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A mixed methods study of middle students' science motivation and engagement profiles

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A R T I C L E I N F O

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A B S T R A C T

Targeting motivation and engagement in science is crucial for middle school students' achievement. This mixed methods study aimed to better understand middle school student engagement and motivation profiles in science by applying latent profile analysis ($N = 1828$) and student focus group interviews ($n = 27$). Quantitative results showed five profiles characterized by unique configurations of motivation (self-efficacy, mastery and performance goal orientations) and engagement. Specifically, three profiles (*Highly Motivated and Engaged, Average Motivation and Engagement, Below Average Motivation and Engagement*) demonstrating level effects and two profiles that demonstrated shape effects (*Unmotivated and Disengaged*, *Mastery Motivated and Engaged*) emerged. Grade and school level socioeconomic status were significant predictors of profile membership, and profiles characterized by higher motivation and engagement were associated with higher science achievement. Qualitative findings provided insight into how profile indicators manifest in urban classrooms including how the various motivation and engagement dimensions co-occur as students participate in various science activities. The integration of quantitative profiles and qualitative themes contribute to our understanding of not only how students differ in their motivation and engagement, but also what these profile indicators look like in situ and relate to science learning outcomes. Practical implications for teachers, such as differentiated approaches to support students' unique motivation and engagement needs, are discussed. Finally, lines for future research are outlined, underscoring the affordances of the mixed methods approach in person-centered work.

1. Introduction

The importance of students' motivation and engagement in school for positive learning outcomes is well-established in the literature (Fredricks et al., 2016; Midgley et al., 1998; Pintrich et al., 1993; Sinatra, 2005). Less understood are the ways students display motivation and engagement in idiosyncratic ways. This aligns with the emerging literature from person-centered studies that identify discernable clusters of students characterized by unique configurations of motivation and engagement (e.g., Bae et al., 2020; Snodgrass Rangel et al., 2020). Student science motivation and engagement are particularly important during the middle school years, which are marked by increased specialization in science that sets the foundation for students' future pursuit of study in scientific fields (Britner & Pajares, 2006; Usher & Pajares, 2008; Sadler et al., 2013). Unfortunately, studies show that student engagement and motivation (e.g., goals, self-efficacy) in science, technology, engineering, and mathematics (STEM) decreases throughout middle school (Morgan & Gerber, 2016).

This mixed methods profile study draws from motivation and engagement frameworks to 1) quantitatively identify motivation and engagement profiles of middle school students, 2) examine student motivation and engagement profiles in relation to student and school level predictors and science achievement, 3) qualitatively examine motivation and engagement indicators within profiles, and 4) integrate the quantitative and qualitative findings to present a more complete picture of how student motivation and engagement profiles manifest in classroom activities. This mixed methods approach to integrating motivation frameworks to quantitatively identify profiles then further exploring qualitative indicators in a discipline-specific context is important for better understanding the diverse types of learners in science classrooms. This will support both practitioners and researchers in developing approaches for students with different combinations of motivation and engagement in science classrooms.

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2. A theoretically integrative and mixed methods approach to student profiles

2.1. Student motivation and engagement in science

Motivation refers to the drive that underlies and sustains student learning behaviors (Pintrich et al., 1993; Schunk et al., 2014; Sinatra, 2005). Engagement refers to how students connect to learning and is often studied as an outcome of students' motivation (Fredricks et al., 2004; Lawson & Lawson, 2013). Traditional approaches of using a single motivation theory often fail to develop an understanding of the complex ways students are driven to persist and engage in learning (Hattie et al., 2020; Linnenbrink-Garcia & Wormington, 2019). An integrative approach has the potential to address the gap between the siloed motivation and engagement literature. This is important because it 1) demonstrates the different ways students use various motivation resources that uniquely contribute to learning behaviors, and 2) captures the complexity of students' motivation and engagement in dynamic classroom contexts. To this end, we take an integrative approach (Linnenbrink-Garcia & Wormington, 2019) by drawing on three prominent motivation and engagement theories that have shown to be related to desirable students' science learning (e.g., Linnenbrink-Garcia et al., 2018; Sinatra et al., 2015) including: achievement goal orientation (Midgley et al., 1998; Pintrich, 2000), social cognitive theory (Bandura, 2002), and engagement theory (Fredricks et al., 2016). These motivational frameworks were chosen due to the body of former studies relating achievement goal theory to social cognitive theory to more fully understanding students' self-beliefs in relation to their academic goals, connections to learning tasks (i.e., engagement), and achievement (e.g., Huang, 2016; Liem et al., 2008). Each of these is described next.

2.1.1. Achievement goal theory

Achievement goal theory is a widely used motivation framework that proposes two major types of goal approaches that drive behaviors, including mastery goals and performance goals (Ames, 1992; Dweck, 1986; Pintrich, 2000; Wormington & Linnenbrink-Garcia, 2017). Mastery goals are characterized by an orientation towards learning that focuses on understanding the content and improving related skills, whereas performance goals are characterized by an external orientation. Performance goals are further distinguished by performance-approach goals (orientation towards showcasing ability) and performance-avoidance goals (orientation towards avoiding being perceived as incompetent, Harackiewicz et al., 2002; Midgley et al., 1998).

2.1.2. Social cognitive theory

Self-efficacy is defined as students' beliefs in their ability to successfully complete an academic task (Bandura et al., 2001; Usher, 2015). Within social cognitive theory, it is posited that students' self-efficacy in science is influenced by personal, social, and environmental factors that reciprocally influence one another (i.e., reciprocal determinism; Usher & Pajares, 2008). For example, observing peers succeed in science (social) can serve as a vicarious experience in the classroom that increases a student's own (personal) self-efficacy (e.g., "If they can do it, I can too"), which in turn helps that student believe they can make a positive impact in their classroom learning community (environmental). The positive classroom climate (environment) will in turn, create more opportunities for students and their peers to have successful learning interactions (social) and support students' individual self-efficacy (Britner & Pajares, 2006; Chen & Usher, 2013).

2.1.3. Engagement theory

Similar to self-efficacy, student engagement in school is traditionally conceptualized as a socio-psychological construct that refers to how students connect to learning tasks (Fredricks et al., 2004, 2016; Lawson & Lawson, 2013). A widely used engagement framework organizes the way students connect to learning along four dimensions including cognitive (e.g., mental involvement in learning tasks), behavioral (e.g., staying on-task while completing assignments), affective (e.g., excitement and other emotions associated with the learning task), and social (e.g., working with peers to complete a task) engagement.

2.1.4. Understanding students' science motivation and engagement in context

To further our understanding of motivation and engagement in context, it is crucial to examine how students' achievement goals, self-efficacy, and engagement co-occur in classroom activities. Thus, this study takes a theoretically-integrated approach to examine the situation-specific and momentary nature of students' motivation and engagement in science. The constructs examined in our study, including achievement goals (mastery and performance), self-efficacy, and engagement come from unique theoretical traditions, but what these all share are the tenets of social cognitive theory which posit a reciprocal influence between personal, social, and contextual factors.

