

Understanding motivational structures that differentially predict engagement and achievement in middle school science

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ABSTRACT

Middle school has been documented as the period in which a drop in students' science interest and achievement occurs. This trend indicates a lack of motivation for learning science; however, little is known about how different aspects of motivation interact with student engagement and science learning outcomes. This study examines the relationships among motivational factors, engagement, and achievement in middle school science (grades 6–8). Data were obtained from middle school students in the United States ($N=2094$). The theoretical relationships among motivational constructs, including self-efficacy, and three types of goal orientations (mastery, performance approach, and performance avoid) were tested. The results showed that motivation is best modeled as distinct intrinsic and extrinsic factors; lending evidence that external, performance based goal orientations factor separately from self-efficacy and an internal, mastery based goal orientation. Second, a model was tested to examine how engagement mediated the relationships between intrinsic and extrinsic motivational factors and science achievement. Engagement mediated the relationship between intrinsic motivation and science achievement, whereas extrinsic motivation had no relationship with engagement and science achievement. Implications for how classroom practice and educational policy emphasize different student motivations, and in turn, can support or hinder students' science learning are discussed.

ARTICLE HISTORY

Received 21 June 2015
Accepted 22 December 2015

KEYWORDS

Engagement; middle school; motivation; science; self-efficacy; achievement

Introduction

Although student motivation is a topic of significant interest in the science education research community, the concept of motivation for science learning remains vague and poorly understood (Osborne, Simon, & Collins, 2003). Research is needed to explicate how distinct constructs underlying students' motivation support learning behaviors (e.g.

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engagement) and ultimately, achievement in science. Specifically, there is a gap between the broad study of motivation in science education and the body of work in related fields of education and psychology, where multiple frameworks and constructs of motivation have been developed (e.g. Ames, 1992; Bandura, 1997; Harackiewicz, Barron, Pintrich, Elliot, & Thrash, 2002; Ryan & Deci, 2000a).

A deeper examination of the nature and role of students' motivation in science learning and achievement is of particular importance given the advent of the *Next Generation Science Standards* (NGSS) in the United States (US). The NGSS presents a vision for science education that requires significant shifts in science teaching and learning away from rote learning of discrete facts and toward an integrated approach where students engage with scientific practices and cross-disciplinary concepts to develop a deep understanding of science ideas (NRC, 2012). Achieving this vision necessitates genuine student engagement and positive attitudes toward learning science. Unfortunately, studies have shown that students who lose interest in science often do so during the pivotal middle school years (ages 11–13) (Britner & Pajares, 2006; Pajares, Britner, & Valiante, 2000), and as a result, choose against pursuing science courses beyond what is required for high school graduation (Grolnick, Farkas, Sohmer, Michaels, & Valsiner, 2007; Kahn & Kellert, 2002; Mullis & Jenkins, 1988). These trends are likely contributing to the steady decline of students entering science careers since the mid-1960s (Yager, Harms, & Lunetta, 1981).

Understanding how to motivate students to be more engaged in science and exhibit achievement in science fields is a matter of considerable concern, given the economic utility and global relevance of scientifically literate citizens (Jenkins, 1994; Osborne et al., 2003). A better understanding of how student motivation manifests in learning and achievement is thus critical. Unfortunately, the study of motivation in science education largely ignores the complex structures underlying motivational constructs. To address this gap, this study first presents a test of several theoretical models of motivation. Then, the unique influences of different types of motivation are examined with respect to students' engagement and science achievement. Motivation (discussed in detail below) is broadly conceptualized as the 'drive' that directs students' learning (Cerasoli, Nicklin, & Ford, 2014; Eccles & Wigfield, 2002; Ryan & Deci, 2000a), whereas engagement refers to the actual learning processes along behavioral, affective, and cognitive indicators (Fredricks, Blumenfeld, & Paris, 2004). This study aims to address the vague conceptualizations of motivation in science education by examining the relationships among distinct motivational factors, and their unique and interactive effects on engagement and science achievement in middle school.

Multiple frameworks for understanding the role of student motivation in learning and achievement

Motivation is a fundamental component of any model for understanding academic achievement (Cerasoli et al., 2014; Hidi & Harackiewicz, 2000; Valentine, Dubois, & Cooper, 2004). A large body of work unequivocally points to the important role of motivation in a host of desired student outcomes (e.g. Anderman & Maehr, 1994; Kupermintz, 2002; Ryan & Deci, 2000b). In science education, motivation has been linked to students' academic achievement (Britner & Pajares, 2006), positive attitudes toward science, effective approaches to learning (Britner & Pajares, 2006; Pajares et al., 2000), and choice to pursue science at postsecondary levels (Gwilliam & Betz, 2001; Kupermintz, 2002;

Luzzo, Hasper, Albert, Bibby, & Martinelli, 1999). This makes motivation a prime focus for educators aiming to support students' long-term interest and accomplishment in science. However, a close look at the literature shows diverse theoretical frameworks and definitions of motivation across studies that are nebulous and often poorly articulated. To better understand the role of motivation in students' science learning and achievement, it is critical to first identify the relationships among different motivational theories and constructs.

In both educational psychology and science education research, several constructs of motivation have been studied through different theoretical perspectives. These include motivation directed by mastery versus performance goals under goal orientation theory (e.g. Ames, 1992; Hulleman, Schrage, Bodmann, & Harackiewicz, 2010; Midgley, Kaplan, & Middleton, 2001), motivation characterized by students' beliefs regarding their ability (i.e. self-efficacy) under social cognitive theory (e.g. Bandura, 1986, 1997; Pajares, 1996), and a distinction between intrinsic versus extrinsic motivation under self-determination theory (e.g. Deci & Ryan, 1985; Harter, 1981; Ryan & Deci, 2000b). In their review of these motivational theories, Eccles and Wigfield (2002) called for theoretical integration, arguing that, 'although there are some differences across these [motivation] constructs, the similarities likely outweigh the differences' (p. 127). This study addresses the call for theoretical integration by empirically examining the relationships among motivational constructs from different theoretical traditions identified prominently in the literature. Drawing from theoretical and empirical evidence, three models that integrate and organize different motivational constructs are proposed for empirical testing (Figure 1). Each model is explained in turn below, with accompanying explanation of the theoretical and empirical debate underlying the proposed model.

