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One size doesn't fit all: how different types of learning motivations influence engineering undergraduate students' success outcomes

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Abstract

Background Motivation is the inherent belief to guide students learning goals and behaviors to make continuous efforts and strengthen learning outcomes. Previous research reported the positive impacts of learning motivation on student success, but there have been limited efforts in systematically and structurally studying different types of motivations and their impacts on students' success in engineering education. The current study contributes to the literature by systematically examining two important types of motivations and their influences on undergraduate engineering students in a theoretically grounded manner while using an advanced analytical approach.

Methods The current study conducted a cross-sectional survey with undergraduate engineering students ($n=514$) from 18 different schools across nine U.S. states. The survey assessed students' self-report scores on six types of motivations to study developed based on formative research and the current literature and then collected students' self-reported learning outcomes, current GPA, university satisfaction, engineering program satisfaction, and individual demographic factors. The data were then analyzed using structural equation modeling.

Results The results showed that motivations related to family, personality, and academic expectations were consistently positively associated with all measured students' success outcomes; motivations related to educators were associated with all four outcomes but student GPA; motivations related to course contents were associated with learning outcomes and student GPA; and motivations related to peers did not predict any of the four measured students' success outcomes.

Discussion We explain some of the unexpected results with further literature that examines engineering culture and ecology. We also make recommendations related to cognitive training, tailored engineering education, peer culture interventions, and family orientation programs.

Keywords Student success, Learning motivations, Engineering students, Structural equation modeling

Introduction

As an integral part of higher education missions, student success commonly includes academic achievement, engagement in educationally purposeful activities, satisfaction, acquisition of desired knowledge, skills and competencies, persistence, attainment of educational outcomes, and post-college performance (York et al., 2019). According to the U.S. Bureau of Labor Statistics (2023), economic projections point to a need for approximately 1 million more STEM

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professionals than the U.S. will produce at the current rate by 2025. However, the increased demand for engineers is not proportionate to the increase in engineering graduates due to issues such as relatively low retention and graduate rate (Boles & Whelan, 2017). For example, an academic pathways study conducted by the Center for the Advancement of Engineering Education found that engineering has the most significant percentage decrease in students relative to other majors (Sheppard et al., 2010). Their results showed that students may have significant doubts about staying in engineering majors during their time at school, and those who leave engineering majors are disproportionately from underrepresented minority student groups (e.g., women) and racial minority groups (Atman et al., 2010). Thus, these issues call for engineering education research to identify factors that improve student success so they can effectively retain and supply future workforces. Among all the factors examined in engineering education, motivation, precisely motivation to learn, has been identified as an essential contributor to student success (Nadelson et al., 2015).

From an educational perspective, "motivation to learn" has been described as a student's energy and drive to learn, work effectively, and achieve their potential (Dökme et al., 2022; Plante et al., 2013). Motivation is not a single construct but rather subsumes a variety of different constructs like motivational beliefs, task values, goals, and achievement motives (Murphy & Alexander, 2000; Wigfield & Cambria, 2010). The self-determination theory explains two types of motivations that encourage someone to reach satisfaction and achieve outcomes: intrinsic and extrinsic motivations (Ryan & Deci, 2017). *Intrinsic* motivations (e.g., competitive personality) motivate learners to reach within themselves to find a motive to accomplish tasks. In contrast, *extrinsic* motivations (e.g., family expectations) motivate learners with external expectations other than their inherent satisfaction (Ryan & Deci, 2020). Prior studies sought to understand the relationships between various school and student characteristics (e.g., school type, race, gender) and student success outcomes (Boles & Whelan, 2017; Fletcher and Nusbaum, 2008; Kuh et al., 2006). However, most studies focused either on how motivations influence students' occupational choices or how motivation influences students' learning effectiveness in one engineering topic (e.g., Kunicina et al., 2018; Meyer & Marx, 2014). To the best of our knowledge, there has been limited work to systematically and structurally examine the relations between different types of motivation and student success outcomes. To address this gap, the current study seeks to systematically examine both intrinsic and extrinsic motivations and their potential multiple points of influence on undergraduate engineering students in a theoretically grounded manner.

Literature review

Students' success outcomes

Previous studies conceptualized and operationalized student success in a variety of ways, but usually with all student success measures divided into two groups: objective measures and subjective measures. Based on the previous literature and instructive perspectives, the current study conceptualizes students' success outcomes as grade point average (GPA), learning outcomes, program satisfaction, and university satisfaction. First, one of the most often utilized objective student success measures is GPA (Al-Sheeb et al., 2019). However, solely relying on GPA as the student success outcome might not be sufficient, so it is important to triangulate student success outcomes with other measures. Second, we include learning outcome as a student success indicator, which is commonly defined as a statement of what a student understands and can do after completing a learning process (Pascarella & Terenzini, 2005). Learning outcomes (both objective and subjective) could measure student success according to students' perceptions of progress toward their goals and/or their cognitive investment in and emotional commitment to their learning (Zepke & Leach, 2010). The scope of learning outcomes could include, but is not limited to, theoretical knowledge, practical skills and strategies, and social competencies (Sahinkarakas et al., 2010). Lastly, students' overall satisfaction with both the university and the program has been considered to be a critical subjective student success outcome, as it is related to a wide range of crucial constructs, such as retention and graduation rates (Wach et al., 2016; Weerasinghe & Fernando, 2017).

Learning motivations and self-determination theory

Motivation is critical to learning as learning is an active process requiring conscious and deliberate activities (Steel & König, 2006). Previous studies showed that stronger learning motivation was positively related to students' success outcomes, commonly conceptualized as academic achievement, satisfaction, and learning outcomes (Caruth, 2018; Marbouti et al., 2021). Motivation has been defined as an internal state of desire or wants that energize and direct goal-oriented behaviors (Kleinginna & Kleinginna, 1981). The internal state of desire or wants is often influenced by external factors, such as grades and opinions from others, as well as internal factors, such as interests and curiosity. The intricate interplay among those factors and their influences on human behavior are stated and researched under the Self-Determination Theory (SDT). The SDT represents an overarching and broad framework for understanding human motivation and personality (Chiu, 2022). The theory defines and describes the types and respective roles of intrinsic and extrinsic motivation in cognitive development and individual differences (Ryan & Deci, 2000). The SDT has been widely adopted to understand and predict motivation in the classroom (Savage et al., 2011). The theory states that motivation is enhanced when satisfaction of three psychological needs of autonomy, competence, and relatedness is achieved (Ryan & Deci, 2000). In higher education, a student's level of satisfaction with these needs could be determined by various motivational factors, such as self-efficacy, expectations, interactions with others (e.g., peers), personality, and learning content.

Firstly, Ryan and Deci (2017) describe the need for autonomy as a self-endorsed behavior that originates from within and is not controlled by others. Satisfying the need for autonomy could lead to a sense of competence in students' behaviors, thoughts, and feelings (Vansteenkiste et al., 2004). The need for competence can be activated when a student encounters a challenge and is satisfied by receiving positive feedback, which is related to the experience of mastery and effectiveness in the learning activities that students are engaging in (Deci & Moller, 2005). Education research has shown that self-efficacy positively correlates with this intrinsic motivation, and improving self-efficacy could develop students' needs for autonomy and competence (Niemiec & Ryan, 2009). Self-efficacy is an internal desire to overcome challenges, produce high-quality work, or interact with others (Bandura & Schunk, 1981). Resources of self-efficacy, such as mastery experiences and social persuasion, could provide students with support and opportunities to develop autonomy and competence and eventually promote intrinsic motivations (Bandura, 1978).