Increasingly scholars are examining these or similar motivation and engagement constructs together, with findings demonstrating notable links to students' learning and academic achievement. For example, it has been theorized that mastery goal orientation (e.g., focus on deeper understanding and skill development, persistence in applying strategies like planning and monitoring) will lead to academic success, which in turn will increase students' self-efficacy (confidence in that academic domain; Bandura, 2002; Dweck, 1986). Empirical support for this positive link was shown in a meta-analysis, demonstrating a strong correlation between mastery goals and high self-efficacy beliefs and moderate correlations between performance goals and low self-efficacy beliefs (Huang, 2016). Findings from recent empirical studies are also pointing to achievement goals and self-efficacy positively influencing student engagement and achievement (e.g., Lee et al., 2022; Olivier et al., 2019). For example, Lee et al. (2022) examined reading mindset, self-efficacy, achievement goals, engagement, and reading achievement among fourth grade students. Using a person centered approach, they identified three distinct profiles showing that students who held the highest levels of master orientation, also had the highest levels of self-efficacy, behavioral engagement, cognitive engagement, and achievement (Lee et al., 2022). Olivier et al. (2019) examined the longitudinal relationships among self-efficacy, emotional and behavioral engagement, and academic achievement from 4th to 6th grade. Results demonstrated a positive relationship between 4th grade self-efficacy and later emotional engagement and academic achievement, whereas emotional engagement in 5th grade was negatively related to academic achievement in 6th grade (Olivier et al., 2019). Self-efficacy also mediated the relationship between emotional engagement and academic achievement (Olivier et al., 2019). Taken together, there is a history of understanding achievement goals and self-efficacy in relation to students' learning behaviors (e.g., engagement, academic achievement, Dweck, 1986). Further, recent studies point to meaningful interactions among these constructs (e.g., Lee et al., 2022; Olivier et al., 2019). This study extends this contemporary work by examining how achievement goals, self-efficacy, and engagement cluster together in unique science learning profiles among middle school students in urban education contexts.

In addition to taking a more theoretically-integrated approach, this study will apply qualitative methods to explore in more depth how students' motivation and engagement manifest in classrooms as they participate in various science activities. Contemporary studies demonstrate the context-specific and momentary nature of students' motivation and engagement in science learning (e.g., Adler et al., 2018; Bae and Lai, 2020; Bae et al., 2022; Inkinen et al., 2020). For example, Adler et al. (2018) found that rather than a fixed entity, student motivation is contingent on how appropriately teachers scaffold open-ended inquiry activities to a level that students feel is achievable. Similarly, Inkinen et al. (2020) showed that student engagement was situational, and peaked when students were working with models (e.g., diagrams, physical replicas) in class to explore complex and abstract phenomena in chemistry and physics compared to when they were in a unit that did not use models. This study will expand on this work by qualitatively examining the disciplinary and classroom-based nature of students' science motivation and engagement.

Taken together, much of the literature to date has examined engagement or motivation profiles in science separately (e.g., Sutter et al., 2022) and almost entirely quantitatively (with few exceptions such as Louick et al., 2016 and Pugh et al., 2017). Scholars have also recently called for the need to apply integrated and qualitative approaches to shed light on how motivation and engagement profiles manifest in context (e.g., Salmela-Aro et al., 2016).

2.2. Person-centered approaches to student motivation and engagement profiles

Students' motivation and engagement in science classrooms is largely informed by findings from variable-centered studies, which assume that students hold level or uniformly high, moderate, or low levels of motivation, and focus primarily on the main effects of motivation variables on outcomes of interest (Bergman & Trost, 2006; Collins & Lanza, 2009). Person-centered approaches, in contrast, allow researchers to examine whether differential levels of motivation and engagement among a set of indicators (shape effects) are simultaneously held by students (Marsh et al., 2009; Muthén & Muthén, 1998; Pastor et al., 2007). For example, it is possible that a student may have high levels of self-efficacy, and also simultaneously hold high-performance goals (e.g., orientation to demonstrate competence for external rewards) and low mastery goals (e.g., orientation towards developing deeper understanding (e.g., Linnenbrink-Garcia et al., 2018).

An emerging body of person-centered research shows that students do, in fact, hold varying levels of motivation and engagement in science. Some studies examined Expectancy Value Theory (EVT; Wigfield & Eccles, 2000), which is a framework for understanding student achievement motivation by accounting for their expectations for success, costs, and values (e.g., Perez et al., 2019; Snodgrass Rangel et al., 2020). For example, Snodgrass Rangel et al. (2020) applied EVT to conduct a latent profile analysis to examine motivational beliefs (i.e., self-efficacy, task value, interest/enjoyment value, and attainment value) of underrepresented and first-generation college students in math and science. Four profiles were identified including all low, medium-low math/medium-high science, medium-high math/medium-low science, and all high demonstrating that these motivational beliefs are context-specific and relative to a domain. Perez et al. (2019) also applied EVT to identify four unique motivation profiles. The profiles demonstrating shape effects, Very High Competence/Values, Low Effort Cost, completed the most STEM courses on average over both other groups. This finding provides a better understanding of unique subgroups of college students characterized by different configurations of ability beliefs and values for STEM courses.

Similarly, drawing from a multidimensional framework of engagement (Fredricks et al., 2016; Wang et al., 2016), Bae and DeBusk-Lane (2019) identified three engagement profiles (*Disengaged, Moderately Disengaged,* and *Moderately Engaged*) that exhibited level trends, and two profiles with shape effects, or unique patterns across behavioral engagement indicators (*Behaviorally Engaged* and *Behaviorally Disengaged*). Drawing from multiple motivation frameworks, Radišić et al. (2021) identified five secondary students' interest and enjoyment profiles in science that included six indicators (enjoyment, interest, motivation, self-efficacy, involvement in different science activities, and epistemological beliefs). The fifth and smallest profile was uniquely characterized by low enjoyment and interest in science, but high self-efficacy, motivation, and engagement in science activities (*Practical Inquirers*; Radišić et al., 2021). Finally, in a mixed methods study of 6th grade students' engagement in earth science, Pugh and colleagues (2017) identified three unique clusters of transformative engagement characterized by qualitatively different patterns of indicators. The low-level cluster included 2 subclusters, one characterized by similar low levels of motivated use (i.e., relating science to out-of-school contexts), expansion of perception (i.e., understanding content in deeper ways), and experiential value (i.e., seeing the world differently), and the second subcluster characterized by similar low level of motivated use, but higher levels of expansion of perception and experiential value. Qualitative analyses of student interviews showed that students in the low clusters provided vague or shallow links between real-world experiences and science content (e.g., weak connection between wind and playing baseball), whereas students in the high clusters drew substantive links (e.g., applied concepts of high and low pressure and heat transfer to understand news reports on incoming storms). Taken together, studies of student profiles in science show that motivation and engagement indicators cluster in unique ways, warranting the application of person-centered approaches. This study extends the literature by including achievement goals in addition to self-efficacy (e.g., Radišić et al., 2021; Snodgrass Rangel et al., 2020) and engagement (e.g., Bae & DeBusk-Lane, 2019; Pugh et al., 2017) to identify science motivation and engagement profiles among a diverse sample of middle school students.

2.3. Predictors and outcomes of student science learning profiles

In this study, we also examined student and school-level predictors of profile membership. At the student level, grade level was accounted for given the rapid physical, cognitive, and socio-emotional intrapersonal development that occurs during students' middle school years. These also include year-to-year changes in their engagement and motivation that increasingly differentiate by subject area (e.g., Archambault et al., 2010; Caprara et al., 2008; Guo et al., 2017; Wigfield et al., 2015). Additionally, evidence from prior profile studies also shows evidence that motivation profiles can differ by middle school grade level (Bae & DeBusk-Lane, 2018) and that grade or age level predicts profile membership (Bae et al., 2020). Examining grade level will provide insight into the trajectory of students' motivation and engagement in middle school from a person-centered perspective.