The first model proposes a broad, multidimensional motivation construct that is composed of three constructs from goal orientation theory (mastery, performance approach, and performance avoid) (Ames, 1992; Hulleman et al., 2010; Midgley et al., 2001) and a self-efficacy construct from social cognitive theory (Bandura, 1986, 1997). From the goal orientation perspective, motivation is a manifestation of students' goal pursuit, rather than their innate traits (Ames, 1992; Elliot & Church, 1997; Harackiewicz et al., 2002; Midgley et al., 2001; Pintrich, 2000; Urdan, 1997). The three established facets of goal orientation theory include mastery (orientation toward understanding, mastering material and concepts), performance approach (orientation toward external rewards or appearing competent), and performance avoid (orientation toward avoidance of failure or appearing unable) (Ames, 1992; Midgley et al., 2001; Pintrich, 2000). Self-efficacy comes from social cognitive theory, and refers to the beliefs students have regarding their academic abilities (Bandura, 1997; Pajares, 1996). Studies have shown that in the classroom, students with high self-efficacy are more likely to select and persevere through challenging science activities (Britner & Pajares, 2006; Valentine et al., 2004). Furthermore, research supports the predictive power of self-efficacy on achievement in science (e.g. Gwilliam & Betz, 2001; Pajares et al., 2000; Valentine et al., 2004).

In past studies, these constructs from goal orientation and social cognitive theory have been conflated (although not always acknowledged) (e.g. Brookhart, Walsh, & Zientarski, 2006; Lau & Roeser, 2002; Nicholls, Cheung, Lauer, & Patashnick, 1989; Rawsthorne & Elliot, 1999). For example, in their study of the role of motivation, effort, and classroom assessment environment on middle school achievement, Brookhart et al. (2006)

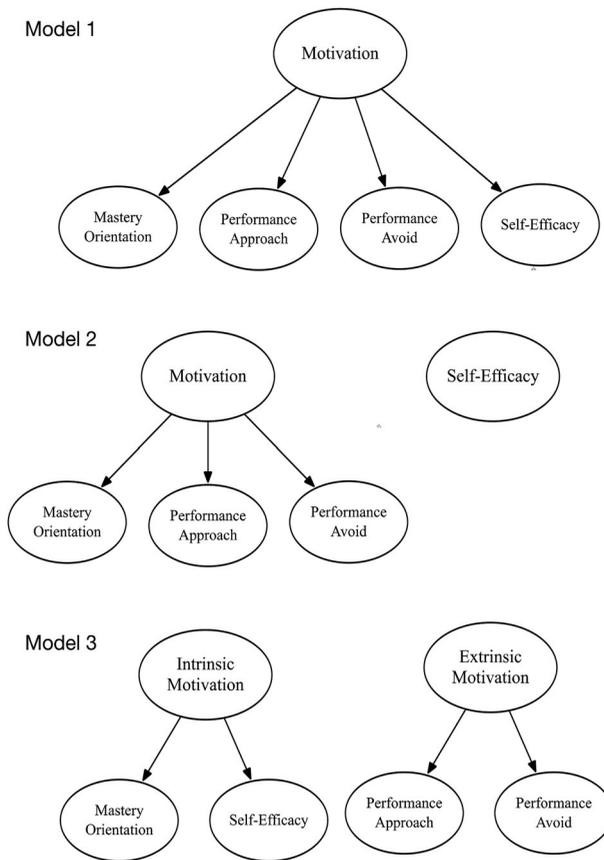


Figure 1. Three competing models of motivational constructs.

conceptualized motivation as a combination of perceived self-efficacy as well as mastery and performance goal orientations. Model 1, in which the three goal orientations and self-efficacy is organized as components of a higher-order motivation construct, is empirically tested to determine the appropriateness of using constructs from goal orientation and social cognitive theory together in reference to a broad motivational construct.

Another point of deliberation relates to whether self-efficacy is a motivational construct, or a separate construct altogether. From one perspective, self-efficacy is considered one of many variables underlying motivation. Model 1 is based on this approach to motivation research that categorizes self-efficacy under motivation theories (Dweck, 1999; Eccles & Wigfield, 2002; Wigfield & Eccles, 2000). In contrast, other studies position self-efficacy beliefs as a construct separate from motivation (e.g. Klassen et al., 2009; Pajares et al., 2000; Usher & Pajares, 2009; Zimmerman, 2000). Here, a clear demarcation is drawn between the *beliefs* that students hold about their abilities (self-efficacy) and the *internal drive* or motivation underlying their behaviors. Thus model 2 tests an alternative theoretical model that draws a distinction between students' motivation and their self-efficacy. These distinctions of self-efficacy as a motivation versus separate construct are pertinent to science education because teaching that target students' confidence and beliefs about their

learning (self-efficacy) may necessitate different approaches, compared to teaching that depends on fostering internal drives (motivation).

Finally, although past studies have conflated indicators of intrinsic and extrinsic motivation to refer to a broad umbrella term of motivation (models 1 and 2), in model 3, we propose and test a theoretical framework that categorizes motivational constructs according to similarity with features of intrinsic motivation (an internal desire to learn, enjoyment in the task itself) or extrinsic motivation (an externally driven desire based on rewards, approval, or compliance) (Deci & Ryan, 1985; Marsh, Hau, Artelt, Baumert, & Peschar, 2006; Osborne et al., 2003; Ryan & Deci, 2000a).¹ This intrinsic versus extrinsic framework has been applied in both science education research, with results showing greater evidence for the positive role of intrinsic motivation on science achievement compared to extrinsic motivation (Osborne et al., 2003).

Students who are intrinsically motivated engage in classroom activities with a full sense of autonomy and volition, rooted in the inherent pleasure that is experienced from the process of learning itself (Cerasoli et al., 2014; Ryan & Deci, 2000b). Mastery orientation and self-efficacy were categorized under intrinsic motivation to test the proposition that both are important for internal sources of motivation. This categorization has both theoretical and empirical bases. Theoretically, mastery orientation and intrinsic motivation are both characterized as a drive derived from interest and desire to develop proficiency in the subject of learning (Ames, 1992; Brookhart et al., 2006; Cerasoli et al., 2014; Midgley et al., 2001; Ryan & Deci, 2000a). Empirically, several studies have consistently demonstrated that intrinsic motivation, mastery orientation, and self-efficacy are positively linked to desired learning behaviors (e.g. persistence on difficult tasks, use of deep processing strategies) and outcomes (e.g. greater conceptual understanding, higher assessment scores) (e.g. Deci, Koestner, & Ryan, 2001; Elliot, Mcgregor, & Gable, 1999; Klassen et al., 2009; Usher & Pajares, 2009).

In contrast, extrinsically motivated students engage in classroom activities due to outside, instrumental factors that have external consequences (Cerasoli et al., 2014; Deci & Ryan, 1985; Ryan & Deci, 2000a). Theoretically, extrinsic motivation and the two performance orientations (approach and avoid) share a drive that is externally regulated (Deci et al., 2001; Elliot & Church, 1997; Harackiewicz et al., 2002; Hulleman et al., 2010; Ryan & Deci, 2000b). Whereas extrinsic motivation is more broadly defined (Deci & Ryan, 1985; Marsh et al., 2006), the two performance orientations delineate different sources of externally driven motivation; motivation to appear competent (performance approach) and motivation to avoid appearing incompetent (performance avoid) (Elliot & Church, 1997; Harackiewicz et al., 2002; Linnenbrink, 2005). Empirically, research examining the relationship between performance orientations and student outcomes shows that performance avoidance orientation is linked to adverse outcomes such as test anxiety, academic self-handicapping, and low achievement (e.g. Anderman & Maehr, 1994; Midgley & Urdan, 2001; Pajares et al., 2000), similar to the negative link between extrinsic motivation and student learning (e.g. Ryan & Deci, 2000b; Weiner, 1990).