Second, students' expectations of academic success could largely influence their satisfaction with those needs defined by SDT (Gómez-Gómez et al., 2021). In the academic context, it could depend on the degree to which individuals believe how successful they should be in their learning experience (Cook & Artino, 2016). Students' previous experiences could influence their achievement expectations and eventually influence the ways they deal with future academic challenges (Török et al., 2018).

Third, the SDT stated the need for relatedness, which often manifests in a feeling of connectedness and belongingness to others. Connectedness can exist between individuals, including peers, family members, and educators (Foster et al., 2017), or between individuals and the academic environment. The need for relatedness is activated when a student interacts with others and is satisfied when one perceives that the other person values their true self and is concerned for their well-being (Beachboard et al., 2011). For example, a study has found that encouragement from friends helped motivate their learning and increase their sense of belonging to school (Glaser & Bingham, 2009).

Lastly, under the guidance of the SDT, personality is a motivational factor influencing the satisfaction of all three types of needs. For example, previous research has found that a student with a high level of conscientiousness is likely to acquire higher grades and consequently satisfy the need for competence to a greater degree (Zhen et al., 2017). Moreover, a highly extroverted person often has a broad social network, which enhances their ability to meet their need for relatedness through frequent social interactions. Conversely, a conscientious student might achieve greater competence by engaging in diligent study habits, thus feeling more capable (Demirbaş-Çelik & Keklik, 2019).

As the SDT suggests, to truly understand what satisfies the psychological needs of autonomy, competence, and relatedness in learning among students in higher education settings, we need to understand the various factors that could facilitate or boost this mechanism. Thus, the current study sets out to examine various intrinsic and extrinsic motivational factors specific to this student population, including self-efficacy, expectations, interactions with others (e.g., peers), personality, and learning content, as shown in Fig. 1. The reasons for selecting these six factors are twofold. First, the SDT only describes the psychological and behavioral mechanisms behind motivation without specifying what motivational factors influence a given behavior; the selection of motivational factors should be based on empirical research. These six motivational variables were chosen as they were most often linked to student achievements, success, and fulfillment in education research and are also directly linked to meeting the psychological needs of autonomy, competence, and relatedness among students (as previously discussed). Second, the selection of these motivational factors, along with our formative research results, suggests these, indeed, could be the most salient motivators among engineering understanding students.

Intrinsic motivational factors

Based on the SDT, the current literature, and our formative research, the current project includes three intrinsic motivational factors, namely, self-efficacy, personality, and academic performance expectations. First, self-efficacy is defined as a student's self-judgment concerning the capability to organize and execute the courses of action required to manage prospective situations (Bandura, 1982; Chyung et al., 2010). Studies surrounding self-efficacy suggest that motivations in learning

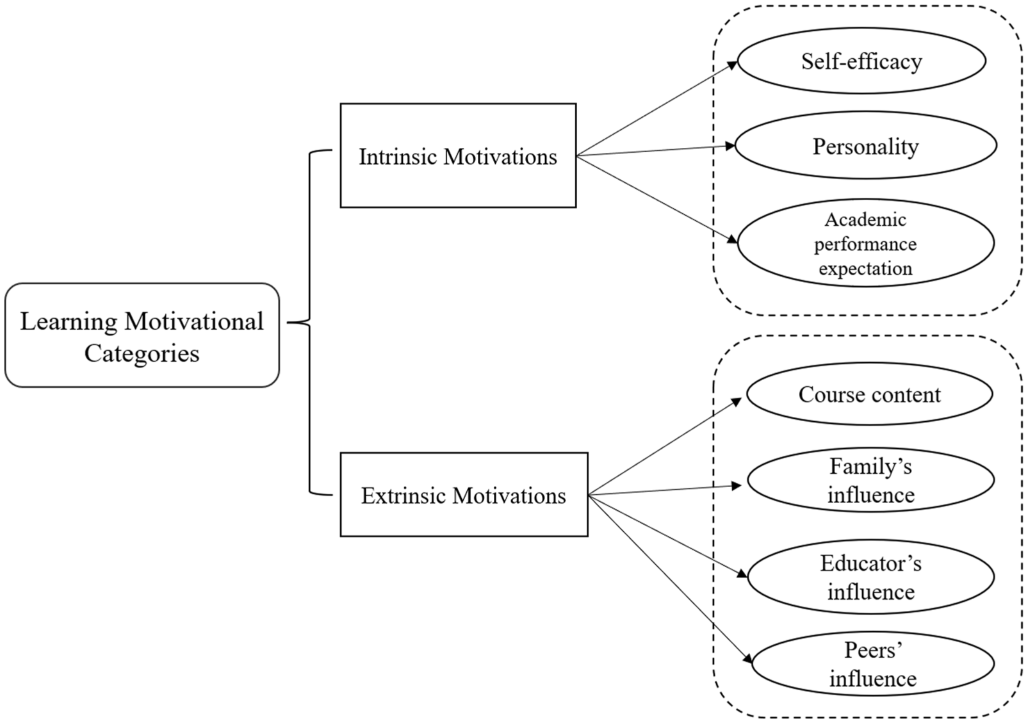

Fig. 1 Intrinsic and Extrinsic Motivational Categories and Factors

activities are based on a student's self-perceived ability to accomplish the task (Hutchison et al., 2006). In other words, when students believe in their ability to achieve educational tasks, they become motivated to act in ways that lead to success (Bandura et al., 1999). Mastery experiences of successfully solving problems using necessary pre-requisite skills are considered the most effective source for developing confidence and self-efficacy in learning (Vitasari et al., 2010). The reason is that these experiences can help students build cognitive foundations for determining the level of effort necessary for success (Heydarnejad et al., 2022). In the context of engineering education, studies have shown that undergraduate engineering students' academic self-efficacy predicts their academic performance and success (Concannon & Barrow, 2010; Mamaril et al., 2016; Robinson et al., 2019). For example, Mamaril et al. (2016) found that engineering students with high levels of self-efficacy tend to strive to develop new skills and acquire knowledge in their education. Moreover, Robinson et al. (2019) found that self-efficacy is closely related to engineering students' intentions to remain in their majors instead of leaving the engineering discipline.

Second, individual differences in personality determine thinking, feeling, and behavior patterns that influence learning (Dirzyte et al., 2021). The role of personality traits as a determinant of student success has been well studied in engineering education (Baruth & Cohen, 2023; Hall & Goh, 2017). There are several personality traits that are relevant to student success outcomes within engineering education, namely, conscientiousness and competitiveness. On one hand, conscientiousness, which denotes a tendency to show self-discipline, has a significant relationship with academic performance (Zhen et al., 2017). Self-discipline facilitates learning behaviors and motivates learners (Furnham et al., 2013). Self-disciplined students are less likely to be disengaged (Van Der Molen et al., 2007). On the other hand, competitiveness, defined as "the enjoyment of interpersonal competition and the desire to win and be better than others," is another facet of conscientiousness related to student success (Spence & Helmreich, 1983, p. 41). Students who demonstrate academic competitiveness tend to desire positive outcomes (e.g., better grades) and often report high levels of learning motivation (Moke et al., 2018). For example, competitive students may participate more in class and attempt to interact with instructors more often outside the classroom to maximize their chances for academic success (Frisby & Martin, 2010). Interestingly, some scholars came to the conclusion that competitiveness might lead to heightened anxiety, distractions from learning, and reduced self-confidence (Bailey et al., 2023; Katz et al., 2011). No matter which direction might the relationships between two constructs be, individual personality and its impacts on student success have been generally under-researched in engineering education, and the current study hopes to contribute to this gap in the literature (Kuh et al., 2006; Simon et al., 2015; Sithole et al., 2017).

