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Student Engagement, Executive Function Skills, and Academic Success: The Connection during the College Years

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Abstract. The present study examined the relationship between executive function (EF) skills, student engagement and academic success during the college years. Prior work on EF and on student engagement have noted the connection of each to academic success. However, recently scholars have highlighted the importance of examining the dynamics of human development, more comprehensively examining the nuanced relationships between individual and cultural systems over developmental time (Raeff, 2016). This leads us to examine whether and how EF may not only influence academic outcomes directly, but also exert effects through students' engagement with learning. Using a national sample of full-time students enrolled in US colleges contacted via social media, two hundred and eight college students completed a survey of student engagement (Marôco et al., 2016) and a survey of executive function (Ramos-Galarza et al., 2020). Analyses focused on developmental differences in EF skills, student engagement, and grades and whether and how student engagement played a mediating role in the relationship between executive function and grades. Independent-sample t-tests were conducted to compare first year and senior students and no support was found for differences, so first year students and seniors were combined for the further analyses. A simple mediational analysis supported hypothesis 2 that student engagement mediates the relationship between executive function and grades. The parallel mediation analysis supported hypothesis 3 for behavioral and emotional engagement, but not cognitive engagement. The results highlight the complex relationships between student engagement, executive function, and academic achievement. Implications for further research and intervention are discussed.

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1. Introduction

Recent work in the developmental and learning sciences has highlighted the importance of moving from transfer models of learning to more engaged pedagogical styles (Sawyer, 2022). Studies of higher education success have pointed out that engaged learning significantly predicts student success in college or university (Li & Xue, 2023). This has led institutions to focus on professional development to encourage more student engagement in the classroom (Budwig et al., 2018). However, in recent years, there are several indicators, often linked to the onset of COVID-19, that students are less engaged academically (Chirikov et al., 2025; Stefenel & Neagos, 2020). Furthermore, while generally student engagement has been linked to better learning outcomes, demographic differences have been reported without clear indications of why (Li & Xue, 2023).

Simultaneously, college campuses have seen increasing numbers of neurodiverse students matriculating, leading colleges and universities to increase services available to support the academic needs of this population (Bakker et al., 2019) and generally be sensitive to issues of executive function. The increased focus over the last decade on the whole student (students intellectual and social development), as well the increased focus on career preparation for college students, has heightened awareness that neurotypical students' ability to manage social interactions with others, and their general use of executive function skills needs additional support (Hilton et al., 2024; Pinochet-Quiroz et al., 2022; Ramos-Galarza et al., 2020). This increased interest has also led to the development of research studying executive function in college students and the development of a scale to measure executive function in college students (Ramos-Galarza et al., 2023).

While engaged learning, with its focus on real world implementation and project-based work, requires strong executive function skills, to date no research has attempted to study these two areas in tandem. Research has proceeded in siloed ways. But recent theorizing in human development and learning provides theoretical frameworks to guide this work. Modern theories of development and learning highlight the dynamics of developmental processes and encourage the use of multiple lenses focused on the interactions between individual development and sociocultural practices (Budwig, 2021; Gutiérrez & Rogoff, 2003; Raeff, 2016).

From this theoretical perspective, human development is best viewed in terms of a framework that encompasses the dynamics of multiple and inter-related processes rather than discrete developments. And second, such developments take place as individuals interact with one another in cultural practices. Looking at development from this process orientation situates individual and cultural institutions (schools, universities) in activity, as opposed to looking at how development in humans occur due to distinct individual or contextual causes.

The sociocultural framework that looks more holistically at individual development and interactions with others allows two new ways to conceptualize the relationship between student engagement, executive function, and academic success. First, both engagement and executive function can be viewed in light of what happens as individuals interact with one another. As Conley (2005) has noted the practices students engage in while learning and how they are organized radically differ as students transition from high school to college in the United States. Students may be engaged learners in both cultural settings, however in college, students are expected to be more agentive and organize their own learning.

Developmentally, participating in engaged learning in college demands require a new level of skills, including those considered under the umbrella term of executive function. This reconceptualization linking student engagement with executive function suggests a second way the theoretical framework allows for new conceptualizations of student development, since it encourages researchers to examine student development holistically as they engage in learning activities.