The role of performance approach orientation in students' learning is less clear. On the one hand, some studies demonstrate a link between performance approach orientation and high academic achievement as well as self-concept (Cury, Elliot, Sarrazin, Fonseca, & Rufo, 2002; Elliot & Church, 1997; Elliot & Harackiewicz, 1996; Elliot et al., 1999). On the other hand, results from other studies have shown that performance approach orientation is associated with maladaptive processes such as poor use of learning

strategies, avoiding seeking help, and cheating (Linnenbrink, 2005; Midgley & Urdan, 2001; Middleton & Midgley, 1997; Murdock, Miller, & Kohlhardt, 2004). Due to the shared external regulation of both performance orientations and extrinsic motivation, as well the empirical support (albeit mixed for performance approach) regarding the negative relationship between externally regulated motivation and academic outcomes, we chose to test both performance orientations under extrinsic motivation in model 3. Practically, this model will inform whether or not science educators should encourage practices that draw upon students' motivation that is externally regulated, such as seeking rewards and gaining praise from teachers, or practices that put greater emphasis on intrinsic factors. Moreover, establishing the nature and role of internal versus external motivation has substantive implications for approaches to grading, testing, and accountability, which heavily rely on external forms of motivation to elicit achievement.

Altogether, motivation and self-efficacy have been demonstrated to be important for students' learning and academic achievement. However, while a series of primary studies has independently examined the impact of different subsets of motivational constructs on student outcomes, a comprehensive test of the relationships among these different motivational constructs is currently lacking. Clarifying these relationships will contribute to advancing our understanding of motivation in science education by moving beyond examining motivational constructs in isolation, or in a conflated way that obscures the underlying meaning, and toward exploring how different sources of motivation may work together in contributing to students' science learning.

The role of student engagement in science education

Whereas motivation is related to underlying psychological processes, engagement, or the ways in which students connect to learning in the classroom, is operationalized as the level of students' active involvement in a task (Appleton, Christenson, Kim, & Reschly, 2006; Marks, 2000). Engagement is categorized according to three dimensions: behavioral (e.g. attendance, conscientious completion of tasks), affective (e.g. positive or negative feelings toward academic task), and cognitive (e.g. mental effort exerted to comprehend complex ideas) (Appleton et al., 2006; Fredricks et al., 2004; Jimerson, Campos, & Greif, 2003; Reeve, Jang, Carrell, Jeon, & Barch, 2004). An extensive body of research shows that the three types of engagement are related to many desirable student outcomes, including self-regulated learning, positive attitudes toward an academic subject, and academic achievement (Fredricks et al., 2004; Jimerson et al., 2003; Pintrich, 2000; Marks, 2000; Skinner, Kindermann, Connell, & Wellborn, 2009). Furthermore, it has been suggested that students' engagement is a critical mediator between classroom instruction and student learning (Lau & Roeser, 2002).

The notion that motivation and engagement jointly influence student outcomes seems obvious, but surprisingly, engagement is often examined in relation to achievement without understanding the intersections with motivation (e.g. Fredricks et al., 2004; Jimerson et al., 2003; Reeve et al., 2004). When considered together, scholars have proposed that motivation serves as a driving force behind students' level of engagement in academic activities (Appleton et al., 2006; Lau & Roeser, 2002; Miller, Greene, Montalvo, Ravindran, & Nichols, 1996; Reeve, 2012). In other words, motivation is an unobservable process that leads to an observable behavior that is engagement. Few studies have empirically examined

these proposed relationships, with emerging findings pointing to the predictive value of motivation on engagement, and in turn, engagement on achievement (e.g. Lau & Roeser, 2002; Reeve, 2012; Wigfield et al., 2015). As an example, Lau and Roeser (2002) found that motivation was significantly predictive of high school students' engagement in science-related assessment, classroom, and extracurricular experiences. Engagement in turn, predicted science test scores and grades (Lau & Roeser, 2002). Taken together, further exploration of engagement as both an outcome of motivation and a predictor student achievement is worthwhile. Particularly in the field of science education, more complex models that account for multiple motivational and engagement constructs, and the relationships among them to predict science achievement have not been tested.

This study thus builds upon emerging research that suggests engagement as mediating the relationship between motivation and achievement in the context of middle school science. Based on the premise that motivation and engagement together are theoretically and practically important for supporting science learning, this study makes a novel contribution to existing literature by first determining the structure of several motivational constructs (mastery orientation, performance orientations, and self-efficacy), then testing their relationships with engagement (cognitive, affective, and behavioral) to predict students' science achievement.

Present study

The unclear conceptualization of motivational constructs in science education, and the lack of studies examining the joint effects of motivation and engagement on student science achievement served as the impetus for this study. Firstly, the need for theoretical integration related to different motivation constructs is addressed. Using latent variable analysis, this study informs current debates about how different constructs of motivation (mastery, performance approach, performance avoid, and self-efficacy) are related by empirically testing three competing models that draw from goal orientation (Ames, 1992; Midgley et al., 2001), social cognitive (Bandura, 1986, 1997), and self-determination (Deci & Ryan, 1985; Ryan & Deci, 2000b) theories of motivation. Secondly, this study makes a novel contribution by examining whether and how engagement mediates various components of motivation in predicting science achievement.

The following research question guided this study: What are the unique and intersecting roles of motivation and engagement in predicting science achievement? Specifically, (1a) what are the underlying constructs and relationships among commonly studied motivational constructs (self-efficacy, mastery, performance approach, and performance avoid)? and (1b) Does engagement play a mediating role between students' motivation and their science achievement?

Method

Sample and procedure

This study was conducted in the context of a larger National Science Foundation (NSF) middle school science professional development project. The motivation and engagement survey was administered in Spring 2014, to 2094 middle school students from 72 teachers

participating in the project, across 8 districts and 30 schools in an urban area in the United States. The schools sampled served a diverse student population (Minority percent ranging from 26.3% to 99.3%) with varying levels of socioeconomic status (Free Reduced Lunch percent ranging from 5.2% to 94.5%). The Spring 2014 data were used for examining the factor structure of the long and short versions of the survey subscales (described under measures) and for testing the latent variable models presented in the findings. In addition, the short motivation and engagement survey was administered to an independent sample of 836 students in Fall 2014 from the same school districts to test for measurement validity. A total of 50 minutes (one class period) was provided for students to complete the survey online or on paper forms.