Lastly, the third relevant intrinsic motivational factor related to student success is the expectations of academic success, which is the degree to which individuals believe how successful they should/ought to be in their learning (Cook & Artino, 2016). Previous studies showed that academic success expectations predicted engagement in learning activities and achievement (Crisp et al., 2009; Rosenqvist & Skans, 2015). For example, students with limited or negative expectations of their academic performance would show a lower level of willingness to engage in academic activities both inside and outside class, as they perceive future attempts as "time-wasting" (Kuh et al., 2006). Such a lack of engagement would consequentially lead to poor student success outcomes. Overall, this intrinsic motivational factor at the individual level (with some studies examining how expectations differ between parents and students, e.g., Yamamoto & Holloway, 2010) is under-researched in engineering education research. However, understanding what motivates engineering students within themselves and how that influences student success would be the first step in building motivational and persuasive messages to entice performance. Thus, the current study examined how intrinsic motivational factors, including self-efficacy, personality, and academic performance expectation, influence undergraduate engineering students' success outcomes, including academic achievement, satisfaction, and learning outcomes. Thus, the current study asks the following research question:

RQ1: How do intrinsic motivational factors, including (a) self-efficacy, (b) personality, and (c) academic performance expectation, influence undergraduate engineering students' success outcomes, including academic achievement, satisfaction, and learning outcomes?

Extrinsic motivational factors

Based on the SDT, the current literature, and our formative research, the current project includes four extrinsic motivational factors, namely, family influences, educator influences, peer influences, and course content. First, the literature reveals a trend that family members get more involved in students' academic careers and have a stronger impact on their academic performance (Waithaka et al., 2017). For one, in educational settings, supportive and caring relationships with parents are positively associated with greater interest in learning activities, higher expectations of success, and increased perceptions of competence (Moss & St-Laurent, 2001). Moreover, students are more comfortable accepting the risks inherent in learning if they live in a home environment that nurtures a sense of competence (Akey, 2006). Other research suggests that siblings could also play an imperative role in influencing college major selection, overall educational attainment (Björklund & Salvanes, 2011), and extended family members (Godwin et al., 2014). Specific to engineering students, researchers found that students who have family members in engineering fields possess an advantage with early exposure to a greater understanding of the profession, often resulting from informal discussions or at-home educational activities (Jarvie-Eggart et al., 2020).

The second extrinsic motivational factor related to engineering student success outcomes is the educator, including teachers and academic advisors. Previous studies in engineering education highlight that teachers can significantly affect engineering students' academic performance (Chen et al., 2008; Marra et al., 2012; Wilson et al., 2020). The literature shows that the interactions between engineering teachers and students inside and outside the classroom could positively influence student academic achievements, satisfaction, and degree attainment (Christe, 2013; Pascarella & Terenzini, 2005). For example, research on high-quality teaching has identified positive teacher–student relationships as a key factor that undergirds student learning outcomes and facilitates student success in engineering (Carberry & Baker, 2018; Neves et al., 2021). A positive teacher–student relationship could continuously develop students' interests in learning and valuing academic tasks (Strayhorn, 2018). Besides teachers, academic advisors play a vital role as motivational factors related to student success by encouraging students to identify issues affecting their academic progress and providing expert advice and resources to enhance their learning effectiveness (Jamaludin et al., 2021). All of these mentioned positive interactions contribute to student's academic performance and learning outcomes, as well as students' sense of belonging to the institution, which increases the likelihood of social integration with others and ultimately impacts students' degree progress and satisfaction with both the program and institution (Barnett, 2011; Jamaludin et al., 2021; Vogt, 2008).

The third extrinsic motivational factor related to student success is peers. In general, peers influence each other in learning motivations, which is a benefit of normative or group-based learning. For example, suppose a student perceives peers who actively and enthusiastically engage in learning activities. In that case, the student, too, will engage in learning and might study harder on the learning tasks (Kozaki & Ross, 2011). Shin et al.

(2017) suggest that motivations from peers might be more impactful than the influences from instructors. In engineering, the use of groups to promote student active learning is prevalent. Activities in many engineering courses are cooperative project based, which require students to work together in groups to complete tasks (Dawes & Senadji, 2010). Previous engineering education literature suggested peer interactions, as one of the leading predictors of engineering student performance and satisfaction has positively affected student performance (Elliott et al., 2021; Martínez-Caro & Campuzano-Bolarín, 2011). Many studies highlight the value of using group work for learning and ultimately increasing student persistence in engineering fields (Kalaian et al., 2018; Marra et al., 2016). In addition, Xu et al. (2023) explored the influences of engineering students' peer pressure on learning behavior. They found that positive peer pressure can increase engineering students' learning motivation and thus promote student success. Besides the interactions regarding coursework, peer relationships can be seen as personal relationships that have the potential to provide emotional support, which is associated with positive academic motivation, including the pursuit of goals to learn, interest in schoolwork, and perceived academic competence (Wentzel & Ramani, 2016).

The last extrinsic motivational factor related to student success is the content of the courses and instructions at large. The amount of effort invested in course learning is a significant predictor of the academic achievement of engineering students, such as GPA (Osunbunmi & Fang, 2023). However, these efforts largely depend on the student's interest in the course content and the course workload (Law et al., 2019; Martin et al., 2008). Previous research has identified that tapping into students' learning interests is an excellent way to motivate students to learn and eventually promote their academic success (Haramain & Afiah, 2022). For example, several studies have noted that engineering students often put more effort into a course with many real-world examples because they highly value and show more interest in the relevance of knowledge to the work of an engineer in reality (Whitcomb et al., 2020; Winkelman, 2009; Zavala & Dominguez, 2016). Students reported that such course content enhances their learning outcomes and is helpful in their short- or long-term goals (Pomales-Garcia & Liu, 2007). In addition, the literature identifies that an excessively heavy course workload could impede a student's learning motivations and success outcomes (Pu et al., 2020). On one hand, students could not see the value in an excessively heavy workload that is not conducive to better learning. On the other hand, having a proper level of rigor could benefit students in terms of outlining the expectations in engineering education and fields. For example, Attewell et al. (2012) noted that an undergraduate's academic course workload in their first year sets a trajectory that strongly influences subsequent degree completion. Students who begin with heavier course loads could display greater motivation and commitment to their academic goals and studies (Attewell et al., 2012).

Overall, there is a robust body of research in general education related to extrinsic motivational factors and their relations with student success, but less is known regarding engineering education. Given the unique peer culture (Jarvie-Eggart et al., 2020), educator–student relationships (Vogt, 2008), and course contents (Martin et al., 2008) in engineering, it is important to examine extrinsic motivational factors in a systematic manner among engineering students. Moreover, understanding what motivates engineering students externally could lead to feasible and implementable program changes that could promote student success. Thus, the current study examined how extrinsic motivational factors, including family's influence, educator's influence, peers' influence, and course content, influence undergraduate engineering students' success outcomes. Thus, the current study asks the following research question:

RQ2: How do extrinsic motivational factors, including (a) family's influence, (b) educator's influence, (c) peers' influence, and d) course content, influence undergraduate engineering students' success outcomes described in RQ1?

Methods

The current study conducted a cross-sectional survey with undergraduate engineering students from 18 different Midwestern and Northeastern U.S. schools, ranging from large state universities to liberal arts colleges. The current project is part of a larger project seeking to understand how demographic, individual, and environmental factors influence undergraduate engineering students' success outcomes. A previous article (Wang et al., 2022) examined how multi-level factors influence these student success outcomes, but there is no significant overlap between the current manuscript and the previous article. The current study examines the impacts of different individual-level student motivations on students' success outcomes, controlling for relevant confounding demographic variables (e.g., age).