The goal of this exploratory study is to examine how reframing the study of student development in college as a dynamic process situated in sociocultural activities enhances our understanding of the nuanced relationships between variables such as student engagement and executive function that to date have been studied in isolation. We turn in section 2 to examining what prior research has found pertaining to student engagement and executive functioning as they have been individually studied, in order to build towards three hypotheses that will guide the current study in section 3.

We believe that more nuanced account of the dynamics of the development of student engagement and executive function during the college years as these relate to academic success will not only deepen our understanding of student success but also will hold the potential to transform how interventions are designed to assure better academic outcomes for students attending universities and colleges.

2. Literature Review

2.1 Student Engagement

Student engagement has been viewed as a complex construct that has been studied extensively over the last two decades as its linkage to academic success has been found. Several researchers have focused on student engagement both as a predictor and a product, emphasizing qualitative aspects, focusing on the amount of effort that students dedicate to educational activities as they learn in school settings (Budwig et al., 2023; Fredricks et al., 2004; Kuh, 2009).

As a multidimensional construct, researchers examining student engagement in middle schools, high schools, and college settings frequently conceptualize this multidimensional construct in terms of behavioral, emotional, and cognitive dimensions (Fredricks et al., 2004). Interrelated and yet considered distinct, these

three dimensions have been used as a dominant framework for the bidirectional effects of student learning. Table 1 defines each of these three dimensions.

Table 1: Definitions of behavioral, emotional, and cognitive engagement (Fredricks et al., 2004)

Type of Engagement	Definition
Behavioral	Rooted in participation, such as academic involvement and partaking in social and extracurricular activities, which has been closely correlated to academic success.
Cognitive	Students' investment in undertaking the effort for comprehension of ideas and developing new skills.
Emotional	Relies on positive and negative reactions to learning, peers, mentors, and the institution—influencing students' motivation.

Studied across the lifespan, these three dimensions, collectively and individually have been linked to academic achievement (Finn & Rock, 1997; Lardy et al., 2022; Lei et al., 2018). While across the board connections have been identified between student engagement and academic achievement, various demographic differences have been found. Level of school (middle, high school, or college), racial and SES differences, and specific linkages of the three dimensions have been noted (Lei et al., 2018; Shernoff & Schmidt, 2008; Skinner et al., 2009). Rarely though are these discussed in terms of a coherent model spanning the institutional and individual factors.

In general, the work on middle school, high school, and college students is done in isolation without a broader systematic framework accounting for developmental changes across the years and institution types. One exception to this is the work of Skinner et al. (2009) who argue for the need to focus on process accounts of student engagement that consider developmental time. Skinner et al. (2009) note in their discussion of development across childhood and through high school (p. 236):

Cumulatively, these cycles may explain how, over developmental time, children energized and focused interactions with academic activities and school partners become part of a process that shapes the emergence of durable energetic resources and liabilities … that eventually lead youth to construct the kind of personal identity that involves lasting commitments to education goals and taking ownership for their own learning.

However, Skinner and colleagues' focus has been on pre-college populations. As for college students, they typically have either been studied in general regardless of years in college or as first year students only (Assunção et al., 2020; Krause & Coates, 2008; Liu et al., 2023; Mandemach, 2015; Maroco et al., 2016). Such work has highlighted the connection between student engagement and grades. The work on first year students at university highlighted the conceptual importance of looking at the first year of college as a transitional time where students will need added support both through orientation programs and in their classes to foster the student engagement required, though many studies combine students

across the college years. All of this suggests that there may be differences in student engagement across the college years if examined.

Student engagement has been assessed in multiple ways, most notably student surveys (self-report), behavioral classroom observations, and interviews with teachers, parents, and students. Evidence from these studies has indicated that student engagement is positively correlated with academic grades and academic success, regardless of method used, though differences have been noted (Lei et al., 2018). Findings from various studies that have examined cultural communities, age, and race highlighted the complex difference across demographic groups, though it is not clear why these differences exist.

For instance, measurement invariance with regard to country and language make it difficult to compare specific findings. This highlighted that while there is a perception of a correlation by individuals, how this plays out can vary tremendously. While correlations exist, an understanding of what drives student engagement to link to grades and academic achievement across developmental time is not well understood, especially during the college years.