Measures

Motivation and engagement survey

The motivation and engagement survey (the Appendix) consisted of the following three major categories: (1) goal orientations (mastery, performance approach, and performance avoid), (2) self-efficacy, and (3) three types of engagement (behavioral, affective, and cognitive). Items for the student goal orientation and self-efficacy components of the survey were drawn from the Patterns of Adaptive Learning Scales (Midgley et al., 2000), including mastery, performance approach, performance avoid (14 items) and self-efficacy (5 items). All survey items were rated on a 5-point Likert scale, ranging from 1 (*Not true at all*) to 5 (*Very true*). Cronbach's α for the goal theory and efficacy subscales in the original research ranged from .74 to .89 (Midgley et al., 2000) and in a separate study, .77 to .89 (Pajares et al., 2000). The engagement items were drawn from the Student Engagement Scale (Fredricks et al., 2004). This scale was adapted from existing measures (Pintrich, Smith, Garcia, & Mckeachie, 1993; Wellborn & Connell, 1987) to assess the three types of engagement: behavioral (5 items), affective (5 items), and cognitive (7 items). Cronbach's α were .76, .83, and .77 for the behavioral, affective, and cognitive subscales, respectively (Fredricks et al., 2004). Evidence for concurrent validity was found through moderate, positive correlations among the three engagement subscales and measures of classroom context (e.g. perceived teacher support, peer support, task challenge) (r ranging from .23 to .49) (Fredricks et al., 2004).

Regarding face validity, and the argument that these student constructs cannot be separated from contexts (Osborne et al., 2003), the items were adapted to ask students about their motivation and engagement in the context of their science classroom (e.g. 'One of my goals in science class is to learn as much as I can'). In addition to consideration of the face validity based on wording of items, construct validity was established by selecting items from existing measures that are theoretically grounded in the literature on motivation (e.g. Ames, 1992; Midgley et al., 2001; Ryan & Deci, 2000a, 2000b), self-efficacy (e.g. Bandura, 1997; Pajares et al., 2000), and engagement (e.g. Appleton et al., 2006; Fredricks et al., 2004).

To address practical challenges associated with administering a lengthy survey among middle school students (e.g. time constraints, risk of cognitive fatigue; Gogol et al., 2014; Marsh, 2006; Moore, Halle, Vandivere, & Mariner, 2002), the long survey of existing measures (total of 36 items) were consolidated to reduce each construct to 3 items (total of 21 items on the short survey), meeting the three indicator minimum requirement

for representing a latent construct reliably (Gogol et al., 2014; Kline, 2011). The following considerations were taken into account during the item selection process including the redundancy of items (analysis of wording as well as inter-item correlations), size of factor loadings from the CFA (index of item-level internal reliability), classical test theory descriptive and internal reliability statistics, clarity of item wording, and preciseness of item wording based on the construct it was developed to measure (face validity) (Gogol et al., 2014; Kline, 2011). Cronbach's α for Spring 2014 scores on the short survey subscales ranged from .67 to .85, providing evidence for the internal reliability of the short survey. Additional evidence for construct validity are presented in the results, based on the factor analyses conducted using the original (Spring 2014) and independent (Fall 2014) data.

Science concept inventories (CI)

Science achievement was measured using a multiple-choice science concept inventory (CI) that corresponded to students' grade level content. The earth science CI (grade 6) consists of 30 items, in which 15 items were drawn from an existing, validated assessment tool developed by Libarkin, Kurdziel, and Anderson (2007) and another 15 items were developed by a content expert (university faculty in geochemistry) to address common misconceptions in middle school earth science (Cronbach's $\alpha = .76$). The life science CI (grade 7) consists of 18 items that were adapted from the *Conceptual Inventory of Natural Selection* (Anderson, Fisher, & Norman, 2002) by university faculty in biology (Korb, Anderson, Silberglitt, Jensen, & Hagedorn, 2013) in order to address common misconceptions in middle school life science (Cronbach's $\alpha = .81$). The physical science CI (grade 8) consists of 25 items developed and validated by the Physics Underpinnings Action Research Team from Arizona State University (Evans et al., 2003). Science CI scores represent the total percentage correct on the test.

Analyses

Descriptive statistics of the motivation and engagement survey

Descriptive statistics (mean, standard deviation, skew, and kurtosis) and tests of reliability were conducted using SPSS version 21. The data were screened for missingness, normality, and outliers. Absolute skewness and kurtosis values above two were considered as not meeting assumptions of normality (Bandalos & Finney, 2010).

Confirmatory factor analyses (CFA) of measurement model

Prior to testing the competing models of motivation as well as the mediation model through structural equation modeling (SEM), a CFA was performed on the measurement model of the seven theoretical constructs (latent variables) using MPlus 6 (Kline, 2011; Knapp & Mueller, 2010). CFA provides supportive evidence for the construct validity of a measure (i.e. the degree to which theoretical constructs account for the scores on the measure) (Knapp & Mueller, 2010). Data from Spring 2014, which included scores for the long and short survey subscales, were analyzed using CFA to determine the construct validity of the scores from the long versus short surveys. The factor structure of the short survey was tested again using an independent sample from Fall 2014.

The maximum likelihood robust estimation was used to account for the non-independence of missing data. Geomin-rotation (which produces oblique or correlated factors)

was used to estimate the factor loadings for each item. We assessed model fit based on a set of absolute (fit from the obtained and implied covariance matrix), relative (fit from model test to a null model that specifies no latent variables), and comparative goodness-of-fit (GOF) indices (relative fit of tested model compared with baseline model), including the root mean square error of approximation (RMSEA), the standardized root mean square residual (SRMR), the comparative fit index (CFI), and the Tucker-Lewis Index (TLI) (Kline, 2011). The cut-off values recommended by Hu and Bentler (1998) were used, with RMSEA and SRMR values equal to or below .06, and CFI and TLI values above .90 indicating good model fit. We also report the chi-square (χ^2) test statistic with a probability value of $\alpha = .05$, which tests the null hypothesis that there is no significant difference between the model's implied covariances and the observed covariance. However, because χ^2 is sensitive to sample size and model complexity (Iacobucci, 2010; Kline, 2011), the absolute, relative, and comparative GOF indices were used to determine model fit. The Satorra-Bentler Scaled χ^2 test, which applies a scaling correction that adjusts the χ^2 when using MRL estimation, was used to compare models (Satorra & Bentler, 2001).

Testing competing models of motivation

Three competing theoretical models of motivation were empirically tested using SEM, which is an extension of general linear procedures such as regression analysis. The goal in SEM is to determine if a hypothesized theoretical model matches the structure of empirical data collected (Kline, 2011).