Procedures

We recruited a convenience sample of undergraduate students enrolled in an engineering program from 18 Midwestern and Northeastern United States schools. We recruited undergraduate students by using snowball sampling. Snowball sampling is a non-probability sampling method that identifies and recruits participants with assistance from individuals who have already participated or qualified to participate (Field, 2013). We sent out a recruitment email to a total of 921 full-time instructors and faculty members at 18 higher education organizations, and we asked the instructors/faculty to share the survey link with their current students. A total of 514 students from 18 different schools responded to the survey, and we removed 46 responses for missing a significant amount of data (>60%). After the consent process, the survey collected the student's demographic information, including age, sex, race, and whether the student was a first-generation college student (i.e., nobody from the core family has ever graduated from college). Then the survey assessed students' self-report scores on six categories of motivations to study, developed based on formative research and the current literature. Lastly, the survey assessed students' self-reported learning outcomes, current GPA, university satisfaction, and engineering program satisfaction. Each participant received an Amazon gift card as compensation upon completion of the survey. The institutional review board at the University of Mount Union approved all research procedures.

Participants

The final sample consisted of 468 undergraduate engineering students from 18 different schools in the Midwestern and Northeastern United States. The age of the students ranged from 18 to 49 ($M=20.97$, $SD=3.10$). Most participants were male ($n=301$, 64.3%). Most participants identified as White/Caucasian ($n=375$, 80.1%); 22 (4.7%) identified as Black/African American; 35 (7.5%) identified as Asian; one (0.2%) identified as Native American; 18 (3.8%) identified as Latinx; five participants (1.1%) identified as Middle Eastern; and 12 (2.6%) participants identified as multiracial. Out of the 468 participants, 119 (25.4%) identified as first-generation students.

Survey instruments

Student motivations

We first gathered information from the current literature and some preliminary data (Wang et al., 2022) regarding what motivates undergraduate engineering students to study. The search yielded six categories of motivations: educator's influences, family influences, peers' influences, course content, personality and academic performance expectations, and self-efficacy. Educators' influences refer to various interactions between instructors/advisors and students (e.g., "efficiency of feedback from the educator(s)"). Family's influences refer to support from various family members (e.g., "motivational support from parents"). Peers' influences refer to the interaction with peers in various settings (e.g., "interactions with peers outside the classroom"). Course content motivations are related to various characteristics of course content (e.g., "the subject is intriguing"). Personality and academic performance expectations refer to intrinsic characteristics that are related to learning (e.g., self-discipline, competitiveness, fear of disappointment). Self-efficacy refers to the self-perceived ability in learning (e.g., "having the pre-required skills (e.g., math) to complete and excel in engineering").

We then conducted an informal focus group with undergraduate engineering students ($n=11$; who did not participate in the final cross-sectional survey) to validate these six categories of motivations and specific factors under each category. The formative focus group first validated the six categories that we presented as, indeed, the factors that motivated them to study. Then, the group confirmed 19 motivational factors (out of 29) yielded from the previous literature and our preliminary study (Wang et al., 2022). Lastly, the focus groups generated ten new additional motivational factors across these six categories. We developed 29 motivational factors and asked students to report how much each factor motivates them to study (i.e., "Please evaluate how much each of the following factors motivates you to study") on a scale from 1 to 7 (1 = Not at All, 7 = Very Much So). As these categories of motivation factors are not pre-validated measures, we performed a confirmatory factor analysis (CFA) in the measurement model following the conventional methods (more details in the *Analysis Plans;* Schreiber et al., 2006) using AMOS 27. We assessed the factor loadings of each item in the CFA and dropped three items that had a factor loading smaller than 0.60 per MacCullum et al.'s (2001) recommendations. The self-efficacy category presented unacceptable CFA results and reliability scores, and the self-efficacy scale and its four items were *removed* from future computations and analysis. The descriptive statistics and factor loadings of all final motivational factors that were included in the final analysis (after CFA screening) within each category are presented in Table 1.

Learning outcomes

We measured two sets of learning outcomes, including the self-reported GPA and a 16-item survey instrument. The student's GPA ranged from 1.88 to 4.00 on a four-point system ($M=3.45$, $SD=0.45$). The 16-item instrument measuring students' learning outcomes was created based on the Associations of American Colleges and Universities (AACU) guidelines on important learning outcomes for engineering students. AACU listed four categories of essential learning outcomes, including intellectual and practical skills, communication and collaboration skills, personal and social responsibility skills, and advanced learning skills. We assessed student's utilization

Table 1 Descriptions, descriptive statistics, and factor loadings of the motivational factors in the structural equation model (SEM)

Motivational factors	*M* (*SD*)	Factor Loading
Educator's influences		
Interactions with educator(s) inside the classroom	4.93 (1.57)	0.61***
Interactions with educator(s) outside the classroom	4.21 (1.79)	0.63***
The efficiency of feedback from educator(s)	4.99 (1.65)	0.67***
Educator(s)' classroom performance	5.02 (1.59)	0.77***
Motivational support from teacher(s)	4.72 (1.58)	0.64***
Motivational support from academic advisor(s)	3.60 (1.90)	0.61***
Family's influences		
Motivational support from parents	5.54 (1.64)	0.77***
Motivational support from sibling(s)	3.98 (2.07)	0.66***
Encouragement from family members	5.12 (1.82)	0.66***
Desire to please family members	5.08 (1.56)	0.63***
Peers' influences		
Interactions with peers inside the classroom	4.77 (1.53)	0.63***
Interactions with peers outside the classroom	5.00 (1.57)	0.62***
Motivational support from peers	4.88 (1.57)	0.86***
Motivational support from friends	5.01 (1.51)	0.70***
Course contents		
Quality of course content	5.66 (1.41)	0.90***
The subject is intriguing	5.56 (1.49)	0.70***
High (too) amount of work+	5.36 (1.50)	0.59***
Personality and academic performance expectations		
Competitiveness	5.35 (1.74)	0.61***
Self-discipline	4.58 (1.95)	0.61***
Feeling indifferent about grades+	4.84 (1.77)	0.62***
Lack of care+	5.31 (1.63)	0.75***
Desire to be a good student	5.74 (1.48)	0.75***

The self-efficacy category was removed from the study due to unacceptable CFA model fit indices. The factor loadings presented in this table were the final factor loadings in the structural model

*** indicates $p<.001$; + indicates reverse coding. The categories (scales) and items in each category included in this table were all first validated using confirmatory factor analysis

of these 16 in their engineering education on a 4-point Likert-type scale (1 = never; 4 = frequently; Ma & Klinger, 2000). Higher scores indicated more frequent applications of essential skills learned in engineering education. The items formed a measure ($M=3.15$, $SD=0.56$) with acceptable reliability ($\alpha=0.90$). As this is an established and validated measure, we did not perform CFA and reported the reliability of the scale instead.

Satisfaction

We measured students' satisfaction with their program and university. We used five pairs of opposite adjectives (i.e., bad–good, harmful–beneficial, unimportant–important, invaluable–valuable, uninspiring–inspiring) on a 7-point semantic differential scale to evaluate students' satisfaction with their program and university. Higher scores indicated more favorable evaluations of their program and university. The items formed a program satisfaction measure ($M=5.72$, $SD=1.04$) with acceptable reliability ($\alpha=0.85$) and a university satisfaction measure ($M=5.43$, $SD=1.32$) with great reliability ($\alpha=0.93$). As this is an established and validated measure, we did not perform CFA and reported the reliability of the scale instead.