In addition, we examined how context-level variables including the percentage of school level Free Reduced Lunch, English Language Learner, and Minority population, influenced profile membership. These predictors represent a comprehensive set of indexes that have been used in past studies as proxy variables for socioeconomic status (Sirin, 2005) as well as indexes of diverse urban school contexts (Welsh & Swain, 2020). It was an intentional choice to include these predictors at the school-level to provide context for the students' learning environment, rather than at the student-level as to not perpetuate a deficit mindset on individual students (Alexander et al., 2012; Byrnes, 2020; Lewis & Farkas, 2017). A large body of literature demonstrates that factors related to students' school ecologies influence classroom climate learning opportunities that impact their individual motivation and engagement. Specifically, in science, inequities in access to resources such as lab equipment and high-quality curricula have been documented along socioeconomic lines (Banilower et al., 2013). Additionally, accountability pressures tend to be stronger in low-income schools, which has been associated with instruction focused on coverage on content assessed on standardized tests and minimal hands-on and authentic investigation of scientific phenomena (Hanushek & Rivkin, 2006; Hayes & Trexler, 2016; Lankford et al., 2002). Past studies have also shown that school SES predicts students' science achievement, even after accounting for student-level characteristics (e.g., Bae et al., 2021; Baker et al., 2002; Caldas & Bankston, 1997). Further, there is an eclectic body of literature showing that urban education settings are dynamic spaces in which both inequity and possibly can exist (Green, 2015). For example, racial and cultural diversity of students in a school, and in turn, increased intergroup contact, has been associated with more complex identities, higher engagement, and a sense of belonging among adolescents (Graham, 2018). Finally, person-centered studies have examined how student-level minority status predict profile membership, with results showing that students in underrepresented minority groups (e.g., racial/ethnic, first-generation) are represented in higher numbers in certain motivation profiles (Perez et al., 2019; Snodgrass Rangel et al., 2020). We contribute to the extant literature by examining a comprehensive set of predictors at the school level (socioeconomic, racial, and linguistic makeup of students) to explore contextual influences on students' profile membership.

Lastly, we examined how the student science learning profiles related to academic outcomes in science. Past research indicates that students' motivation and engagement profiles are significantly related to a range of outcomes in school (e.g., GPA, course completion, subject matter content knowledge, Bae et al., 2020; Perez et al., 2019; Snodgrass Rangel et al., 2020). As expected, the emerging literature showed that profiles characterized by higher motivation and engagement are associated with more desirable outcomes, and the reverse is shown to be true for profiles characterized by lower motivation and engagement (e.g., Perez et al., 2019; Snodgrass Rangel et al., 2020). However, the relationship between profiles characterized by varying levels of motivation or engagement indices and academic outcomes is mixed. For example, profiles characterized with different levels of math and science motivation beliefs (e.g., medium/high in science but medium/low in math) were not significantly different from other profiles in terms of which STEM courses they took, but did differ significantly in terms of GPA in STEM those courses (Snodgrass Rangel et al., 2020). This study will contribute to additional evidence to tease apart these mixed findings between profiles that demonstrate shape effects and science achievement.

3. Current study

The first purpose of this mixed methods study was to identify student motivation and engagement profiles in science classrooms. We extend the literature by taking a theoretically integrated approach that draws from achievement goal, social cognitive, and engagement theory to estimate unique student profiles in science using latent profile analysis. Secondly, we examined school-level, contextual predictors (% of students who qualify for Free Reduced Lunch (FRL), % of English Language Learners, and % of Ethnic/Racial minority students) and student-level predictors (grade level) of motivation and engagement profile membership. Thirdly, we examined the relationships between profiles and science achievement.

Fourthly, we qualitatively explored how the profile indicators manifest during science activities, providing in-depth information about what middle school students' motivation (achievement goals, self-efficacy) and engagement looks like in classrooms. Finally, we integrated the quantitative results with the qualitative findings to provide a fuller picture of the nature of student science profiles in context. The theoretically integrated and mixed methods approach taken in this study affords a fuller understanding of the different ways middle school students are motivated and engaged in science learning.

The following research questions guided this study:

(1) What science motivation and engagement profiles, characterized by goal orientations, self-efficacy, and engagement, exist in middle school? (quantitative)
(2) How do student-level factors (grade level) and school-level, contextual factors (% of students who qualify for Free Reduced Lunch (FRL), % of English Language Learners, and % of Ethnic/Racial minority students) predict profile membership? (quantitative)
(3) Do the student learning profiles differ in science achievement (quantitative)?
(4) How do the motivation and engagement profile inputs co-occur and manifest during science learning activities? (qualitative)
(5) What is the nature (person-level characteristics), learning behaviors, and outcomes of each student profile in the context of science classrooms? (integrated)

Given our theoretical framework and prior findings from contemporary profile studies of engagement and motivation, the following hypotheses were developed. In terms of profiles, we hypothesized that a four to five profile solution would be identified. Specifically, we expected three level profiles (in which all indicators are below average, average, or above average), as these three types of profiles are commonly identified in past person-centered studies across age groups and domains (Linnenbrink-Garcia et al., 2018; Perez et al., 2019; Snodgrass Rangel et al., 2020). Additionally, we expected one or two profiles in which the self-efficacy and performance goal indicators differed from the mastery orientation and engagement indicators, based on similar profile solutions identified in elementary and college-aged samples (Linnenbrink-Garcia et al., 2018). Additionally, we hypothesized that higher grade level, schools with a higher % of students who qualify for Free Reduced Lunch (FRL), % of English Language Learners, and % of Ethnic/Racial minority students would more likely be associated with profiles characterized by lower mastery goals, lower self-efficacy, and lower engagement. These patterns have been identified in past profile studies, and largely explained by contextual factors that limit opportunities for students to participate meaningfully in science learning (e.g., Bae & Lai, 2020; Banilower et al., 2013; Perez et al., 2019; Snodgrass Rangel et al., 2020).

4. Method

4.1. Sample

The quantitative sample consisted of a total of 1831 middle school students in grades 6 (n = 498), 7 (n = 531), and 8 (n = 799), across seven urban school districts in the western United States, who participated in the study in spring of 2015. The students were between the ages of 10 to 14 (M = 12.22), identified as male or female (53.6 %), and European American/White (25.9 %), Latinx (45.3 %), Asian (20.8 %), African American/Black (6.2 %), and Other (1.7 %). A total of 50.18 % of the students qualified for FRL and 17.92 % were identified as English Language Learners. The qualitative, purposeful sample consisted of 27 students, chosen from the quantitative sample, across six focus groups (ranging from 3 to 6 students per group) using a maximum variation selection strategy (Patton, 1990). Each focus group was intentionally homogeneous in terms of students' grade level and teacher (thus reporting on the same class). Additionally, the six focus groups were intentionally heterogeneous in terms of students' gender and racial/ethnic background; the students identified as 12 male/15 female, and 69.3 % Latinx, 13.6 % European American/White, 9.2 % African American/Black, 7.5 % Asian, and 0.4 % Other. Finally, to represent schools from a broad range of socioeconomic backgrounds, the distribution of school %FRL was used to create tertile groups (high, middle, and low socioeconomic background) and two student focus groups were selected per tertile group (see Bae and Lai, 2020 for additional details). Pseudonyms are used in the qualitative findings. University institutional review board approval and consent were obtained prior to data collection from students and their primary guardian.

4.2. Mixed methods design

An explanatory mixed method design was used, in which the quantitative analyses are conducted first, and the quantitative results are explored in more depth using qualitative approaches. The findings from both quantitative and qualitative phases are then integrated in the interpretation phase (Creswell & Plano Clark, 2017; Fig. 1). In the quantitative strand, student science motivation and engagement profiles were identified, and the relationship between student and school-level,