2.2 Executive Function

Executive Function (EF) skills are higher-order cognitive abilities that enable individuals to regulate their thoughts, emotions, and behaviours in a goal-directed manner (Miyake et al., 2000). Cooper-Kahn and Dietzel (2019) define EF as a person's ability to manage cognitive resources in order to function efficiently. EF encompasses core cognitive components such as working memory, cognitive flexibility, and inhibitory control. These collectively facilitate complex learning processes such as organizing information, adapting to changing demands, and sustaining focus (Zelazo & Carlson, 2020).

In the higher education setting, these skills are particularly critical as students are often expected to manage their learning autonomously, balancing academic demands with personal responsibilities (Dembo & Seli, 2008). These practices highlight the importance of metacognition, where students actively monitor their understanding, adjust their learning strategies, and reflect on their performance to achieve academic success (Bowmer et al., 2018). It's important to view these practices as an active process that students in an academic setting are involved with.

Although EF has been widely studied in early childhood and neurodiverse adult populations (Bull & Lee, 2014; Lee et al., 2021), its role during the college years remains underexplored. Yet, emerging research suggests that EF skills continue to develop well into early adulthood, shaped by both neurological maturation and contextual demands of the academic environment (Casey et al., 2019; Stark & Lindo, 2022; Zelazo & Carlson, 2020). As students navigate increasingly complex coursework, EF skills enable them to plan effectively, regulate emotions, and stay engaged with learning tasks (Duckworth & Seligman, 2005; Zimmerman, 2002).

Deficiencies in EF during this developmental window have been linked to difficulties in planning and task initiation, leading to procrastination, disorganization, and ultimately, lower academic achievement (Dent & Koenka, 2016; Steel, 2007). Furthermore, prior research highlighted the importance of different dimensions of EF in academic performance and learning success (Díaz-Guerra et al., 2024; Ramos-Galarza et al., 2020). The idea that EF skills are essential in planning, problem solving, implementation of strategies all components necessary in this period of higher education for professional development has been postulated in a few studies (Ramos-Galarza et al., 2023).

Current work has also revealed that in a higher education academic setting, students reported a greater need for using specific EF skills as compared to high school academic settings. And in college, students also reported a higher use of specific EF skills at a later period of college than in the earlier years suggesting that these skills are developed through academic and socio-cultural practices throughout the college years (Halder & Budwig, 2024).

Recent studies showed there is a growing interest in the relationship between EF and academic performance (Dias et al., 2022). Focusing mainly on elementary and middle school populations, it has been argued that EF skills play an important role in knowledge acquisition thus, when students are better at focusing and refocusing their attention, holding information and resisting distraction, they are better placed at acquiring knowledge and skills in the classroom (Pellicano, 2012). Such work has primarily focused on the relation between EF skills and academic outcomes such as GPA, grades or standardized test scores.

In contrast, research on the relationship between EF and grades in higher education contexts have more mixed results, primarily because many of these studies have focused on neurodivergent students with various labels (Southon, 2022). Southon found that the relationship between EF and academic achievement was mediated differently for students with different labels (e.g. ADHD vs. ASD). However, Ramos-Galarza et al. (2020) in a sample of college students identifying as neurotypical found that low academic performance of university students is associated with lower executive functions.

3. The Current Study

The present study is part of a larger study on the transition to college. Here we focus on the relationship between EF and student engagement and the impact of these variables on academic success. Prior and emerging work on EF and work on student engagement during the college years has highlighted the connection of both to academic success, often measured by grades. This leads us to examine whether and how EF may not only influence academic outcomes directly but also exert its effects through students' engagement with learning.