Analysis plans

We used structural equation modeling (SEM) to test the relationships between different categories of motivations and the student success outcomes, while controlling for the relevant confounding demographic variables. SEM is considered a more accurate analytical approach to data structure that includes directionality and latent structure (Kaplan, 2001). This is particularly suitable to our data as (1) motivations directly influence student outcomes (not the other way around) and (2) there are multiple factors under each motivation type (as shown in Fig. 2) that work

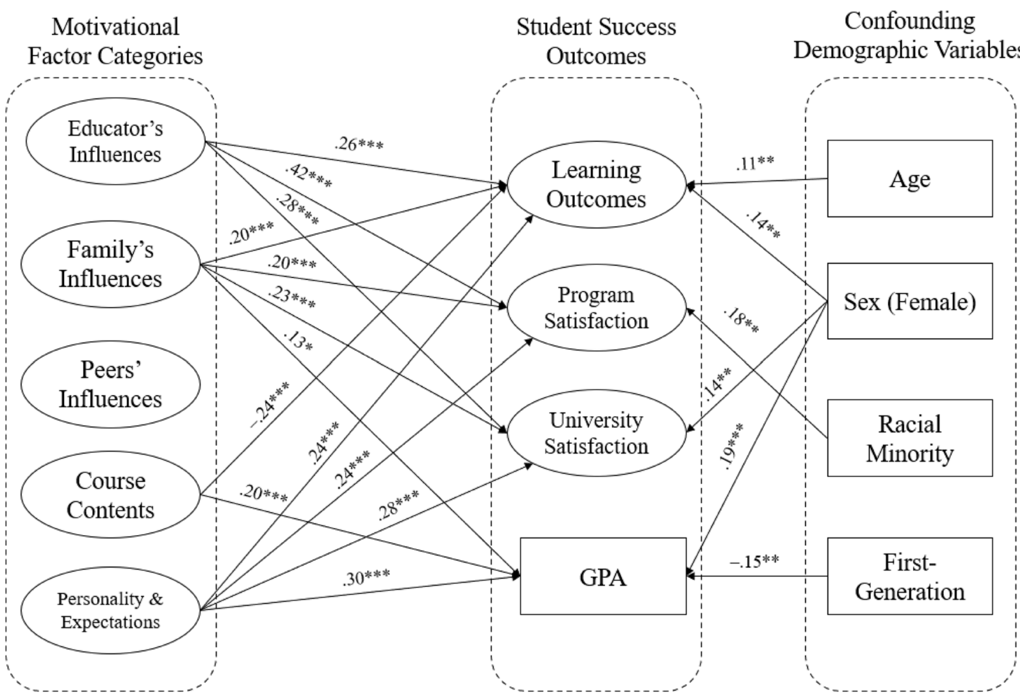

Fig. 2 Structural equation model with significant path and standardized path coefficients. This figure only shows statistically significant paths; the path coefficients are all standardized. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$. GPA = grade point average. An oval shape represents a latent variable; a rectangular shape represents an observed variable

together to influence outcomes. Establishing the optimal sample size for SEM remains controversial in research, but our sample size meets the highest requirement for SEM established by a previous statistical simulation study (Wolf et al., 2013). For demographic variables, we first dummy-coded race (0 = White, 1 = all other races), sex (0 = male, 1 = female), and first-generation college student status (0 = not first-generation, 1 = first-generation). We then checked the assumptions of the test variables in the dataset. The univariate normality of each endogenous variable was checked using the skewness and kurtosis values. Three of the 16 learning outcome items were not normally distributed (kurtosis > 1). We then used the methods of forming percentile ranks and then normally distributed z-scores based on the previously formed percentile ranks to normalize these variables (Templeton, 2011). All three variables were successfully transformed into normally distributed variables (kurtosis < 1). We did not detect any issues of multicollinearity as no correlations among the two variables were greater than 0.92. Then, the variance inflation factor (VIF) was computed to check for multicollinearity. The VIF for the exogenous variables was all below 3, which indicates there was no significant issue with multicollinearity. Lastly, the endogenous variables (i.e., four student success outcomes) were not significantly associated with each other, so they were analyzed as separate constructs rather than being loaded onto a latent variable.

We first built a full measurement model where all variables can freely associate with each other. We specified the five latent motivation variables (self-efficacy was dropped due to factor loading and reliability issues), latent learning outcomes variables, latent program satisfaction variable, and latent university satisfaction variable using items shown in Table 1. GPA (single construct) was entered into the model as observed variables. Then, based on the model fits of the full measurement model, we used standardized factor loadings to identify potential issues with the full measurement model. Using the results of the final measurement model, we then built the structural model. The factor loadings of all the final items included in the structural model are listed in Table 1. In the structural model (Fig. 2), each of the five categories of motivational factors predicted each of the four students' success outcomes. To control for the potential variance related to confounding demographic variables, we added four prominent demographic factors in prior engineering education research. These factors, namely age, re-coded sex, re-coded race, and re-coded first-generation student status, were included in the model. The demographic variables were set to be associated with all endogenous variables. Both measurement and structural models were tested using AMOS 27. The measurement and structural models were tested using 500 bootstrap samples using the maximum likelihood estimation. We used the guidelines offered by Schreiber et al. (2006) when assessing and reporting the results of both the measurement and structural models. We assessed and reported the model fit indices (i.e., χ^2/df, *CFI, GFI RMSEA,* 90% CL and, *PCLOSE;* per Schreiber et al.'s (2006) recommendations), standardized factor loadings, and p values of factor loadings for the measurement model. We assessed and reported the model fit indices, standardized path coefficients between exogenous and endogenous variables, and p values of standardized path coefficients for the structural model.

Results

Measurement model

We specified the full measurement model according to our *Analysis Plans,* where all variables can freely associate with each other. The model fit indices presented a marginal fit to the data, χ^2 (1092, $N=468$) = 3850.42, $\chi^2/df = 3.53$, $p < 0.001$, $CFI = 0.79$, $GFI = 0.80$, $RMSEA = 0.07$ (90% CL = 0.06–0.07, $PCLOSE = 0.00$). We then examined the standardized factor loadings and found one educator's influence factor (i.e., "motivational support from the academic department administrator," $\beta = 0.23$), one family's influence factor (i.e., "motivational support from the romantic partner," $\beta = 0.40$), and one course content factor (i.e., "the courses have materials that are too difficult," $\beta = 0.23$). Those three observed variables were consequentially removed from the model. The model fit of the new measurement model, χ^2 (962, $N=468$) = 2943.50, $\chi^2/df = 3.06$, $p < 0.001$, $CFI = 0.90$, $GFI = 0.90$, $RMSEA = 0.05$ (90% CL = 0.04–0.06, $PCLOSE = 0.00$) improved. We used the final measurement model to build the structural model.