An advantage of SEM is that it allows for the study of relationships among latent constructs that are specified by multiple manifest (or observed) variables (Kline, 2011). Thus, this multivariate analysis technique combines information from various measures with different methods. Benefits of applying SEM include controlling for error variance that is specific to tests, and assessing the fit of structural models (Kline, 2011). In the three motivation models, mastery orientation, performance approach orientation, performance avoid orientation, and self-efficacy were specified as first-order latent variables, specified by the three items from the short survey data collected in Spring 2014.

Model 1 tested a theoretical framework of motivation in which different goal orientations (mastery, performance approach, and performance avoid) and students' self-efficacy are proposed to be components of a broad motivation construct (Dweck, 1999; Eccles & Wigfield, 2002; Wigfield & Eccles, 2000). In this model, a higher-order latent motivation factor was specified by 4 first-order latent variables: mastery, performance approach, performance avoid, and self-efficacy. Model 2 tested an alternative theoretical framework which draws a distinction between students' motivation and their self-efficacy (Klassen et al., 2009; Pajares et al., 2000; Usher & Pajares, 2009; Zimmerman, 2000). In model 2, self-efficacy was estimated as a first-order latent variable separate from the higher-order motivation factor. Finally, model 3 was tested, in which the four constructs under study are organized by intrinsic and extrinsic categories (Marsh et al., 2006; Ryan & Deci, 2000a, 2000b). Mastery orientation and self-efficacy were categorized under a first-order intrinsic motivation latent variable. Performance approach and avoid orientations were categorized under a first-order extrinsic motivation latent variable (Midgley et al., 2001; Ross, Shannon, Salisbury-Glennon, & Guarino, 2002).

Testing a mediation model of the relationships among student motivation, engagement, and science achievement

A major aim of this study was to understand how the resultant motivational structures work with student engagement and science achievement, rather than to simply establish that a total effect exists (Hayes & Preacher, 2010). To this end, a SEM was conducted to examine a model in which engagement mediated the relationship between motivation and science achievement, which allows for inferences to be made regarding direct and indirect effects of motivation (Muthén, 2011). The higher-order intrinsic (indicated by first-order mastery and self-efficacy factors) and extrinsic motivation (indicated by first-order performance approach and performance avoid factors) variables were specified as independent variables, and were specified to predict the engagement latent variable (indicated by first-order behavioral, affective, and cognitive engagement factors). Engagement was specified to predict science achievement (indicated by the science CI score). Intrinsic and extrinsic motivation variables (indirect effects) were specified to indirectly affect science achievement through engagement (mediating variable). Mediation was determined to exist if intrinsic and extrinsic motivation directly predicted engagement, if engagement directly predicted science achievement, and if the indirect effect of intrinsic motivation and extrinsic motivation on science achievement was significant (Hayes & Preacher, 2010; Muthén, 2011). Model fit was determined based on the set of absolute, relative, and comparative GOF indices described in the CFA analysis above.

Results

Descriptive statistics of the observed variables in the original sample (who completed the survey in Spring 2014) are presented in Table 1, and for the independent sample (who completed only the short survey in Fall 2014), in Table 2. Skew and kurtosis values were within a reasonable range.

Measurement model

The factor structure of the full and short motivation and engagement surveys were analyzed using the data from the original sample of 2094 students in Spring 2014, as well as an independent sample of 836 students who completed the only the short survey in Fall 2014 (Table 3). The seven factors estimated using CFA included the following

Table 1. Descriptive statistics of observed variables from original sample in Spring 2014.

Variable	N	M	SD	Min	Max	Skew	Kurtosis
1. Mastery	2092	4.18	0.71	1.00	5.00	-0.88	0.81
2. PerfAp	2091	2.59	1.09	1.00	5.00	0.44	-0.55
3. PerfAv	2091	3.06	1.07	1.00	5.00	-0.01	-0.75
4. Efficacy	2071	3.98	0.84	1.00	5.00	-0.66	0.12
5. EngBeh	2064	3.95	0.71	1.00	5.00	-0.42	-0.01
6. EngAffect	2060	3.75	0.88	1.00	5.00	-0.56	0.17
7. EngCog	2026	3.02	0.90	1.00	5.00	0.20	-0.20
8 Overall CI (%)	2026	43.44	19.20	3.33	100.00	.45	-.39

Mastery, mastery orientation; PerfAp, performance approach orientation; PerfAv, performance avoidance orientation; Efficacy, efficacy; EngBeh, engagement behavioral; EngAffect, engagement affective; EngCog, engagement cognitive; Overall CI, overall % correct on Concept Inventory.

constructs from the original surveys: mastery orientation, performance approach orientation, performance avoid orientation, efficacy, behavioral engagement, affective engagement, and cognitive engagement. The seven factor model showed good fit to the Spring 2014 data from the long survey (RMSEA = .04, CFI = .91, TLI = .90, SRMR = .05). However results showed a superior fit of the seven factor model to the data from the short survey (RMSEA = .03, CFI = .97, TLI = .97, SRMR = .03) (Figure 2). In addition, geomin-rotated factor loadings of the items within each of the seven constructs generally increased for items retained in the short survey compared to the long survey (ranging from .33 to .84 versus .57 to .84 for the long and short surveys, respectively). Of note, the factor loadings of items on the short survey exceeded the criteria of a minimum factor loading of .30 to retain valid items (Kline, 2011). Finally, the change in the Satorra-Bentler scale χ^2 test was significant ($\chi^2 = 3965.74$, $p < .001$) between the 7 factor baseline (short survey) and nested (long survey) models, indicating that the short survey model was a superior fit compared to the long survey model (Satorra, 2000; Satorra & Bentler, 2001). These patterns of results were replicated using data from the independent sample of students in Fall 2014 who completed the short motivation and engagement survey, showing additional evidence for the seven factor structure of the survey (RMSEA = .06, CFI = .92, TLI = .90, SRMR = .06; geomin-rotated factor loadings ranging from .49 to .87). All subsequent results presented were analyzed using the data from the Spring 2014 scores from the items included in the short survey.

Testing competing models of motivation

The GOF indices of the three motivation SEM models are presented in Table 4. Model 1, in which all three types of goal orientation and self-efficacy were estimated under a higher-order motivation construct, demonstrated poor fit to the data (RMSEA = .07, CFI = .92, TLI = .90, SRMR = .11). Examination of the factor loadings showed that the performance approach and avoid orientation latent variables loaded well on the higher-order motivation latent variable (.85 and .92, respectively), whereas the mastery orientation and efficacy factors showed low loadings (.22 and .20 respectively). For model 2, results again did not provide evidence for adequate model fit to the data (RMSEA = .07, CFI = .92, TLI = .90, SRMR = .11), failing to support the theoretical model in which efficacy was estimated as a construct separate from motivation. Similar to model 1, mastery orientation showed a low factor loading on the motivation variable (.22) whereas performance approach and avoid orientations loaded highly (.85 and .92, respectively). These results from models 1 and 2 indicate that mastery orientation is an indicator of a factor separate from performance

Table 2. Descriptive statistics of observed variables from short scale administered to independent sample in Fall 2014.