As noted above, engagement is multi-faceted and often conceptualized through behavioral, emotional, and cognitive dimensions (Fredricks et al., 2004), reflecting the extent to which students actively participate, invest emotionally, and cognitively immerse themselves in learning activities. EF skills like sustained

attention and emotional regulation have been linked to students' active participation and cognitive investment in toddlerhood (McHarg et al., 2020). And noted by Budwig et al. (2023) and Skinner et al. (2009), over developmental time, there is a dynamic and changing level of responsibility and autonomy for learning such that early on teachers and others take responsibility for learning engagement and over time individual students take on increasing responsibility. Given that effective engagement requires sustained attention, emotional regulation, and flexible adaptation—practices closely related to EF—it is plausible that EF serves as a foundational mechanism driving students' engagement in academic contexts. The study proposed three related hypotheses.

Hypothesis 1: There are developmental differences between first year college students and college seniors in EF skills, student engagement, and grades.

Hypothesis 2: Student engagement plays a mediating role in the relationship between executive function and grades.

Hypothesis 3: The specific dimensions of student engagement, such as behavioral engagement, cognitive engagement, and/or emotional engagement, play a mediating role in the relationship between executive function and grades.

It is important to consider how EF influences academic outcomes, both directly and indirectly, through factors like student engagement which as noted above, represents a multidimensional construct encompassing behavioral, emotional, and cognitive dimensions of a student's involvement in learning. This will help not only with research understanding of these complex constructs, but also provide insights into interventions to improve student success.

4. Method

The study employed a quantitative, cross-sectional survey design to examine the relationship between EF skills, student engagement and academic outcomes (grade) in First year and Senior-year college students. This design was selected in light of the study's aim of exploring associations within a defined student population at a single point in time.

4.1 Participants

Data were collected from 208 participants for this study. Participants were recruited using a non-probability convenience sampling technique through social media advertisements, e-mails and University participant pools. Convenience sampling method was chosen for its efficiency and practicality in accessing the target population. It is also a commonly used method in developmental and higher education research (Bornstein et al., 2013). Participation in the survey required some inclusion criteria, such as participants being enrolled full-time either as a first or senior year student in a college/university in the U.S. They also needed to be between the ages of 18-26 years while completing the survey.

The mean age for the sample was 19.5 years (SD = 1.49, *N=208).* 133 (64%) of total participants were First-year students and 75 (36%) were seniors. Additionally,

72.6% of the sample identified as woman, whereas 20.7%, 5.8% and 3.8% identified as man, non-binary and transgender respectively. The majority of the participants self-identified as white (70%). Additionally, 17%, 11% and 9% of the participants were Hispanic, Asian and African-American respectively. The majority of the sample consisted of domestic students (93%). 26% of the participants reported having a learning impairment and 71% reported no disability. The study protocol was approved by the University's internal review board.

4.2 Procedure

Data were collected between January 2025 and May 2025. Participants completed an online survey administered via Qualtrics, a digital data collection tool that was used to create this survey using standardized questionnaires. The survey took approximately 20-25 minutes to complete and was anonymous and voluntary. In the beginning of the survey, participants were informed about the study's purpose, assured of anonymity, and asked to provide consent. After reading and electronically signing the consent form, participants were directed to complete two standardized questionnaires and a demographic survey. Each question was followed by multiple response choices and participants could select one or more option(s) for different questions. The survey was fully accessible to any eligible participant through an electronic device (a smartphone, tablet, computer) following a weblink or a QR code. Digital responses were stored securely for analysis.

4.3 Measures

Student engagement was measured using the University Student Engagement Inventory (USEI; Marôco et al., 2016). The USEI conceptualizes engagement as a multidimensional construct, comprising three domains: cognitive, behavioral, and emotional. The inventory consists of 15 items, rated on a 5-point Likert-type scale (1 = Never to 5 = Always). In the present sample, internal consistency was good for the total scale (α = .852), as well as for the subscales: behavioral engagement (α = .617), emotional engagement (α = .812), and cognitive engagement (α = .751). This inventory has been transculturally validated across four continents (Assunção et al., 2020) and the English version was used in this survey (Appendix 1).

Executive Function was measured using the Executive Function Scale for University students (UEF-1; Ramos-Galarza et al., 2023) (Appendix 2). It was an established self-report instrument with 31-items across seven domains specifically meant for use in higher education academic settings. This context-specific measure was chosen for its relevance to the goals of this study. It was a 5-point Likert type scale with responses ranging from strongly disagree to strongly agree for each item. The UEF-1 scale has been originally validated and normed prior to use in this study. The scale has demonstrated robust psychometric properties in its original validation study with a high Internal consistency, where Cronbach's α ranged from .71 to .85 across its seven domains and inter factor correlations ranged from medium to large magnitudes *(r=.41 to .70)*.