Structural model

We specified the structural model according to the *Analysis Plans*. The model fit indices presented an acceptable fit to the data given a large number of observed variables in the model, χ^2 (1347, $N=468$) = 4723.88, $\chi^2/df = 3.51$, $p < 0.001$, $CFI = 0.82$, $GFI = 0.88$, $RMSEA = 0.07$ (90% CL = 0.06–0.08, $PCLOSE = 0.00$), $SRMR = 0.08$. We then used the standardized path coefficients between latent motivational factor categories and endogenous variables (i.e., four student success outcomes) and their significance levels to examine the significant main paths. The results showed that family influences ($\beta = 0.13$, $p < 0.05$), course contents ($\beta = 0.20$, $p < 0.001$), and personality and academic performance expectations ($\beta = 0.30$, $p < 0.001$) all predicted student GPA. Educator's influence ($\beta = 0.26$, $p < 0.001$), family's influences ($\beta = 0.20$, $p < 0.001$), course contents ($\beta = -0.24$, $p < 0.001$), and personality and academic performance expectations ($\beta = 0.24$, $p < 0.001$) all predicted learning outcomes. Educator's influence ($\beta = 0.42$, $p < 0.001$), family's influences ($\beta = 0.20$, $p < 0.001$), and personality and academic performance expectations ($\beta = 0.24$, $p < 0.001$) predicted program satisfaction. Educator's influence ($\beta = 0.28$, $p < 0.001$), family's influences ($\beta = 0.23$, $p < 0.001$), and personality and academic performance expectations ($\beta = 0.28$, $p < 0.001$) all predicted university satisfaction. Peers' influence did *not* predict any of the four students' success outcomes. Overall, family's influences and personality and academic performance expectations were consistently associated with all four students' success outcomes, and educator's influences were associated with all four outcomes *but* student GPA. Moreover, some confounding variables were directly related to some of the students' success outcomes. Being older significantly predicted ($\beta = 0.11$, $p < 0.01$) learning outcomes; being a female student significantly predicted learning outcomes ($\beta = 0.11$, $p < 0.01$), university satisfaction ($\beta = 0.14$, $p < 0.01$), and GPA ($\beta = 0.19$, $p < 0.001$); being a racial minority student significantly predicted program satisfaction ($\beta = 0.18$, $p < 0.01$); and being a first-generation student significantly *negatively* predicted program satisfaction ($\beta = -0.15$, $p < 0.01$). In Fig. 2, we presented only the statistically significant paths for clarity, not the non-significant paths and factor loadings onto latent variables for readability. The full results of all standardized path coefficients in the full structural model are shown in Table 2.

Discussion

Students' motivation levels affect their engagement with and contribution to learning activities, which eventually influence their academic success. Motivation is not a single construct; it could be intrinsic factors within the student or extrinsic within the student's overall environment. Most studies in engineering education focused on students' motivations to choose engineering as their career choice and mainly attempted to identify ways to prevent high dropout rates. To the best of our knowledge, this is the first study that comprehensively examined the roles of both intrinsic and extrinsic motivational factors on student success. Our study examined how different learning motivations influence student success outcomes among undergraduate engineering students with a more comprehensive list of motivations and an analytical approach that reflects the intercorrelated and latent structure of the multi-faceted motivational factors. We used a structural equation modeling approach to test the relationships between different motivations and student success outcomes while controlling for the relevant confounding demographic variables. Overall, the extrinsic

Table 2 All standardized path coefficients between exogenous and endogenous variables and p values

Exogenous variable	Endogenous variable	β, p
Motivational factor categories		
Educator's influences	GPA	–.08, p = .09
Educator's influences	Learning outcomes	0.26***
Educator's influences	Program satisfaction	0.42***
Educator's influences	University satisfaction	0.28***
Family's influences	GPA	0.13*
Family's influences	Learning outcomes	0.20***
Family's influences	Program satisfaction	0.20***
Family's influences	University satisfaction	0.23***
Peers' influences	GPA	0.01, p = .96
Peers' influences	Learning outcomes	0.01, p = .84
Peers' influences	Program satisfaction	0.07, p = .15
Peers' influences	University satisfaction	0.06, p = .09
Course contents	GPA	0.20***
Course contents	Learning outcomes	–0.24***
Course contents	Program satisfaction	0.08, p = .08
Course contents	University satisfaction	–0.04, p = .46
Personality & expectations	GPA	0.30***
Personality & expectations	Learning outcomes	0.24***
Personality & expectations	Program satisfaction	0.24***
Personality & expectations	University satisfaction	0.28***
Confounding Demographic Variables		
Age	GPA	–0.01, p = .75
Age	Learning outcomes	0.11**
Age	Program satisfaction	0.06, p = .19
Age	University satisfaction	–0.02, p = .68
Sex (female)	GPA	0.19***
Sex (female)	Learning outcomes	0.14**
Sex (female)	Program satisfaction	0.05, p = .28
Sex (female)	University satisfaction	0.14**
Racial minority	GPA	0.01, p = .99
Racial minority	Learning outcomes	0.07, p = .10
Racial minority	Program satisfaction	0.18**
Racial minority	University satisfaction	0.01, p = .77
First-generation status	GPA	–0.15**
First-generation status	Learning outcomes	–0.03, p = .45
First-generation status	Program satisfaction	–0.04, p = .39
First-generation status	University satisfaction	–0.05, p = .25

*** indicates p < 0.001

** indicates p < 0.01

* indicates p < 0.05

motivations influenced students' success outcomes to varying degrees, except for peers' influence. As for the intrinsic motivations, all but self-efficacy (excluded due to low-reliability scores) were positively associated with all measured students' success outcomes. We further expand on some of the interesting findings and their practical implications in engineering classrooms and programs. Specifically, we found two points of unexpected results: (1) the educator's influence did not significantly and almost negatively impact GPA, and (2) the influence of peers did not predict any of the four students' success outcomes. We expand on the discussion of these unexpected results in the following sections.

Personality and academic performance expectations

Our results showed that personality and academic performance expectations were mostly consistently and positively associated with all four student success outcomes, and such finding is consistent with findings in the current literature on engineering education. First, considerable research found that self-discipline skills are essential for success in their studies and personal pursuits. Students with stronger grits over their behaviors could strengthen their overall academic performance, making them more likely to persist, have interpersonal success, attain good grades, and remain in college (Horton, 2015). In addition, many of the surveyed participants in the current study experienced significant distance learning during and after the COVID-19 pandemic. Successful online learning requires students to discipline themselves to maintain their schedule and focus on learning tasks (Waschull, 2005), so it makes sense that the distance learning environment coupled with stronger self-control would positively influence student's academic performance. Second, the result affirms the positive outcomes of competitiveness in driving student performance, which aligns with some of previous educational studies on student success (Baumann & Winzar, 2016; Krskova & Baumann, 2017). Competitiveness has been tested and validated both as a driver of educational performance and its outcome (Baumann & Harvey, 2018). Competitive students have been characterized as being more engaged in class (Nguyen & Nguyen, 2010). Furthermore, a true competitive nature has not been found to affect group academic outcomes negatively (Onwuegbuzie et al., 2009). By considering the uniqueness of different student populations within their classrooms, engineering educators and administrators should have more comprehensive views of student success than GPA, DFW rates, or test scores. In addition to the important technical knowledge and skills to prepare students for college and careers, engineering educators could incorporate some factors in their teaching and curriculum design that focus on cognitive and/or self-control skills such as time management, conflict management, help-seeking behaviors, and communication skills. Previous successful programs incorporated conflict negotiation training that focused on the basics of conflict, negotiation, and styles for constructive negotiation in senior capstone courses. The program evaluations indicated that the workshop was effective, and such effectiveness was positively associated with students' cognitive learning outcomes (Sollitto & Mehrubeoglu, 2020).

The case with engineering educators

Our results showed that educator's influence did not significantly and *almost* negatively impacted GPA. The following reasons might explain such unexpected and seemingly counterintuitive results. First, the overall expectations of the course content do not necessarily align with what the instructor (s) offers, which indicates that there might be a match issue, particularly for students with higher GPAs. Nowadays, students come from a variety of academic backgrounds. The diversity is not only in learning ability but also in behaviors, study goals, and learning style, which could potentially influence student success, as proven by the vast literature on education (Boles & Whelan, 2017). For instance, students come to class with different goals and focus. Some focus on acquiring and developing competence, while others focus on demonstrating their competence and outperforming others (Senko et al., 2011). The former favors instructors who challenge them intellectually for a deep understanding of the course subject, while the latter favors instructors who present the material clearly and provide clear guides about how to succeed. Instructors could easily make incorrect assessments about a student's learning effectiveness without familiarizing themselves with students' characteristics and tailoring the content and pedagogical methods, which eventually leads to inconsistent and poor student success. One ongoing debate in higher education research and pedagogy is whether instructors should educate a diverse student population with a universal approach or whether students should be sorted by learning ability or other characteristics. Most education scholars agree that students' characteristics could significantly influence their learning outcomes and effectiveness (Podell & Tournaki, 2007). However, engineering instructors might not consider students' characteristics during interactions in the classroom because they might see personal characteristics as irrelevant in the scientific environment (Bilimoria & Stewart, 2009; Miller et al., 2021). If students feel uncomfortable around "chilly" classrooms, they might become unconfident and put less effort into learning, which could eventually lead to academic stress and failure (Vogt et al., 2007).