Variable	N	M	SD	Min	Max	Skew	Kurtosis
1. Mastery	836	4.19	.67	1.00	5.00	1.06	1.10
2. PerfAp	834	2.98	.91	1.00	5.00	.18	-.35
3. PerfAv	832	3.40	.89	1.00	5.00	-.34	-.29
4. Efficacy	814	3.99	.83	1.00	5.00	-.67	.29
5. EngBeh	825	4.10	.70	1.00	5.00	-.66	.70
6. EngAffect	816	4.01	.80	1.00	5.00	-.70	.49
7. EngCog	815	3.07	.84	1.00	5.00	.09	-.04

Table 3. Comparison of CFA goodness-of-fit indices and standardized factor loadings of items between the long and short survey forms for the motivation and engagement measurement models.

Model	# of items	χ^2	df	p-value	RMSEA	CFI	TLI	SRMR	Δ Satorra-Bentler Scaled χ^2	Standardized factor loadings	
										Min	Max
Spring 2014 <i>Original Sample</i> (N = 2094)											
Long survey (7 factors)	37	4802.83	573	<.001	.04	.91	.90	.05	–	.33	.84
Short Survey (7 factors)	21	826.96	168	<.001	.03	.97	.97	.03	3965.74*	.57	.84
Fall 2014 <i>Independent Sample</i> (N = 836)											
Short Survey (7 factors)	21	605.02	168	<.001	.06	.92	.90	.06		.49	.87

Note: Short version of survey consists of 3 items per construct assessed. Reported Satorra-Bentler χ^2 , CFI, and RMSEA are based on robust estimates.

* $p < .001$.

Table 4. Results of CFA comparing three competing models of motivation.

Model (first-order latent variables are listed in parentheses)	χ^2	df	p-value	RMSEA	CFI	TLI	SRMR	Standardized factor loadings	
								Min	Max
Model 1: Motivation (mastery, perfap, perfavoid, efficacy)	601.21	50	< .001	.07	.92	.90	.11	.20	.92
Model 2: Motivation (mastery, perfap, perfavoid) and Efficacy	589.19	49	< .001	.07	.92	.90	.11	.22	.92
Model 3: Intrinsic Motivation (mastery, efficacy), Extrinsic Motivation (perfap, perfav)	181.19	49	< .001	.04	.98	.98	.03	.67	.94

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

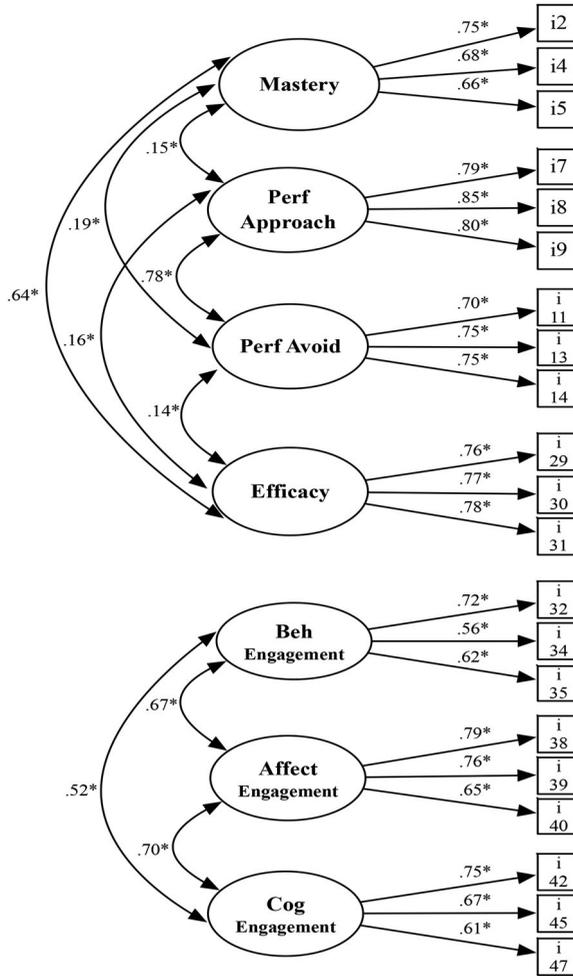


Figure 2. Measurement model for the 7-factor, 21-item (3 items per construct) short motivation and engagement survey using data collected in Spring 2014.
* $p < .01$.

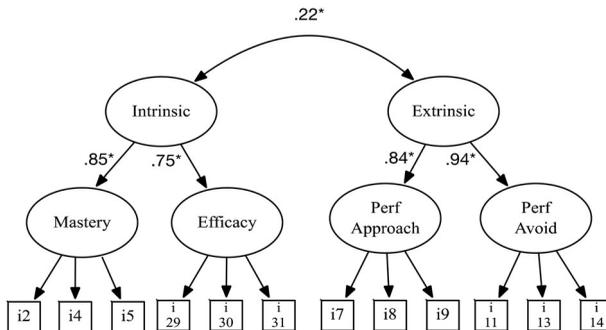
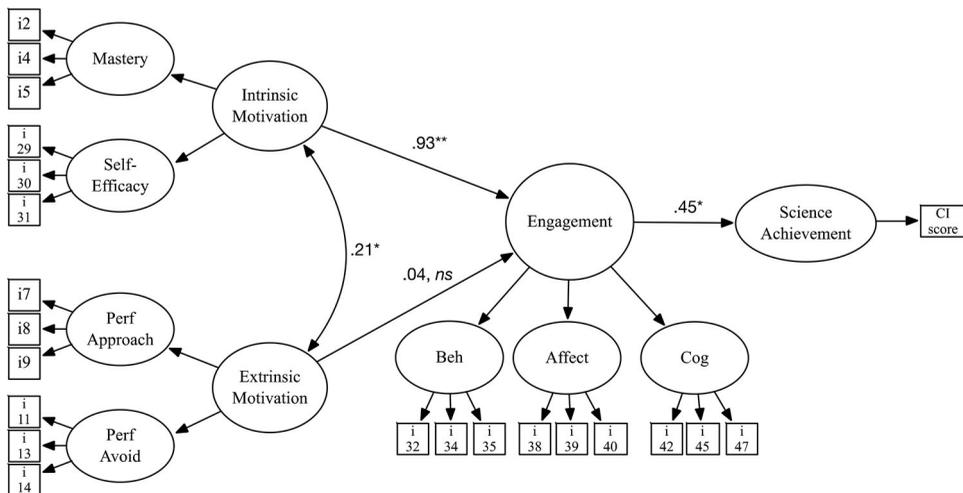


Figure 3. Model 3 of motivational constructs including self-efficacy, mastery orientation, performance approach orientation, and performance avoid orientation.
* $p < .01$.

approach and performance avoid orientation, and that efficacy should be considered a part of motivation. In contrast to models 1 and 2, results from model 3, in which the four constructs under study are organized by intrinsic and extrinsic categories (Figure 3), showed the good fit to the data (RMSEA = .04, CFI = .98, TLI = .98, SRMR = .03). In addition, examination of the factor loadings showed that all first-order latent variables loaded highly on their corresponding higher-order latent variable; intrinsic motivation which was specified by mastery orientation (.85) and efficacy (.67), and extrinsic motivation which was specified by performance approach (.84) and performance avoid (.94) orientations. Overall, results showed the greatest evidence for model 3, which categorized mastery orientation and self-efficacy under intrinsic motivation, and performance approach and avoid orientation under extrinsic motivation.