The seven different domains of EF skills namely, Conscious regulation of behavior, Conscious monitoring of responsibilities, Verification of fulfilment of behavior, Deliberate regulation of emotions, Decision making, Supervisory attentional system, and Management of elements to solve tasks had Cronbach's α of 0.76, 0.80, 0.71, 0.82, 0.71, 0.85 and 0.76 respectively (Ramos-Galarza et al., 2023). In the present study, we administered the items without modification, and the scale demonstrated an excellent internal consistency in this sample, with Cronbach's alpha coefficient being .920 (α = .920).

In addition, fifteen demographic questions were included that asked about participants' age, class year, types of courses they have taken, grades, type of school they are attending, expected highest level of education, highest level of education completed by parents, gender identity, ethnic identity, sexual orientation, disability status and international student status. Further information about the demographic survey can be found in Appendix 3. Survey responders completed the UEF-1 survey followed by the USEI survey and finally the demographic survey.

4.4 Analysis Plan

To explore developmental differences, we compared first year and senior students on executive function, engagement dimensions, and grades using independent-sample t-tests to assess whether there were any class level differences. Descriptive statistics including means and standard deviations were calculated for key variables. Pearson correlation analyses were conducted to test the linear relationships among executive function, student engagement dimensions, and academic performance (grades). The Statistical Package for Social Sciences (SPSS 29.0) was used for all statistical analyses.

To test the mediating role of engagement, two models were tested using Hayes' (2022) PROCESS macro model 4 with 5,000 bootstrap samples and 95% confidence intervals: (1) a simple mediation model tested whether overall student engagement mediated the relationship between executive function and grades; (2) a parallel mediation model that executive function was hypothesized to have an impact on grades through the mediators of behavioral engagement, emotional engagement and cognitive engagement. The PROCESS macro model 4 was selected because it provides a robust method to estimate simple and parallel mediation models. Using 5,000 bootstrap samples and reporting 95% confidence intervals increases the reliability and validity of the estimated mediation effects, as recommended by Hayes (2022). All statistical tests were two-tailed, and significance level was determined at $p < .05$.

5. Results

5.1 No Significant Differences in Executive Function, Student Engagement, or Grades Between First Year and Senior Students

Independent-sample t-tests were conducted to compare first year and senior students on executive function, student engagement, and grades (see Table 2). There was no significant difference found for executive function ($t(204) = -.73$, $p = .469$), overall student engagement ($t(204) = -.38$, $p = .702$), behavioral engagement ($t(204) = -.173$, $p = .863$), emotional engagement ($t(193) = 1.092$, $p = .276$), cognitive

engagement ($t(204) = -.02$, $p = .983$) or grades ($t(204) = .13$, $p = .898$). The findings suggested that executive function, student engagement and academic performance did not differ significantly with academic progression. Hypothesis 1 was not supported.

Table 2: Means and standard deviations for first year and senior students on study variables

Variable	First year students	Senior students
Executive function	3.89 (0.52)	3.94 (0.56)
Student engagement	3.73 (0.55)	3.70 (0.45)
Behavioral engagement	4.12 (0.54)	4.13 (0.49)
Emotional engagement	3.40 (0.77)	3.30 (0.56)
Cognitive engagement	3.66 (0.69)	3.66 (0.65)
Grades	6.92 (1.27)	6.89 (1.15)

5.2 Significant Positive Correlations Between Executive Function, Student Engagement and Grades

Table 3 presents the correlations among the study variables. Pearson's correlation analysis showed that there was a significant positive correlation between executive function with overall student engagement ($r = .49$, $p < .001$), behavioral engagement ($r = .57$, $p < .001$), emotional engagement ($r = .33$, $p < .001$), cognitive engagement ($r = .33$, $p < .001$), and with grades ($r = .25$, $p < .001$). Overall student engagement was positively associated with grades ($r = .27$, $p < .001$). Behavioral engagement ($r = .30$, $p < .001$), and emotional engagement ($r = .26$, $p < .001$), also positively correlated with grades. The significant positive correlations indicated that higher executive function was associated with greater student engagement across various types, and better academic performance. These findings provided empirical and statistical justification for the subsequent simple and parallel mediation analyses.