Second, the interactions with engineering instructors might not always be perceived as positive by students. In some cases, engineering instructors might consider students' individuality in a negative light. Much of the research suggests that there are disparities in the effects of instructor interactions on student success (Cole & Griffin, 2013; Kim, 2010; Park et al., 2022). The positive influence of the interaction on student outcomes varies on student characteristics such as gender and race. For example, Park et al. (2022) suggest that students who interacted more frequently with the instructor were also more frequently exposed to racial discrimination from the instructor, which eventually negatively affected college GPA. Similarly, Kim and Sax (2009) found that positive relationships with engineering instructors tend to be more pronounced among male students than female students. Moreover, some engineering instructors, especially at research-intensive institutions, often value science more than practical impact and applications to society for the advancement of knowledge (Karakas, 2009). It may not align with values, such as social responsibility and civic outcomes, that motivate students of color and women to be successful in engineering education (Garibay, 2018).

Lastly, engineering instructors might lack the motivation to improve their teaching quality and actively integrate innovations in their courses. Driven by the increasing number of National Science Foundation (NSF)-sponsored engineering education programs, a lot of effort has been invested in engineering education, such as creating innovative pedagogies and curricula (Trapani & Hale, 2022). However, it raises the question of how many of these changes result in major systematic improvements in engineering classrooms (Chalmers et al., 2017). Moreover, a related question is how many engineering instructors would read the literature and subsequently change their teaching practices (Stains et al., 2018). Most engineering instructors are trained as researchers in their discipline, so the study of teaching and learning theories might not usually be part of their formal education (Oreovicz, 2002). Engineering instructors could lack formal and systematic training and professional development regarding learning theories and pedagogical practices during and after graduate school. Their teaching might simply replicate that of their instructors when they were students (Borrego et al., 2010; Cuevas, 2015; Oleson & Hora, 2014).

Our results suggest some of the issues related to engineering instructors and perhaps the misalignment between students' preferences/expectations and what engineering instructors offer. Thus, we recommend that engineering educators and program administrators consider the following recommendations. First, engineering instructors should understand students and meet where students are. For example, an engineering instructor could conduct a student expectation assessment at the beginning of the semester to foster a positive and supportive assessment culture in the classroom. It helps students become more aware of their perceptions of course topics and their own strengths and limitations (León et al., 2023). More importantly, it could help instructors understand what backgrounds, skills, and values students are entering the classroom with. This understanding can help improve the instructor's course plans on pivotal details such as in-class activities, term project topics, cognitive skill training, and group assignments. Second, engineering instructors need to create a "warm" atmosphere, which means a positive and inclusive learning environment in the classroom. As suggested by studies in the field of communication, immediate behavior identified by vocal expressions, smiling, engaging in eye contact, and exhibiting body gestures is associated with reducing the psychological distance between instructor and student (Witt & Wheeless, 2001). Also, engineering instructors should maximize the classroom learning process's transparency by making students comfortable to be wrong. Students can learn from an error than a perfectly executed example (Canning et al., 2019; Farrell et al., 2021). Lastly, engineering instructors should integrate as many socially relevant applications as possible into their teaching and curriculums, such as engineering ethics studies. The purpose is to better align with students who attach great importance to a culture of social responsibility (Rulifson & Bielefeldt, 2017). It could eventually help the instructor enhance engineering students' sense of belonging, which is inextricably linked to students' overall success outcomes in an engineering program.

Peers do not matter?

Our results showed, at least at the face values, that peers' influence did not predict any of the four students' success outcomes, which contradicted prior general education research. Such discrepancies in our results could be related to the unique nature and culture of engineering fields. A widespread belief about modern engineering is that it requires superior intellectual ability (Heil et al., 2013), which is frequently and mostly assessed with individual grades and test scores to represent student academic success in engineering (Dringenberg et al., 2022). Engineering students are often expected to be self-reliant, capable, and not emotionally demonstrative due to the fact they *self-expect* themselves and their peers to be all high achievers academically with above-average ability in mathematics and scientific understanding (Godfrey & Parker, 2010; Jensen & Cross, 2021). Such engineering culture might lead to dire consequences in peer culture among engineering students. Instead of fostering collaborative and supportive peer support, such a culture could lead to engineering peers who have diminished expectations and trust in each other. Consequentially and perhaps unsurprisingly, such peer culture combined with "unrealistic" expectations of high academic performance leads to isolation, missed opportunities, and eventually poor success outcomes. For example, Dringenberg et al. (2022) found that engineering undergraduate students described a common belief that being recognized/perceived as smart (or not) greatly influences their access to interpersonal opportunities. Engineering students who were not perceived as smart or having low academic ability by their peers were often not welcomed in discussions and teamwork, as well as in day-to-day interactions in engineering classrooms (Dringenberg et al., 2022; Secules et al., 2018).

The peer culture in engineering might influence female and underrepresented (e.g., racial and sexual minority) engineering students more than any others. The negative bidirectional cycle exists between the objective poorer student success outcomes and their peers' unjust and subjective interpretations of their intelligence/ability among female and underrepresented engineering students. Many studies revealed the unequal learning opportunities that female and underrepresented students could have in their learning experience (Isaac et al., 2023; Meadows & Sekaquaptewa, 2013). Female and underrepresented students are more likely than others to feel singled out because their peers do not respect their intelligence or experience. For instance, in the Vooren et al. (2022) study, female students reported that their male peers gave their ideas less credit and failed to trust them with technical work on group projects. Such culture and negative cycles are often criticized as one of the main reasons for the underrepresentation of women and students of color in engineering (Pawley, 2019). Female and underrepresented students often have to study harder to overcompensate for the unjust peer interpretation or leave engineering majors to reduce the psychological cost of the interactions with peers who question their competence (Vazquez-Akim, 2014).

Success starts and ends with cultural changes, and peer culture among engineering students is no exception. We recommend that engineering educators and program administrators consider the following recommendations to address the peer culture issues where students might distrust or unfairly assess each other inside and outside the classroom. First, classrooms are socially dynamic places for each student. What identities students have and what matters to students are inextricably linked to their sense of belonging and ability to engage in learning and participating (Steele & Cohn-Vargas, 2013). Engineering educators are responsible for creating an equitable, intellectually exciting, and socially supportive learning environment and carefully managing collaborative work to support positive and inclusive interactions. However, most of the time, engineering educators believe that "flat-out" or "universal" equal treatment for all students is an effective strategy for creating inclusive and equitable classrooms. Unfortunately, simple equality is often not enough to develop and enhance the sense of belonging for all engineering students (Farrell et al., 2021). Educators could improve this situation by 1) giving more recognition of improvement instead of solely focusing on objective scores, 2) devoting resources and attention to individualized communication, feedback, and assessment, and 3) intentionally creating intercultural dynamics among diverse students to improve psychological safety and innovations in teams (Butterfield et al., 2018; Farrell et al., 2021; Reed et al., 2016). Second, engineering programs could facilitate intraminority understanding and shared solidarity among underrepresented minority and female students instead of focusing on one specific minority group. Intraminoirty understanding refers to mutual understanding across different minority groups, including but not limited to gender, race, and sexual orientation (Craig & Richeson, 2016). Previous research has shown that intraminority understanding promotes shared solidarity, positively contributing to resilience, perceived social support, and group bonds across various minority groups (Cortland et al., 2017; Craig & Richeson, 2012). To foster intraminority understanding, engineering educators and programs could implement workshops that address the history and current manifestations of broad-spectrum bias and common strategies to improve overall diversity, inclusion, and equity (DEI) in engineering across various minority identities. Students could engage in intercultural interpersonal conversations that develop critical consciousness and mutual understanding, which could eventually foster broader support and form a shared identity despite the differences (Lake, 2017).