Mediation model of the relationships among motivation, engagement, and science achievement

We built upon model 3 of motivation to test a mediation model in which engagement mediated the relationship between motivation (intrinsic and extrinsic) and student achievement (Figure 4). Results showed that the mediation model had a good fit to the data (RMSEA = .04, CFI = .96, TLI = .96, SRMR = .04). Intrinsic motivation had a strong, positive significant direct effect on engagement ($\beta = .93, p < .001$), whereas extrinsic motivation had a weak and non-significant direct effect on engagement ($\beta = .04, p = .10$). As expected, engagement had a moderate, positive, and significant effect on science achievement, measured by students' scores on a comprehensive science CI ($\beta = .45, p < .05$). Intrinsic motivation was significantly related to science achievement ($\beta = .61, p < .05$), whereas extrinsic motivation was not ($\beta = .14, p = .47$). As would be expected from these



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

Figure 4. Mediation model of the relationships among motivation, engagement, and science achievement.

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

results, the indirect effect tested between intrinsic motivation and science achievement was significant ($\beta = .32, p < .05$), whereas the indirect effect tested between extrinsic motivation and science achievement was not significant ($\beta = .16, p = .52$). Overall, results showed evidence that engagement mediates the relationship between intrinsic motivation and science achievement.

Discussion

Based on the premise that students' motivation and engagement are critical factors influencing science achievement in middle school, the goal of this study was twofold: (1) to examine the relationships among commonly studied motivational constructs from goal orientation, social cognitive, and self-determination theories in efforts to move toward theoretical integration and (2) to test a model of engagement as a mediator of the relationship between various motivational constructs and science achievement. This study was conducted among middle school science students, an important population to examine due to documented declines in science interest during middle school (Britner & Pajares, 2006).

In regards to the first aim of this study, results clearly point to a structure of motivation characterized by intrinsic and extrinsic factors. Regarding the debate as to whether self-efficacy should be conceptualized as a construct distinct from motivation or not, our findings provide evidence for conceptualizing students' self-efficacy (confidence in their academic ability) together with students' mastery orientation (drive toward understanding) under a broader drive to learn rooted in the enjoyment of learning science (intrinsic motivation). In addition, this study sheds light on the debate regarding whether performance approach orientation is more closely related to mastery orientation, which is consistently linked to positive student learning outcomes, or more closely related to performance avoid orientation, which has shown to have detrimental effects on students' learning behaviors (e.g. Ames, 1992; Anderman et al., 2001; Linnenbrink, 2005; Midgley et al., 1998; Murdock et al., 2004). Our results indicate that students' orientation toward external accomplishments (performance approach) functions more similarly to performance avoidance in comparison to mastery orientation. Specifically, whereas an intrinsic drive characterized by the desire to understand the material (mastery orientation) predicted engagement, extrinsic motivation characterized by the desire to appear competent (performance approach) or the desire to avoid looking incompetent (performance avoid), did not.

Additionally, this study makes a novel contribution to the literature by examining the joint contribution of intrinsic and extrinsic motivation as well as engagement on students' science achievement. Building on past research that suggest motivation as internal processes that predict engagement (observable learning behaviors), and engagement as both an outcome of motivation and a predictor of achievement (Appleton et al., 2006; Lau & Roeser, 2002; Miller et al., 1996; Reeve, 2012), we empirically tested the mediating role of engagement between two categories of motivation (intrinsic and extrinsic), and science achievement. Results showed that engagement mediated the relationship between intrinsic motivation and science achievement; however, this was not the case for extrinsic motivation.

The findings regarding the positive pathways between intrinsic motivation (mastery orientation and self-efficacy) and engagement, and between engagement and science

achievement, highlight the importance of implementing pedagogies and classroom activities that provide students with a sense of autonomy and confidence in their own learning (self-efficacy) and develop their interest in mastering the topic of study (mastery orientation). This includes creating a classroom culture that fosters internal forms of motivation through students' curiosity and interest in the topic, and minimizing classroom structures that foster students' orientation toward exhibiting good or avoiding bad performance. For example, common classroom practices such as emphasizing grades and competition draw on extrinsic factors to motivate students; however, our results indicate that this type of motivation is not predictive of students' engagement in learning and subsequent science achievement in middle school. These findings can be explained by previous studies that showed evidence that extrinsic motivators (e.g. awards, praise) can undermine curiosity, persistence, and interest (Cerasoli et al., 2014; Deci et al., 2001; Ryan & Deci, 2000a, 2000b)—attributes that are associated with behavioral, cognitive, and affective engagement in learning tasks, and ultimately, achievement in school.

For science education, our findings imply a shift in pedagogy aligned to the Framework for K12 Science Education and the NGSS (NRC, 2012), that call for more authentic, practice-based science that increase opportunities for students to develop authentic mastery goal orientations (interest in the science learning task) and self-efficacy (confidence in science ability) (Britner & Pajares, 2006). Further implications for the classroom include employing methods of assessment and feedback that are formative (used to explore students' ideas rather than to evaluate) (Levin, Hammer, & Coffey, 2009) and focus on effort and improvement rather than ability (Dweck, 1999) in order to support students' intrinsic motivation and confidence in the process of learning of science.

Unfortunately, entrance into middle school is often associated with a rise in assessment pressures, increased academic rigor, and heightened mistrust between teachers and students (Anderman & Maehr, 1994; Ryan & Patrick, 2001; Wentzel, 1997). This may facilitate an orientation away from mastery and toward performance (e.g. achieving good grades, competing with others), and such an approach may undermine students' intrinsic drive to engage science learning (Britner & Pajares, 2006). Moreover, previous studies have shown that motivation that is internally regulated and stems from the enjoyment in the task itself (i.e. intrinsic motivation) is susceptible to a variety of outside factors such as the presence of incentive systems, methods of evaluation, degree of agency, and rigid deadlines (Cerasoli et al., 2014; Deci et al., 2001). Likewise, students' self-efficacy for any given subject is vulnerable to the nature of the feedback (e.g. praise and/or criticism) they receive (Dweck, 1999) as well as additional internal and external sources of efficacy (e.g. physiological state, vicarious and mastery experiences) (Usher & Pajares, 2009). Thus, future lines of research are needed to explicate how alternative classroom conditions can support students' intrinsic motivation.