Table 3: Descriptive statistics and correlations of variables.

Variable	*M*	*SD*	1	2	3	4	5	6
1. Executive function	3.90	0.53	1					
2. Student engagement	3.71	0.51	0.492**	1				
3. Behavioral engagement	4.12	0.52	0.570**	0.748**	1			
4. Emotional engagement	3.36	0.70	0.333**	0.831**	0.443**	1		
5. Cognitive engagement	3.66	0.68	0.332**	0.832**	0.467**	0.509**	1	
6. Grades	6.91	1.22	0.253**	0.274**	0.299**	0.255**	0.129	1

Note. $^{**}p < .001$

5.3 Student Engagement as a Mediator Between Executive Function and Grades

We tested whether overall student engagement mediated the relationship between executive function and grades. All analyses used 5,000 bootstrap samples with 95 percent confidence intervals. A simple mediation analysis showed that executive function significantly predicted overall student engagement, $b = 0.47$, $t = 8.10$, $p < .001$, 95% CI [0.36, 0.59]. Overall student engagement significantly predicted grades, $b = 0.47$, $t = 2.59$, $p < .05$, 95% CI [0.11, 0.83]. The total effect of executive function on grades was also significant, $b = 0.58$, $t = 3.76$, $p < .001$, 95% CI [0.27, 0.88]. The direct effect of executive function on grades remained

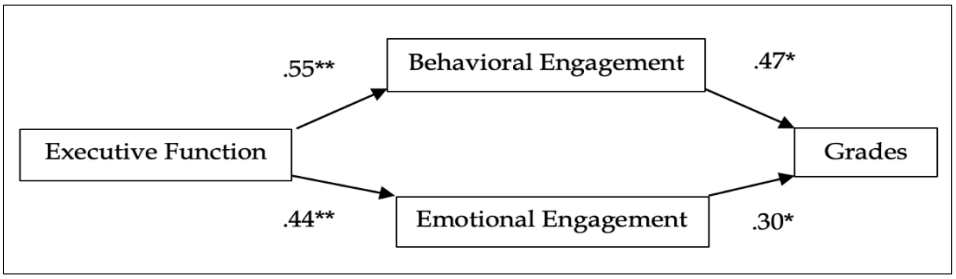
significant after accounting for overall student engagement, b = 0.36, t = 2.04, p < .05, 95% CI [0.01, 0.70]. The indirect effect via overall student engagement was significant, b = 0.22, BootSE = 0.09, 95% CI [0.06, 0.40]. These statistics showed that overall student engagement mediated the relationship between executive function and grades, supporting hypothesis 2.

A parallel mediation model was conducted to further test the hypothesized mediating role of behavioral engagement, emotional engagement, and cognitive engagement, in the relationship between executive function and grades. All analyses used 5,000 bootstrap samples with 95 percent confidence intervals. Significant path coefficients are displayed in Figure 1. The total effect of executive function on grades was significant, R = .25, R^2 = .06, F (1, 206) = 14.10, p < .001. The regression coefficient for executive function was b = 0.58, t = 3.76, p < .001, 95% CI [0.27, 0.88], supporting hypothesis 3. When including the mediators (behavioral engagement, emotional engagement, cognitive engagement), the direct effect of executive function on grades became nonsignificant.

Executive function significantly predicted behavioral engagement, R = .57, R^2 = .32, F (1, 206) = 99.01, p < .001. The regression coefficient for executive function was b = 0.55, t = 9.95, p < .001, 95% CI [0.44, 0.66]. Executive function significantly predicted emotional engagement, R = .33, R^2 = .11, F (1, 206) = 25.66, p < .001. The regression coefficient for executive function was b = 0.44, t = 5.07, p < .001, 95% CI [0.27, 0.61]. Executive function significantly predicted cognitive engagement, R = .33, R^2 = .11, F (1, 206) = 25.57, p < .001. The regression coefficient for executive function was b = 0.42, t = 5.06, p < .001, 95% CI [0.26, 0.59].