The key roles of family

In contrast to peers' influence, the results showed that family influence was consistently and positively associated with all four students' success outcomes. This finding is largely consistent with many previous studies that acknowledged the importance of considering family influences in college success (Jarvie-Eggart et al., 2020). College students today depend on their families for a longer period of time than half a century ago (Settersten & Ray, 2010). Students frequently communicate with their families and receive various forms of support (Sax & Wartman, 2010). Family influence, in the forms of financial and social capital, advice, social support, and development opportunities, could have a substantial overall effect on the desire to enroll and complete a post-secondary program (Bers & Galowich, 2002; Puccia et al., 2021; Sundly & Galway, 2021). In recent years, higher education institutions have increasingly been considering engaging parents to foster student success (Hamilton, 2016). Besides recruiting family members to serve on councils and represent the university in marketing initiatives, they could also be engaged in discussions about engineering students' academic and social needs. Family members may be more likely to detect academic, social, or emotional challenges that influence students learning motivation and academic performance, which can facilitate early intervention before challenges lead to academic departure or failure. For example, a family orientation could effectively engage family members to understand the student learning environment better. Such orientation could include a resource fair and meeting with faculty, staff, and fellow students. Also, engineering programs could support family engagement by developing workshops that give students and their families hands-on experience in engineering practices. Zimmerman et al. (2021) created a series of workshops related to aerospace engineering for students and parents to learn and work together on weekends. Their work suggests that parents as learning partners could add critical learning support during engineering-making activities of such informal programs (Zimmerman et al., 2021).

In the current study, the family's influence was shown as a positive type of motivation for student success, but it might not be the case for first-generation students. The results showed that being a first-generation student significantly *negatively* predicted program satisfaction. The reason could be that first-generation students might feel out of place in their higher education due to their lack of social capital (Verdín & Godwin, 2015). Social capital indicates the resources gained through relationships, which first-generation students might lack (Holland, 2010). In other words, the resources available in first-generation student families' social networks might not be able to provide valuable educational support like their peers, such as financing help, positive academic role models, and connections with engineering companies for potential job opportunities in the future (Martin et al., 2020; Moschetti & Hudley, 2015). To help first-generation students be successful in their academic careers, engineering educators and program administrators could first build peer mentoring programs. Studies have shown that peer mentoring helps first-generation students overcome academic challenges and build a sense of belonging in engineering programs (Ahmed et al., 2021; Martin et al., 2020). Engineering programs could also create more dedicated extracurricular activities, either social events or student competitions tied to a specific engineering project, to increase the opportunities for first-generation students to build connections with instructors and professionals from industries, which could positively contribute to their social capital.

Contributions

The current study utilized empirical evidence, formative research with the target student population, and, more importantly, stayed within the bounds of the SDT. The findings extend the empirical understanding of the SDT and other motivational theories to an understudied population and reveal nuanced differences between engineering students and others. For example, many motivational theories (i.e., the need for relatedness in the SDT) suggest the important influences of peers, but our data did not support those theoretical stances. This calls for further replication studies among engineering studies and studies that examine the underlying mechanisms that explain why peers did not serve as an important motivator. Further understanding could make new theoretical propositions and extend the bonds of motivational theories.

In addition, there are instruments and frameworks that have been useful in conducting motivation research, such as the Expectancy-Value Theory (Wigfield, 2000) or MSLQ (Motivational Strategies for Learning Questionnaire) (Duncan & McKeachie, 2005). However, these instruments and frameworks are not particularly designed for engineering students. Since every discipline has its specialized learning outcomes and requirements, the instruments should be tailored to measure students' learning motivations. This study makes important contributions to the literature by applying a well-known motivational framework to investigate factors specifically influential for engineering students. This study investigates factors influencing students' motivation to learn and how motivation can be nurtured. If motivational influences vary or differ based on the discipline, pedagogical methods should be adjusted to enhance learning experiences, improve student success, and eventually reduce dropout rates. In addition, although the current study focuses on students majoring in engineering, the results could also be referenced and applied in other STEM disciplines due to the similarities in pedagogical content knowledge and thinking. For example, engineering and other STM (Science, Technology, Engineering, Mathematics) disciplines of learning and thinking are usually situated in the context of problem solving (Leung, 2020), which means there is a high probability that educators could have similar teaching philosophies such as project-based learning.

Limitations

The current study should be interpreted within its four limitations. First, due to the limited sample size and article length, the current study did not test any effects of different motivational factors on student success outcomes. It is plausible that the combination of two or more motivational factors could have amplified effects on student success. For example, as previously discussed, alignments between educator's influence and course content expectations could potentially be influential to all four student success outcomes. The current study focuses on testing the motivational factors and student success outcomes comprehensively and systematically, but future studies should consider exploring such moderation effects. Second, the reason why the self-efficacy items that we used did not form a reliable measure could be related to the broad and varied interpretation of self-efficacy in the literature and our preliminary research. The current study had to balance between including the unique facets of self-efficacy in engineering and established measures. Future research could reexamine self-efficacy with conventional pre-established self-efficacy scales commonly found in social science and behavioral research (e.g., Witte et al., 1996). Although unlikely given the anonymous survey format, self-report GPA could include some social desirability bias, especially considering our previous discussion of engineering student peer culture. Future studies could include subjective education records as a measure of student success. Lastly, the data were collected from students in only the Midwestern and Northeastern United States to control for the variance related to regional differences. For example, students from different countries might have drastically different educational experiences than those from the United States. In order to more accurately account for such regional variance, a much larger nationwide and international-wide sample of students is needed, but such a project, unfortunately, was beyond the scope of the current study. Due to the constraints of resources, schools were chosen based on geographical proximity. Future studies should consider regional differences by including a wide variety of schools and recruitment.

Conclusion

To the best of our knowledge, the current study is the first to systematically examine different types of motivations and their influences on undergraduate engineering students' success outcomes. The current study examined intrinsic and extrinsic motivations by applying motivation theories in learning. As engineering education is a multi-faceted issue requiring more systematic research, our findings uniquely contribute to understanding both positive and negative impacts on students' success outcomes from each type of motivation. We hope our findings help educators understand students' learning motivations and inform better class design, pedagogical methods, communications with students, and policymaking.

Abbreviations

STEM	Science, technology, engineering, and mathematics
GPA	Grade point average
AACU	Associations of American Colleges and Universities
CFA	Confirmatory Factor Analysis
VIF	Variance Inflation Factor
DFW	The percentage of grades of D or F or Withdraw
NSF	National Science Foundation
IRB	Institutional Review Board
FERPA	The Family Educational Rights and Privacy Act

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Author contributions
XW completed data collections and wrote Introduction, Literature review, Discussion, and Conclusion of the manuscript. XW also assisted in the overall proofreading of the manuscript. MD led data curation and analysis of questionnaire data and wrote Abstract, Methods, Results, and Limitations of the manuscript. MD also assisted in the overall proofreading of the manuscript. KS assisted in the writing of the discussion section and overall proofreading of the manuscript. All lead authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was reviewed and approved by the University Institutional Review Board (IRB 2021-482) at the University of Mount Union.

Competing interests
The authors declare that they have no competing interests.

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