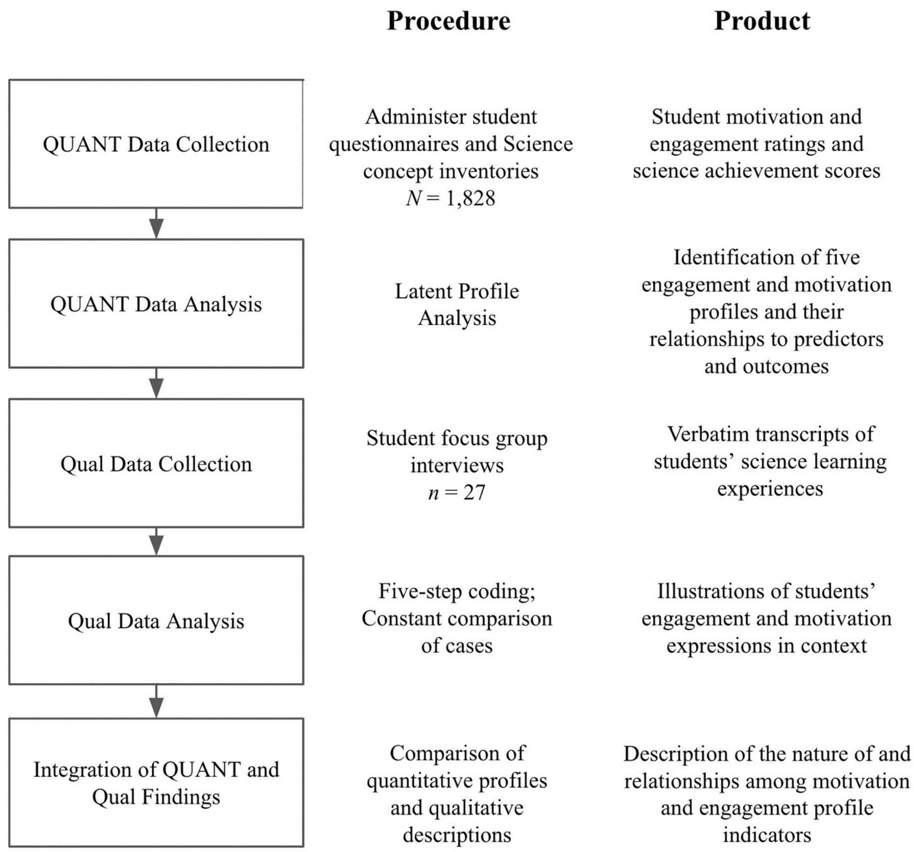

Fig. 1. Explanatory sequential mixed methods design.

contextual predictors, science achievement outcomes, and profiles were analyzed. In the qualitative strand, student focus groups were analyzed to examine how the motivation and engagement indicators used to estimate the profiles manifest in relation to specific science learning activities. Findings from both strands were integrated to provide a more complete picture of the nature of student science learning profiles.

4.3. Data collection and analysis

4.3.1. Quantitative strand

Student questionnaires. The student self-efficacy subscale was drawn from the Patterns of Adaptive Learning Scales (PALS) (Midgley et al., 2000). Past studies showed that Cronbach's α for the self-efficacy scale ratings ranged from 0.74 to 0.89 (Lee et al., 2016; Midgley et al., 2000; Pajares et al., 2000). Cronbach's alpha presented next are based on the ratings analyzed in this study. Three goal orientation scales were also adapted (Lee et al., 2016) to examine mastery (e.g., "It's important that I learn a lot of new concepts in my science class", $\alpha = 0.75$), performance-approach ($\alpha = 0.86$), and performance-avoidance ($\alpha = 0.78$) goals. The engagement items were adapted from existing measures (Fredricks et al., 2004) to assess three dimensions (behavioral, affective, cognitive) of engagement that are aggregated: behavioral (e.g., "I follow the rules in my science class", $\alpha = 0.76$), affective (e.g., "I like being in my science class", $\alpha = 0.83$), and cognitive engagement (e.g., "During science class, I talk, participate, and contribute to the discussion", $\alpha = 0.77$). Profile inputs represented the composite score on the mastery, performance-approach, performance-avoidance, and engagement subscales. The engagement items were combined into one aggregate score representing a general engagement factor to maintain model parsimony (Marsh et al., 2009) and based on recent studies demonstrating evidence for a global engagement factor (Bae et al., 2020; Wang et al., 2016).

Science assessments. Science achievement was measured using concept inventories (CI) that align to the middle school grade level content, providing a more proximal measure of students' science achievement (Ruiz-Primo et al., 2002). Sixth graders completed an earth science CI with 30 items ($\alpha = 0.86$; Libarkin et al., 2007). Seventh graders completed a life science CI adapted from the Conceptual Inventory of Natural Selection (Anderson et al., 2002) with 18 items ($\alpha = 0.84$). Eighth graders completed a physical science CI developed and validated by the Physics Underpinnings Action Research Team from Arizona State University with 25 items ($\alpha = 0.71$; Evans et al., 2003). All CI scores were calculated as the total percentage correct.

Latent profile analysis. Student survey data was collected and analyzed using LPA (Masyn, 2013). Using *M*Plus*8* (Muthén & Muthén, 1998–2017), two to seven LPA models were estimated, constraining the between profile indicator variances equal while allowing profile indicator means to be freely estimated. Model fit was evaluated based on minimum values of Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), sample-size adjusted BIC (aBIC), and compared using Vuong Lo-Mendell-Rubin (VLMR) *p*-values (Lanza et al., 2013), whereby non-significant VLMR *p*-values suggests that the *k*-1 profile model is preferable over the *k* (estimated) model (Lanza et al., 2013). The extent to which the profiles were substantively distinguishable was also examined, to determine the most interpretable number of profiles (Marsh et al., 2009; Nylund et al., 2007). The use of statistical and substantive evaluations provides a strong evidence base for the final class solution (see Table 1).

Analysis of profile predictors and outcomes. To gain a better understanding of how individual and contextual factors influence profile membership, we used Mplus' R3STEP approach. This method estimates a multinomial logistic regression (log-odds that represent *k*-1 coefficients compared to the reference profile) with the categorical profile as the response variable to examine the extent to which each predictor, accounting for the others, influences profile membership (Muthén &

Table 1
Latent profile analysis fit statistics for 2 to 7 class solutions.

$N_{Classes}$	Log L.	AIC	Δ AIC	BIC	Δ BIC	VLMR-LRT	*p* value	Entropy
2	−9669.027	19,364.055		19,435.719		−10,377.535	<0.001	0.717
3	−9377.720	18,791.439	572.616	18,890.666	545.053	−9669.027	0.0020	0.765
4	−9257.980	18,561.959	229.48	18,688.749	201.917	−9377.720	0.0174	0.761
5	**−9201.809**	**18,459.619**	**102.34**	**18,613.972**	**74.777**	**−9257.980**	**0.0001**	**0.759**
6	−9160.783	18,387.567	72.052	18,569.483	44.489	−9201.809	0.2923	0.739
7	−9124.760	18,325.520	62.047	18,535.000	34.43	−9160.783	0.0271	0.745

Note. LogL = Log Likelihood; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion; aBIC = Sample Size Adjusted Bayesian Information Criterion; VLMR-LRT = Vuong Lo-Mendell-Rubin Likelihood Ratio Test. Minimal BIC indicates best relative fit. Significant VLMR denotes an improvement in fit given the additional class. Bold values represent the final model selected.

Muthén, 1998). Log odds were transformed to odds ratios for interpretability. Additionally, science achievement was assessed between profiles using *M*plus' BCH function, which computes a Wald chi-square test to examine the equality of outcome means across profiles (Asparouhov & Muthén, 2014). All outcomes were assessed within-grade, as science achievement was measured with grade-specific materials.

4.3.2. *Qualitative strand*

Student focus group interview protocol. A semi-structured interview protocol was used (Morgan, 1996), consisting of nine open-ended questions regarding students' learning experiences in their science classrooms (see Appendix). The questions were written to gather students' perspectives about specific learning activities and experiences in their science classrooms, rather than their general retrospective attitudes towards science learning. Follow-up probes were also given (e.g., “Can you tell me more about how that activity was interesting?”). Interviews lasted approximately 30 to 45 min and were audio-recorded and transcribed verbatim.

Interview analysis. A codebook with definitions of the indicators used in the LPA, including student engagement, self-efficacy, and goal orientation was used to code each segment. Engagement was more specifically coded for affective, behavioral, cognitive, and social engagement. Goal orientations were represented by mastery and performance orientation codes, with performance orientation being further broken down into approach and avoidance. Thus, the qualitative findings also allowed us to examine different dimensions of engagement and performance orientation.

Dedoose (2015) was used to code the transcript, establish inter-rater reliability, calculate code frequencies, and identify exemplar quotes to illustrate the themes identified (see Table 2). Inter-rater reliability was established at 0.87 Cohen's kappa. The coders met weekly to discuss and resolve discrepant codes. The combination of final codes for each student were compared across cases using a constant comparative method, in which segments coded to represent expressions of student motivation and engagement were examined in terms of frequency then grouped to generate descriptive themes (Crabtree et al., 1999; Miles & Huberman, 2002).