The overall model using executive function, behavioral engagement, emotional engagement and cognitive engagement to predict grades was significant, R = .35, R^2 = .12, F (4, 203) = 6.98, p < .001. The regression coefficient for behavioral engagement was b = 0.47, t = 2.29, p < .05, 95% CI [0.06, 0.87]. The regression coefficient for emotional engagement was b = 0.30, t = 2.21, p < .05, 95% CI [0.03, 0.58]. The regression coefficient for cognitive engagement was b = -0.16, t = -1.13, p > .05, 95% CI [-0.45, 0.12].

The total indirect effect of executive function on grades was significant, b = 0.32, 95% CI [0.09, 0.56]. As shown in Figure 1, behavioral engagement was a positive mediator in the relationship between executive function and grades; emotional engagement was a positive mediator in the relationship between executive function and grades. Cognitive engagement did not play a mediating role of the association between executive function and grades. Taken together, hypothesis 3 was supported for behavioral and emotional engagement, but not cognitive engagement. The findings suggested that students with stronger executive function skills may achieve better grades by participating in academic tasks and emotionally investing in their learning.



Note. *p < .05, **p < .001

Figure 1: Parallel mediating effects of behavioural engagement and emotional engagement between executive function and grades

6. Discussion

The findings from this study highlight the complex relationship between executive function, student engagement, and academic success during the college years. They extend beyond prior literature that connected each of the variables with one another, showing how the student engagement and executive function combine to impact student success. Hypothesis 1 surprisingly found no support for group differences between first year and senior college students in executive function, overall student engagement, behavioral, emotional, cognitive engagement, and for that reason class years were combined.

Subsequent analysis using the simple mediational model shows that overall student engagement mediated the relationship between executive function and grades, supporting hypothesis 2. With regard to hypothesis 3, the parallel mediational analysis revealed that behavioral and emotional engagement were positive mediators in the relationship between executive function and grades. However, there was no support for cognitive engagement as a mediation role.

We expected developmental differences between student engagement, executive function, and grades across the college years. The number of first years and senior college students varied and this may have impacted our results. Furthermore, our sampling technique used word of mouth and tapped a wide population at individual schools often co-varying class year. It could be that a more controlled sampling technique that assured better comparison between the first years and seniors sampled would find developmental differences.

The mediating role of behavioral and emotional engagement reveals a more nuanced understanding of the mechanism through which executive functioning influences grades. This result is consistent with previous literature indicating that executive function skills like working memory, cognitive flexibility and inhibitory control are crucial for younger students' academic success (Zelazo & Carlson, 2020). For instance, doing homework on time, an example of behavioral engagement, requires the metacognitive abilities that executive function skills provide.

Similarly, students with greater inhibitory control might find it easier to resist distractions and stay focused in classes or while doing homework. And feeling the excitement for school and school work, two examples of emotional

engagement, also seem to depend on strong executive functioning skills. College requires students to be much more autonomous in their learning. In high school, teachers often scaffold progress towards academic goals. Neither improving executive function nor student engagement alone seem to work without the other.

While behavioral and emotional engagement mediated the linkage between executive function and grades, we noted it was surprising that cognitive engagement did not. Cognitive engagement depends on processing, critical thinking, and deep understanding of course material and executive functioning provides such skills to enhance these cognitive abilities. However other research examining the relationship between student engagement and grades among second language learners of English in China also found behavioral and emotional engagement to be stronger predictors than cognitive engagement (Liu et al, 2023).

One possibility worth further examination is whether students may overrate their use of both cognitive engagement and executive function skills. On this account, methods other than self-report may provide a different picture of the relation between executive function and student engagement. And one possibility may be that the finding is an artefact of self-report methods. More specifics are needed to understand why these differences between cognitive and other dimensions of student engagement exist.

There are several limitations of the study, including the broad sampling across the types of demographic categories including school types and student characteristics. While grades are regularly used as a proxy for academic success and are used regularly in research on student engagement, as Kuh points out, grades measure over the life of a university experience, while engagement typically is measured in terms of only recent experiences (Kuh, 2009). And as already mentioned, the use of student reports limits validity, including for the use of grades. This work paves the way for further research using other methods to understand these nuanced relationships between previously unconnected influences on academic achievement.