We would like to note that although we did not find evidence of a link between performance approach orientation and science engagement or achievement, some studies have suggested that performance approach orientation may facilitate achievement at later ages (Elliot & Church, 1997; Elliot & Harackiewicz, 1996; Pajares et al., 2000). Furthermore, recent research suggests that intrinsic and extrinsic sources of motivation may account for different amounts of variance in performance, dependent on whether performance quality or quantity is being assessed (Cerasoli et al., 2014). Thus future lines of research are needed to test our proposed mediation model among older student populations and

in regards to different indicators of achievement. Additionally, while examining other variables is beyond the scope of this study, we acknowledge that different facets of motivation and engagement are very likely to interact with other important social and contextual constructs to influence students' overall learning in science. For example, some researchers argue that in order to understand motivation, attention to taxonomy of goals, emotions, and personal agency beliefs (Wentzel, 1997) as well as person-environment interactions (e.g. students' history of academic achievement, types of classroom assessments) (Brookhart et al., 2006; Urdan & Maehr, 1995) is required. Furthermore, information regarding students' engagement was gathered using self-report surveys. Although evidence for the reliability and validity of the engagement subscales was found in this study and past research, by nature, self-report surveys pose risk to the reliability and validity of the data due to context and person-specific characteristics (e.g. social desirability bias, cognitive fatigue) (Stapleton, 2010). Future research may explore more direct indicators of student engagement using classroom observation instruments (although this method may restrict the sample size due to the resource-intensive nature of observation data collection). Given these limitations, direct applications of findings regarding personal goal orientations and efficacy beliefs to classroom contexts must be made cautiously.

Overall, a long history of scholarship has highlighted the merits of intrinsic motivation for student engagement and achievement (e.g. Marsh et al., 2006; Osborne et al., 2003; Ryan & Deci, 2000a, 2000b), whereas some researchers claim that aspects of extrinsic motivation are also beneficial (e.g. Cerasoli et al., 2014; Cury et al., 2002; Elliot & Church, 1997). This debate matters because if extrinsic motivation is linked to learning and achievement, then external rewards, competition, and tangible accomplishments become acceptable approaches to fostering students' drive in classrooms. What we found here refutes this approach, supporting the implicit elements of the Framework for K12 Science Education and the NGSS that sets a vision for science education rooted in real-world phenomenon that drives students' natural curiosity and engagement in scientific practices to deepen their understanding of disciplinary ideas. We argue that it is important to provide students with low-risk opportunities (i.e. not grade-focused or high-stakes evaluation tasks) to reason around complex science phenomena in meaningful ways. In contrast to traditional instruction that cast students as passive recipients of information delivered by the teacher, science activities that engage students in authentic science practices (e.g. planning and conducting investigations) in support of deep understanding of disciplinary science ideas is more likely to develop students' motivation rooted in the intrinsic value of grappling with science and build confidence in their ability to take ownership of their learning (Bransford, Brown, & Cocking, 1999). Simultaneous to NGSS supporting and creating the conditions for building intrinsic motivation, other policies and conditions such as accountability, college entrance exams, grading, and competition encourage extrinsic and performance motivations. Given the importance of intrinsic motivation for engagement and achievement shown in this study, educators and policy makers should carefully consider implications of the externally driven incentive systems (e.g. standards and accountability structures, systems of grading) for student learning.

Note

1. Ryan and Deci (2000a, 2000b) provide a more detailed gradation of intrinsic and extrinsic motivation in their Self-Determination Theory, which presents motivation on a continuum ranging from intrinsic to amotivation, including four different types of extrinsic motivation (integrated, identified, introjected, and external). However, because it was beyond the scope of this study, intrinsic and extrinsic motivation was not examined at this grain level.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the National Science Foundation [grant number 0962804].

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Appendix. Motivation and engagement survey

Construct	Subconstruct	Motivation and engagement survey item wording
Goal orientation theory	Mastery approach	<ol style="list-style-type: none"> 1. It's important that I learn a lot of new concepts in my science class. 2. One of my goals in science class is to learn as much as I can.^a 3. One of my goals is to master a lot of new science skills this year. 4. It's important to me that I thoroughly understand my science class work.^a 5. It's important to me that I improve my science skills this year.^a

(Continued)

Continued.

Construct	Subconstruct	Motivation and engagement survey item wording
	Performance approach	6. It's important to me that other students in my science class think I am good at my class work. 7. One of my goals is to show others that I'm good at my science class work. ^a 8. One of my goals is to show others that science class work is easy for me. ^a 9. One of my goals is to look smart in comparison to the other students in my science class. ^a 10. It's important to me that I look smart compared to others in my class.
	Performance avoid	11. It's important to me that I don't look stupid in science class. ^a 12. One of my goals is to keep others from thinking I'm not smart in science class. 13. It's important to me that my science teacher doesn't think that I know less than others in class. ^a 14. One of my goals in science class is to avoid looking like I have trouble doing the work. ^a
Self-efficacy	Self-efficacy	27. I'm sure I can become really good at the skills taught in science class this year. 28. I'm sure I can figure out how to do the hardest science class work. 29. I can do almost all the work in science class if I don't give up. ^a 30. Even if the science class work is hard, I can learn it. ^a 31. I can do even the hardest work in science class if I try my best. ^a
Engagement	Behavioral	32. I pay attention to all of the learning activities in my science class. ^a 33. When I am in science class, I just act as if I am working. 34. I complete my science homework on time. ^a 35. I follow the rules in my science class. ^a 36. I get in trouble in my science class.
	Affective	37. I feel bored when I'm learning science. 38. I feel excited by the learning activities in my science class. ^a 39. I like being in my science class. ^a 40. I am interested in conducting scientific experiments. ^a 41. My science classroom is a fun place to be.
	Cognitive	42. When I learn a new science lesson, I ask myself questions to make sure I understand what I am learning about. ^a 43. I look for chances to be part of science events that are related to things we are doing in my science class. 44. I talk with people outside of school about what I am learning in my science class. 45. I look for extra information (books or internet) to learn more about things we do in science class. ^a 46. If I don't understand what I read in science class, I go back and read it over again, look it up, or discuss it with someone. 47. During science class, I ask questions and offer suggestions. ^a 48. During science class, I talk, participate, and contribute to the discussion.

^aRepresents items used in the motivation and engagement short survey.