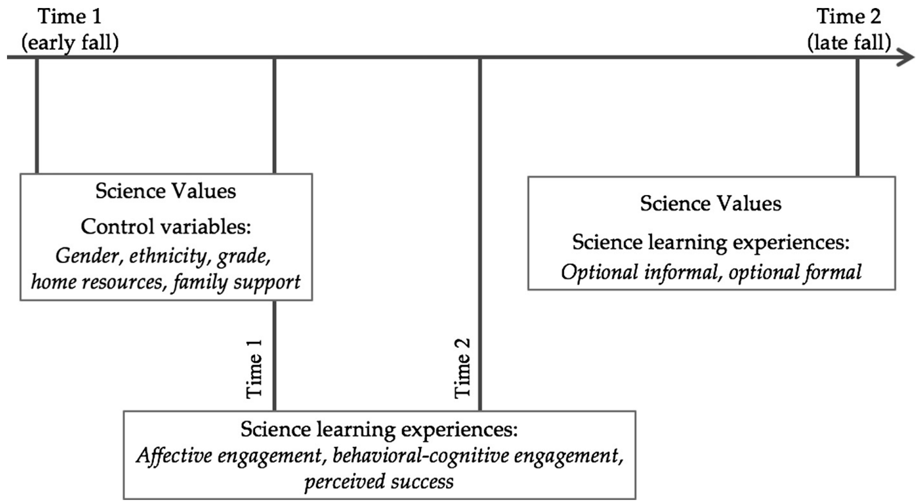

Fig. 2. Fall data collection timeline.

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, Moorman, & Litwack, 2007). As such, we wanted 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 0.73.

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 ($\alpha = 0.78$), 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.

3. Results

3.1. Data cleaning & screening

We began 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 1). Further, the regression analyses revealed acceptable VIF statistics (i.e., multicollinearity is not a concern).

Next, we addressed 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%).

3.2. To what extend does optional science experiences relate to changes in utility value?

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 are 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.[3]

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 2). In addition, there is little substantial shift in Betas (especially in terms of which relationships are significant), showing the

[3] 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).

Table 1
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		0.32	0.23	0.20	0.31	0.13
Affect Eng.			0.54	0.41	0.23	0.11
Beh-cog Eng.				0.40	0.13	−0.03
Perc. Success					0.16	0.10
Opt. Informal						0.50

Note. All correlations were statistically significant at $p < 0.01$ with the exception of formal experiences with behavioral-cognitive engagement, which was $p = 0.07$.

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

Predictor	Model 0 Single factor	Model 1 Classroom experiences	Model 2 Optional experiences	Model 3 Final Model
Time 1 Values	0.54***	0.49***	0.48***	0.45***
Affective Eng.	0.15***	0.11***	–	0.07**
Beh-cog Eng.	0.11***	0.03	–	0.06*
Perceived Success	0.11***	0.07***	–	0.05*
Optional Informal	0.24***	–	0.18***	0.16***
Optional Formal	0.20***	–	0.12***	0.13***
Adjusted R^2, Step 2		35%	38%	39%

Note: The overall models for each regression were significant at the $p < 0.001$ level for each step. Adjusted R^2: Model 1, Step 1 = 0.31; Model 2, Step 1 = 0.31; Model 3, Step 1 = 0.30. Adjusted R-squares for the regressions run in model 0 ranged from 30% to 37%.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

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 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.

The final model (model 3) was replicated for 6th and 8th grade independently to see check for consistency across grades. The pattern of results is similar with two exceptions: Affective engagement significantly predicts changes in utility value only in 6th grade and perceived success is predictive of utility value changes only in 8th grade, although the difference in standardized beta for the latter is quite small (0.03 increase in 8th grade). Otherwise, the results are consistent (i.e., both forms of optional experiences and behavioral-cognitive engagement are similarly predictive across grades).

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. 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 ($1/2$ SD = 0.23) above or below the mean change in values (M = −0.01) was used as the cut point to group the participants into one of three categories: Grow (growth from pre to post by more than 0.22 on the values measure), decline (decline from pre to post by more than 0.24), maintain (the remaining students). This procedure provided suitable power to each category (i.e., moving to 1 SD would have led to underpowered group sizes), created pragmatically meaningful change outcomes (i.e., less than ½ SD would not be a notable enough shift on our outcome scale), and has been previously argued to be a useful benchmark for meaningful change in self-report measures (Norman, Sloan, & Wyrwich, 2003). Table 3 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.

3.4. Are classroom and optional science experiences differentially related to different types of shifts in utility value?

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 4 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

Table 3
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[a]	2.5	0.7	2.3	0.7	2.2	0.7
Optional Formal[a]	1.9	0.8	1.7	0.7	1.6	0.7
Total N (% of total)	*701 (30%)*		*1094 (46%)*		*559 (24%)*	

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

Table 4
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	*

Note: Nagelkerke pseudo $R^2 = 0.26$.
t $p<0.20$.
+ $p < 0.08$.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

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[4]).

As a concrete example, Table 4 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 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 & Cumming, 2009. This approach examines the degree of overlap in the confidence intervals for each e^Bas calculated using a bias corrected bootstrap technique (1000 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 ($p < 0.20$), 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.

3.5. Continuous versus categorical change

Table 5 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,

[4] 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.

Table 5
Patterns of impact of all variables for growth and decline groups (relative to maintenance group) for science values.

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

Notes: Time 1 (for multinomial regressions) and control variables (for both) are included in the models but are not shown in the table. $^{+}p < 0.08$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$; 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 $p < 0.10$.

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.

4. Discussion

4.1. Which factors are most strongly associated with changes in utility values?

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 & Pintrich, 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.

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 5). 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 (see Table 5). 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 et al., 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., Dabney et al., 2012; Maltese et al., 2014). 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, Rennie, Anderson, & Ellenbogen, 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.

4.3. Implications and future directions

For researchers and practitioners, the current work makes clear that change in motivation is not a single outcome, but rather can and should be divided into enabling growth and preventing declines. For researchers, the asymmetrical drivers of growth and decline could help account for differences in findings across studies. In some contexts, the population may already be high at pretest and thus preventing the decline is the primary possible outcome, whereas in other contexts, the population may be quite low at pretest and thus enabling growth is the primary possible outcome. This conceptual distinction in growth is likely to be important for motivational change in academic learning beyond science, since the affordances and challenges of school experiences and optional learning experiences are likely general (Dierking et al., 2003). However, future research is required to examine the mechanisms behind the differential effects on growth vs. decline of utility values.

Specific to practitioners, thinking about changes in motivation in terms of growth and decline creates pragmatic opportunities to differentiate intervention by context, and the specific findings of the current study clearly indicate which kinds of experiences are likely to have larger effects in supporting growth vs. preventing decline. Educators could easily use short surveys 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 (Jang, 2008; Smart & Marshall, 2013; Chin & Osborne, 2008; Hulleman, Godes, Hendricks, & Harackiewicz, 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.

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