4.3.3. *Integration*

In the integration phase, the characteristics of the quantitative profiles and the qualitative findings of students' expressions of the profile inputs were examined together (Tashakkori & Teddlie, 2009). The quantitative profiles provided information about how the four engagement and motivation indicators clustered above, at, or below the mean. The qualitative findings illustrated in more depth how different dimensions of the engagement (behavioral, affective, cognitive, and social) and motivation (mastery, performance-approach, performance-avoid, and self-efficacy) indicators manifest in the context of classroom science activities, independent of the identified student profiles. The findings from the quantitative and qualitative strands were integrated to examine the nature of and relationship among indicators within profiles and in the context of science classrooms.

Table 2
Engagement, achievement goal, and self-efficacy codes, definitions, and example quotes.

Profile indicators	Definition	Exemplar Quote
Behavioral engagement	On task behaviors	“Take a test tube, put the same amount of…liquid, put it on a weight…see how much that weighs, and then you put the water or whatever liquid…”
Cognitive engagement	Sense-making, grappling with ideas	“I changed my idea because at first I put Alisha and I put all forces of the ball were balanced as it went down the ramp but then…I saw that it kind of like 3 and 4 where balanced but 1 and 2 weren't really balanced because as it was going down the ramp.”
Affective engagement	Emotional connections and reactions	“The hands-on in the group work every day…is a lot more fun and it'll help you remember instead of doing work from a book and lectures and notes.”
Social engagement	Interpersonal processes and interactions	“Especially when we're with groups, you get more opinions, and…all your thinking comes… in a group and you're thinking, oh we can do this and that, but then, but then that won't work for this, and then okay, then do this, that and then that.”
Mastery orientation	Oriented towards deeply understanding content and practices	“...if we fail, then we can try again.”, “…if you make mistakes you learn from it and then next time you do it you can understand what it is.”
Performance approach orientation	Oriented towards demonstrating ability	“It gives us the right sentence to say to the other group, to the other person. So you say no you're dumb, I'm right.”
Performance avoidance orientation	Oriented towards avoiding perception of lack of competence	“Like when you're doing it by yourself you don't get as much help…if you miss something… your grade will go down.”
Self-efficacy	Belief in one's ability to successfully complete a task	“Well we don't have to be asking the teacher everything, because we can do it our own way.”

5. Results

5.1. *Quantitative results*

5.1.1. *Student science motivation and engagement profiles*

Fit indices for two to seven latent profile solutions are presented in Table 1. The information criterion values continued improving with the addition of latent profiles. However, based on the non-significant VLMR *p*-value for profile 6, which indicates that the *k* - 1 class solution is optimal, there was statistical evidence for the 5 profile solution. We also

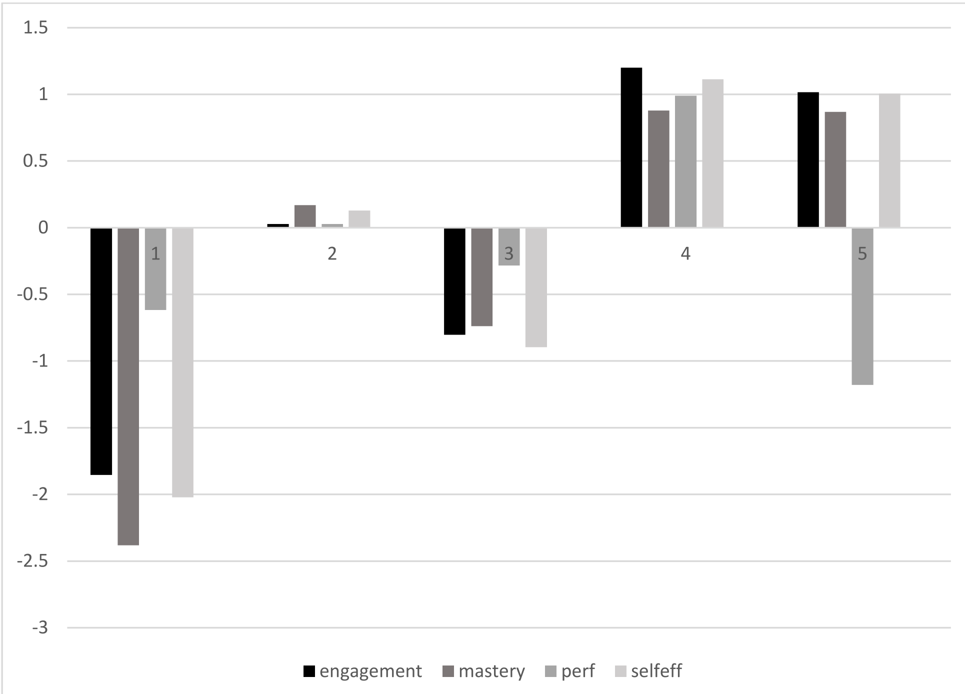

Fig. 2. Five profile solution.
Note: Five profile solution showing *Z*-standardized mean scores of students' engagement, mastery orientation, performance orientation, and self-efficacy indicators, 1 = *Unmotivated and Disengaged* (n = 64), 2 = *Average Motivation and Engagement* (n = 878), 3 = *Below Average Motivation and Engagement* (n = 477)*,* 4 = *Highly Motivated and Engaged* (n = 306), 5 = *Mastery-Motivated and Engaged* (n = 106).

examined whether the 4 vs. 5 profile solutions were substantively distinguishable based on theory and previous research (Marsh et al., 2009). Specifically, the four profiles from the 4 profile solution were substantively replicated in the 5 profile solution; however, a new '*Mastery-Motivated and Engaged*' profile was identified that accounted for approximately 5 % of the sample, and theoretically aligned with the literature that indicates a subgroup of students who demonstrate mastery orientation and engagement, with low performance goals (e.g., Pajares et al., 2000). Additionally, the entropy value for the 5 profile solution (0.759) indicated greater classification accuracy. Thus, based on the fit indices and theory, the 5 profile solution was selected as the most optimal (Fig. 2).

The largest profile identified was labeled *Average Motivation and Engagement* (n = 878; 48.0 %). All motivation and engagement indicators in this profile were close to the mean. The second largest profile identified, *Below Average Motivation and Engagement* (n = 477; 26.1 %), exhibits motivation and engagement approximately 0.5 to1 standard deviation below the mean across all indicators. Although not the lowest across indicators, these students still fall below the mean for all motivation and engagement indicators. A third profile of students, *Highly Motivated and Engaged* (n = 306; 16.7 %), exhibit the highest overall motivation and engagement. They have the highest engagement and self-efficacy indicators (over 1 standard deviation above the mean).

The fourth profile with very high engagement and motivation indicators was labeled *Mastery-Motivated and Engaged* (n = 106; 5.8 %). This profile was uniquely characterized by extremely low-performance orientation. The fifth and smallest profile identified, *Unmotivated and Disengaged* (n = 64; 3.5 %), showed low averages across all engagement and motivation indicators.

5.1.2. *Predictors and outcomes of student profiles*

Next, we examined whether student-level (grade level) and school-level (% of students who qualify for Free Reduced Lunch (FRL), % of English Language Learners, and % of Ethnic/Racial minority students) factors predicted profile membership. Overall, grade level was the strongest predictor of profile membership across all profile comparisons; however, school FRL percentage was also found to be a significant predictor. Notably, for each increase in grade, while holding contextual factors constant, the odds were about 59 % higher for students being in the *Average Motivation & Engagement* profile compared to *Mastery-Motivated & Engaged* profile, and 63 % higher for the *Highly Motivated & Engaged* profile compared to the *Mastery-Motivated & Engaged* profile (distinguished by below average performance orientation). For school level predictors, results showed that those attending lower %FRL schools were more likely to be in the *Highly Motivated & Engaged* profile. The % FRL also differentiated strongly between the *Below Average Motivation & Engagement* profile and *Motivated & Engaged*. For every 10 % increase in school level %FRL, the odds increased by about 34 % for being in the *Unmotivated & Disengaged* profile or the *Below Average Motivation & Engagement* profile compared to the *Highly Motivated & Engaged* profile or the *Mastery-Motivated & Engaged* profile. Results showed that school % ELL and %Ethnic/Racial Minority did not influence profile membership once grade level and school level FRL were accounted for.

Science achievement, regardless of grade, was a well-differentiated outcome variable, showing significant differences between all profiles. All within-profile means, 95 % confidence intervals, and tests of significance for each grade-level specific outcome are in Table 3. Generally, profiles that exhibited higher motivation (mastery and/or performance approach goals) and engagement tended to have higher science achievement. Of note, there were more significant differences between profiles in grades 7 and 8 compared to grade 6. For grades 7 and 8, statistically significant differences were identified between the *Below Average Motivation and Engagement* profile and the *Highly Motivated and Engaged* and *Mastery Motivated and Engaged* profiles. A similar statistically significant pattern was also found when comparing the *Average Motivation and Engagement Profile* with the *Highly Motivated and Engaged* and with the *Mastery Motivated and Engaged* profiles.

5.2. *Qualitative findings*

The qualitative analyses shed light on how the profile indicators manifest in science activities, providing a more in-depth and contextualized description of students' motivation and engagement in the classroom. The qualitative findings are presented within two major themes: 1) *diverse and discipline-specific expressions* of motivation and engagement indicators and 2) *co-occurrence* of certain engagement dimensions

Table 3
Science achievement by profile and grade level.

	1-Unmotivated & Disengaged	2-Avg. Mot. & Engagement	3-Below Avg. Mot. & Engagement	4-Motivated & Engaged	5-Mastery-Motivated & Engaged	Summary of Significant Differences
	M	*M*	*M*	*M*	*M*	
Grade 6 Sci Achievement	23.0	36.6	32.8	37.2	39.7	1 < 2–5, 2 > 3
	[15.9, 30.0]	[32.3, 40.9]	[28.9, 36.7]	[28.4, 46.0]	[29.5, 49.9]	
n	22	216	146	77	37	
Grad 7 Sci Achievement	29.6	50.8	41.4	54.0	60.7	1 < 2–5, 2 > 3, 2 < 5, 3 < 4:5
	[25.9, 33.7]	[45.5, 56.1]	[37.1, 45.7]	[46.9, 61.1]	[54.8, 66.6]	
n	14	259	136	88	34	
Grade 8 Sci Achievement	32.1	43.0	36.6	48.5	53.3	1 < 2:4:5, 2 > 3, 2 < 4:5, 3 < 4:5
	[24.7, 39.5]	[39.7, 46.3]	[33.5, 39.7]	[42.8, 54.2]	[44.9, 61.7]	
n	28	401	194	141	35	

Note: Mean (*M*) achievement scores represent % correct. 95 % confidence intervals are presented in brackets.

with achievement goal orientation in response to *dynamic* classroom events.

5.2.1. Discipline-specific expressions of engagement and motivation indicators

Segments that represented students' connections to science learning activities were coded for cognitive, social, affective, social and/or behavioral engagement (Wang et al., 2016). *Cognitive engagement* in science learning activities was characterized by students identifying patterns among variables from their data (e.g., relationship between temperature, time, and state of matter), communicating their reasoning to support a claim (e.g., how the change in speed and direction of objects represent balanced or unbalanced forces), and grappling with discrepancies in ideas (e.g., data that doesn't support hypotheses). There were also several examples of social engagement, characterized by collaborative activities (e.g., setting up the sandbox and ramp to model river erosion) and asking peer-to-peer questions in small groups about natural phenomena. In terms of *affective engagement*, students reported both positively (e.g., “It was interesting and fun to do”) and negatively (e.g., “Muy frustrado.”) valenced emotional responses. Finally, behavioral engagement was characterized primarily by being on-task such as reading “from the science book”, completing worksheets or handouts in class, or following the steps of an experiment.

In terms of goal orientations, students' expressions of mastery approaches towards science learning were the most common. Students demonstrated various forms of *mastery approaches to* science learning including the evolving nature of scientific knowledge in light of new evidence (e.g., “coming to an answer isn't as important as getting more questions...to solve more problems”, “science is an ongoing cycle”), and persistence when faced with challenging material or making mistakes (e.g., “you learn from making mistakes, you don't learn from getting everything right…”). Students' often described their mastery approaches to science learning in the context of group activities. For example, in the following excerpt, students describe how they revised their original ideas to reach consensus by considering various sources of evidence:

Sara: A little woodpecker [finch from Galapagos]. Another person in our group thought that wood-peckers was [sic] a type of finch.

Stephanie: We thought it was not until we saw a film of it and then he was actually right. It is a species of finches. Yeah, so we argued about that.

Tom: Yeah, it happened with me too in my group…because I saw how three or four of them would be looking similar [sic] and their beaks were similar too. But from the different ways they looked and the different beaks they had … and that's when I started agreeing with John.

Expressions of *performance goals* included both an approach and avoidance orientation. Students referred to approach orientations spurred by a desire to demonstrate competence in front of their teacher and peers (e.g., “It gives us the right sentence to say to the other person. So you say, no you're dumb, I'm right.”), as well as an avoidance orientation in which students desired to avoid looking incompetent (e.g., “...a bunch of people would...do no work and wait until [the teacher gave the answer]”). These findings extend the quantitative strand by illustrating how dimensions of engagement and achievement goals manifest in discipline-specific ways.

5.2.2. Co-occurrence of engagement dimensions with achievement goals

The qualitative findings also illustrated how engagement and motivational indicators co-occurred during science learning activities. Cognitive engagement and mastery approaches to learning were frequently coded within the same excerpt, characterized by students engaging in deep sensemaking with the goal of better understanding the science concepts. For example, after completing a force and motion lab Linda shared her new understanding that forces can be balanced in a moving object: “But then on my post-test, I [got] it backwards, like that it was actually balanced...I realized when we did the tennis ball it was the same thing, that's how I realized.”

Similarly, in the following excerpt, students reported both cognitive and affective engagement in the relation to making real-time observations of objects at different states that supported them in focusing on understanding the difference between balanced and unbalanced forces (*mastery orientation*).

Paula: We did different kinds of stations. Trying to figure out which station was balanced and what was unbalanced. And then wrote down our evidence.

Linda: It was very interesting and fun to do, and we also learned a lot about unbalanced and balanced forces.

Paula: I feel like it is easier to get what balanced and unbalanced means because we are actually seeing the “what ifs”. What happens when the object is moving and when it stops? You cannot really see that in the textbooks.

Several co-occurrences of social engagement and mastery approaches were also observed, largely in the context of discourse-rich activities. For example, a 6th grade student shared the following about a whole class discussion related to climate change:

“I also like the science talk like when we are gathered around talking about the experiment because I get to hear…other people's answers and how it's similar or different to mine and how I understand or how I don't understand other people's answers.”

In another example, Billy shared how listening to his peer's explanation of balanced and unbalanced forces prompted him to revise his ideas, facilitating a deeper understanding of forces: “Well now I changed my mind because of what Paula said...when we learned about it more and more than you start arguing with other people and that's how you get to know what we are doing better.” These examples illustrate how discourse activities created opportunities for social engagement that also supported students in adopting a mastery orientation towards learning science.

Co-occurrences of engagement with performance approach orientations were also observed. For example, when asked about the purpose of using sentence stems to communicate one's scientific argument, students communicated the desire to be "right":

Paula: And we had to give our evidence and why do we think that.

Linda: Yeah because like when we argued we couldn't just say oh it's that one. We had to give the evidence.

Ron: It gives us the right sentence to say to other group, to the other person. So you say no you're dumb, I'm right.

Finally, in another example, a student shared that she was motivated to ask a lot of questions in class because of the incentives provided by the teacher (*performance approach*): "I used to ask questions and then he couldn't answer them and he'd just give me points...I've gotten multiple points for, like, asking him crazy questions." These qualitative findings illustrate how various dimensions of engagement co-occur with both mastery and performance goal orientations.

5.2.3. Integration of findings

A summary of the major quantitative, qualitative, and integrated findings is presented in Table 4. Converging evidence from both strands indicate that mastery orientation tends to cluster closely with indicators of engagement in level ways (e.g., high mastery, high engagement). On the other hand, performance orientation was shown to vary noticeably in relation to engagement and other motivation (mastery, self-efficacy) indicators in the quantitative profiles (e.g., positively and inversely related to engagement in profiles 4- *Highly Motivated and Engaged* and 5- *Mastery-Motivated and Engaged*, respectively). The qualitative findings illustrated how these unique relationships among motivation and engagement indicators were expressed in science classrooms. For example, when students were both engaged and mastery-oriented, they were connecting to the science activity due to the inherent enjoyment of learning itself (e.g., being curious about discrepant results across small groups), whereas when students were engaged and performance-oriented they were actively participating in activities (i.e., engaging behaviorally, cognitively) to either obtain external rewards (e.g., receive points) or demonstrate their ability (e.g., prove their peers wrong).

Table 4
Major qualitative, quantitative, and integrated findings.

Major quantitative findings	Major qualitative findings	Integrated findings
Five unique science learning profiles were identified, generally demonstrating similar degrees of engagement, self-efficacy, and mastery orientation (e.g., high, average, low) whereas performance orientation was either lower or inversely related to the other profile inputs. Grade level and school FRL are statistically significant predictors of the likelihood of profile membership, and profiles are also differentially related to science achievement.	Engagement and achievement goals (mastery, performance approach) co-occur and manifest in diverse and discipline-specific (e.g., grappling with discrepant ideas related to scientific phenomena) ways in response to dynamic classroom events. In particular, socio-cognitive engagement was often accompanied with mastery and performance approach goals, in the context of hands-on experiments that facilitated student-to-student discourse.	Students' cluster into five unique profiles characterized by different levels of engagement and motivation that are differentially related to science achievement. The expressions of these engagement and achievement goal orientations can be observed along more specific dimensions (cognitive, behavioral, affective, social) and goals that are either focused on understanding (mastery orientation), demonstrating ability, and/or in some cases avoid being perceived as inferior and external incentives (performance approach, avoid orientations).

6. Discussion

6.1. Student engagement and motivation profiles in science

A total of five student profiles in science were identified. The three profiles identified in this study that were characterized by below average, average, and above-average levels of motivation and engagement align with the extant person-centered literature that also documents similar profiles characterized by uniform indicators (e.g., Perez et al., 2019; Snodgrass Rangel et al., 2020). Our results also follow the patterns in profile sizes reported in prior work, showing that the motivation and engagement profile characterized by mean levels across indicators (e.g., *Average Motivation and Engagement*) was the largest in size, representing almost half of the students in the sample (47.95 %), followed by the normative motivation and engagement profiles characterized by slightly below-average and above average levels across indicators (*Below Average Motivation and Engagement,* 26.05 %; *Highly Motivated and Engaged,* 16.71 %). These convergent findings point to clearly distinguishable subgroups of students who systematically differ in degree of science engagement and motivation.

The distribution of profile sizes is also noteworthy. In line with the broader literature documenting a drop in students' motivation and engagement during the middle school years (Morgan & Gerber, 2016), a notable number of students (~26 %) fell into the *Below Average Motivation and Engagement* profile. The identification of this profile aligns with broader trends that show acute drops in students' motivation and engagement during the formative middle school years (Eccles et al., 1997; Usher & Pajares, 2008). This is concerning because middle school is a period during which students begin to formalize their academic identities, interests, and pursuit of specialized academic activities and courses (Kaplan & Garner, 2017; Wang & Holcombe, 2010).

In addition, we also identified a fourth, *Unmotivated and Disengaged,* and a fifth, *Mastery Motivated and Engaged,* profile that demonstrate shape effects. Both were small in size (accounting for approximately 4 to 6 % of the students in the sample) and uniquely differentiated by the performance orientation indicator. These findings align with past studies that also found profiles demonstrate shape effects to be smaller in size (e.g., Perez et al., 2019), and studies that identified profiles characterized by differentiated mastery and performance goal orientations (e.g., Fong et al., 2018; Sun & Xie, 2020). Although small in size, the *Mastery Motivated and Engaged* profile arguably represents an ideal configuration of motivation and engagement for science learning, in that students do not use external goal posts (e.g., comparisons) to drive their learning, but rather, are motivated by the desire to understand science and believe that they do well on academic tasks. A large body of literature shows that mastery-oriented students with high levels of self-efficacy are more likely to persist on challenging tasks in the classroom and pursue science courses beyond what is required in high school (Britner & Pajares, 2006; Midgley et al., 2001; Senko et al., 2011). On the other hand, performance orientation has been linked to adverse externally regulated learning behaviors such as self-handicapping and avoiding help-seeking, with some mixed findings for performance approach versus avoid orientations (e.g. Midgley & Urdan, 2001; Pajares et al., 2000; Urdan & Kaplan, 2020).

This is concerning for the students in the *Unmotivated and Disengaged* profile, characterized by performance orientation near the mean, and engagement, mastery orientation, and self-efficacy indicators significantly below the mean. This profile represents students who are more likely to use externally-regulated goals (e.g., grades, social competition) to drive their behavior, relative to mastery-oriented goals and confidence in their ability to be successful on academic tasks. Taken together, our findings align with prior work showing that for the majority of students, both mastery and performance goals are endorsed at similar levels, whereas, for a smaller subset of students, performance goals are not held in similar ways to mastery goals, or their self-efficacy and engagement. Our findings extend the current literature examining student motivation profiles by examining achievement goals (mastery and performance orientation) in combination with engagement and self-efficacy indicators to draw more coherence between the motivation and engagement literature (Linnenbrink-Garcia & Wormington, 2019; Senko & Tropiano, 2016).

Another notable contribution of our study is the illustrations of how student motivation and engagement are expressed in science classrooms. The need for qualitative approaches to situating the latent profiles in learning contexts has been noted (e.g., Salmela-Aro et al., 2016), but few studies have integrated students' qualitative perspectives in profile studies. The qualitative component of our study underscores the multifaceted nature of student motivation and engagement, and how these are expressed in situation-specific ways to social activities in which students are exploring scientific phenomena. For example, the qualitative findings showed how cognitive engagement is expressed through sharing and resolving different results from the same experiment, whereas affective engagement is expressed by heightened emotional reactions (e.g., frustration, excitement) when pushed to defend one's scientific claims. The qualitative findings also illustrated co-occurrences of motivation and engagement, such as socio-cognitive engagement (deeper thinking of discrepant ideas facilitated by a peer-to-peer discussion), the interactions between students' performance orientation and engagement in science learning (students grappling with contradicting evidence and being motivated to 'prove' another group wrong). The integrated findings that include the quantitative profiles coupled with the qualitative illustrations provide a more complete picture of student engagement and motivation in middle school science.

6.2. Predictors and outcomes of profile membership

Findings from this study also demonstrate that both person (grade) and context (school %FRL) factors were statistically significant predictors of students' science engagement and motivation profile membership. Notably, grade-level was the strongest predictor of profile membership, with results showing that being in a later grade level was associated with a greater likelihood of being in the *Average Motivation and Engagement* and the *Highly Motivated and Engaged* profiles compared to the more ideal *Mastery Motivated and Engaged* profile. This finding is in line with a longitudinal goal orientation profile study that found students in 8th grade had more normative and stable profile membership compared to 6th and 7th graders (Bae & DeBusk-Lane, 2018). There are two plausible explanations for our finding that later grades were associated with greater endorsement of performance orientation goals. The first focuses on students' likelihood to become more aware of their own abilities in specific domains compared to their peers, they are more likely to engage in social comparisons that align with performance-oriented goals (e.g., drive to demonstrate ability, desire to not be perceived as less able; Bong, 2009). The second explanation focuses on factors in students' learning environments. From this perspective, the associations between later grade level and endorsement of performance goals (e.g., *Highly Motivated and Engaged*) and/or drop in engagement, self-efficacy, and mastery goals (e.g., *Average Motivation and Engagement*) compared to the profile in which performance goals are below average (*Mastery Motivated and Engaged*) are explained by increases in external pressure to perform well on high-stakes standardized tests and changes in student-teacher relationships (Midgley et al., 2001; Wigfield et al., 2015). For example, the state standardized test in science occurs in 8th grade for middle school students in our sample, which could help explain the increased association between higher grade level and performance orientation found in this study.

Additionally, of the three school-level, contextual predictors of profile membership (%FRL, %ELL, and %Minority), %FRL that represents the socioeconomic background of the school showed to be a statistically significant predictor of profile membership. Specifically, attending a school that serves a higher %FRL predicted the greater likelihood of membership in the two least ideal profiles, including *Unmotivated and Disengaged* and *Below Average Motivation and Engagement,* compared to the two more ideal profiles including *Highly Motivated and Engaged* and *Mastery-Motivated and Engaged.* The role of school-level %FRL in predicting group membership is mixed in the literature (e.g., Bae et al., 2020; Perez et al., 2019; Snodgrass Rangel et al., 2020); however, our results align with the broader extant literature that clearly points to the robust effects of a school's socioeconomic environment on students' motivation and engagement (Lewis & Farkas, 2017; Sirin, 2005; Wang & Holcombe, 2010). Several school-SES related conditions, such as high-stakes testing and accountability pressures, standardized curriculum with limited opportunities for active learning, and lack of resources for enriching science activities negatively impact students' engagement and motivation in school (Bae & DeBusk-Lane, 2018; Hayes & Trexler, 2016; Morgan & Gerber, 2016; Quinn & Cooc, 2015). Our results point to the importance of accounting for system-level variables that afford or constrain potential for students' science motivation and engagement in future person-centered studies. On the other hand, %ELL and %Minority were not statistically significant predictors of students' profile membership. While this did not align with our expectations, the extant literature demonstrates that socioeconomic status, language background, and racial/ethnic minority status have unique and overlapping effects on students' learning experiences and outcomes (Braden et al., 2016; Morgan & Gerber, 2016). Future research is needed to tease apart these effects.

Finally, science achievement was compared between profiles. Overall patterns of results showed that as expected, students in the more motivated and engaged profiles outperformed students in the less motivated and engaged profiles. This aligns with past variable- and person-centered studies that consistently demonstrate students' engagement, goal orientations, and self-efficacy as robust predictors of science learning (e.g., Britner & Pajares, 2006; Chen & Usher, 2013; Linnenbrink-Garcia et al., 2012). An interesting finding was that there was no statistically significant difference between the *Highly Motivated and Engaged* versus the *Mastery-Motivated and Engaged* profiles. These two profiles were distinguishable by a high versus low endorsement of performance orientation, respectively. Thus, the lack of difference in science achievement between these two profiles indicates that holding performance goals may not be harmful for science achievement in middle school. This finding aligns with past studies showing that in some cases, performance-approach goals have positive effects on students' learning behaviors and academic achievement (Harackiewicz et al., 2002; Midgley et al., 1998; Urdan & Kaplan, 2020). It is also possible that holding high mastery approach, engagement, and self-efficacy attenuates the potential negative effects of performance goals.

Our qualitative findings provide insights into the nature of the profile indicators. The expressions of students' performance goals, both approach and avoidance, demonstrate how these more externally regulated forms of achievement motivation may not be as antithetical to learning as theorized in the broader literature base. For example, students' performance goals were often associated with high expressions of engagement in science learning, such as deep reasoning (cognitive engagement) during a debate with peers (to showcase their thinking; performance approach), or positive emotions of excitement (affective engagement) associated with competitions in activities (performance approach). In this way, the integrated findings help us to understand middle school students' science motivation and engagement in a much more nuanced and contextualized fashion.

6.3. Limitations and future directions

The findings presented in this study should be interpreted with the following limitations in mind. First, the profiles were identified from cross-sectional data. This limits our ability to understand the stability and change in students' profile membership. Past studies have shown that students can change profile membership within a single semester or across an academic year (e.g., Gillet et al., 2017). Future research is needed to examine longitudinal trends in profile membership. Second, we used a trichotomous achievement goal framework, future research is needed to examine whether the distinguishing mastery approach and avoidance goals result in different profile solutions (e.g., Lo et al., 2017). Third, the profile indicators represented students' self-report ratings of their motivation and engagement in science. Using self-report questionnaires is the most common approach to measuring internal, affective student characteristics; however, they are susceptible to threats of internal reliability due to factors such as social desirability bias and survey fatigue. Some researchers have suggested requesting teachers or parents to report on their students' or child's learning as a potentially more objective measure (e.g., Pugh et al., 2017). Fourth, because the science achievement assessments were subject-specific (earth, life, and physical science), results regarding the relationship between profiles and science achievement are unique to each middle school grade level and cannot be compared across grades. Fifth, the student focus group interviews conducted in this study were also self-report in nature, and students' responses may have been influenced by their peers and make-up of the groups and variability in students' comfort verbally sharing about their science learning experiences. Additionally, the students in the focus groups could not be directly matched to one of five identified profiles; thus, our qualitative findings represent general manifestations of the profile indicators (rather than qualitatively representing specific profiles). Although we argue that the qualitative findings of this study that present students' first-hand accounts of their motivation and engagement in science learning are a major contribution to the person-centered literature, future research using other qualitative methods such as analysis of classroom video is needed.

6.4. Practical implications

Our mixed-methods approach to identifying student science motivation and engagement profiles has several practical implications. Our findings demonstrate unique clusters of students that can inform more differentiated approaches to address the declines in science motivation and engagement documented in middle school (Britner, 2006; Usher & Pajares, 2008). For example, the student represented in the *Unmotivated and Disengaged* profile may be supported in classrooms with evidence-based pedagogical approaches such as creating autonomous learning activities that integrate student-driven choice, personal and vicarious experiences of success that directly address students' sense of competence (self-efficacy), and framing activities to focus students towards understanding (mastery orientation) (Pajares et al., 2000; Patall et al., 2018).

On the other hand, for students in the more ideal *Highly Motivated and Engaged* profile, explicitly shifting students' focus away from performance-type goals that are externally regulated may be more appropriate, such as decreasing competition-driven activities and increasing co-operative lessons that support students' collectively sharing and testing of ideas towards a more complete understanding of scientific concepts (e.g., Baram-Tsabari & Osborne, 2015). Our qualitative findings provide insight into how teachers can positively reinforce students' statements related to an internalized sense of self-efficacy and mastery orientation (e.g., “if you fail, you can try again”), and target specific types of disengagement (frustration associated with a difficult task).

Another practical implication from this study is recognizing that the manifestation of mastery and performance orientations and dimensions of engagement are situation-specific and can co-occur. This opens up possibilities for teachers to flexibly structure their classroom environments. Our qualitative findings show that mastery and performance goals can co-occur with various forms of engagement in task-specific ways. For example, students reported thinking deeply and feeling excited during a small group debate (cognitive and affective engagement) and being motivated to determine who had a scientific answer or explanation with the most evidence (mastery and performance orientation). This illustrates the importance of teacher discernment when determining how particular activities and learning experiences may or may not be productively motivating and engaging for their students, in contrast to rigid, wholesale approaches (e.g., taking the stance that performance orientation should always be discouraged). Our findings present five profiles that point to unique clusters of motivation and engagement science learning profiles that teachers can consider when making instructional decisions.

CRediT authorship contribution statement

Lauren Cabrera: Conceptualization; Software; Formal analysis; Writing. Christine Lee Bae: Writing; Methodology; Formal Analysis; Validation; Resources; Supervision. Morgan DeBusk-Lane: Formal analysis.

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