7. Conclusion

The findings contribute to a more holistic understanding of the nuanced relationships during the college years of executive function, student engagement, and academic success as measured by grades. By carefully describing the direct and indirect effects, these findings enhance our understanding of two previously unconnected aspects of academic achievement in the college years, namely the connection between executive function and student engagement. Furthermore, the mediational analyses, and in particular the parallel mediational analyses, highlight the nuanced and complex relationships that impact student outcomes. Therefore, this connection warrants further research.

In addition, the findings have important implications for higher education and interventions. Both executive function and student engagement are critical to student success, and this study has highlighted their nuanced relationship. Much attention has been given to providing more engaged learning experiences for

students, but this study highlights further attention to the connection between student engagement and executive function skills can help lead to better student outcomes. In addition, the study highlights that students develop within the context of ongoing activities, and therefore intervention programs must pay greater attention to the sociocultural demands of engaged learning settings and how they may differ for students coming from distinct cultural practices involved in engaged learning. Thus, the findings provide important insights for supporting students as they transition to and progress through college to help them improve learning outcomes and graduate.

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Appendix 1

Executive functions scale for university settings: UEF-1 (Ramos-Galarza et al., 2020)

1	**2**	**3**	**4**	**5**
Totally disagree	**Moderately disagree**	**Don't agree or disagree**	**Moderately agree**	**Totally agree**

	Item in English	Executive function	Score				
1	It is easy to collect and leave my things organized when asked to do so.	Management of elements to solve tasks	1	2	3	4	5
2	I can finish a university assignment when it is very long.	Conscious monitoring of responsibilities	1	2	3	4	5
3	I always act thinking and reflecting on the consequences of my actions.	Conscious regulation of behavior	1	2	3	4	5
4	I properly regulate my emotions.	Deliberate regulation of emotions	1	2	3	4	5
5	I can make decisions independently.	Decision making	1	2	3	4	5
6	I have my things in the right place and organized.	Management of elements to solve tasks	1	2	3	4	5
7	I have an easy time finding my materials by looking for them in my room or desk.	Management of elements to solve tasks	1	2	3	4	5
8	I can complete college assignments independently and without help from others.	Conscious monitoring of responsibilities	1	2	3	4	5
9	I successfully complete my university assignments.	Conscious monitoring of responsibilities	1	2	3	4	5
10	I can concentrate well.	Supervisory attentional system	1	2	3	4	5
11	I can be still and calm while I wait.	Conscious regulation of behavior	1	2	3	4	5
12	I can solve problems at university as well as in my personal life.	Decision making	1	2	3	4	5
13	I focus on my university activities, leaving irrelevant things aside.	Supervisory attentional system	1	2	3	4	5
14	I can maintain my attention on an activity.	Supervisory attentional system	1	2	3	4	5
15	I can do my assignments without someone supervising me.	Conscious monitoring of responsibilities	1	2	3	4	5
16	It is easy for me to behave appropriately in social gatherings.	Conscious regulation of behavior	1	2	3	4	5

17	When someone asks me to, I can easily stop doing something that distracts me.	Conscious regulation of behavior	1	2	3	4	5
18	I let others speak, without interrupting.	Conscious regulation of behavior	1	2	3	4	5
19	I can anticipate the consequences of my actions.	Conscious regulation of behavior	1	2	3	4	5
20	I verify that my university assignments are well done and without errors, before giving them to the professor.	Verification of the fulfillment of objectives	1	2	3	4	5
21	I can make decisions without difficulty, even in the most complicated things.	Decision making	1	2	3	4	5
22	It is easy for me to concentrate on my college activities.	Supervisory attentional system	1	2	3	4	5
23	I check the spelling and wording of my college assignments before I finish them.	Verification of the fulfillment of objectives	1	2	3	4	5
24	I remember to take home assignments, materials, or college papers.	Verification of the fulfillment of objectives	1	2	3	4	5
25	I can keep calm easily.	Deliberate regulation of emotions	1	2	3	4	5
26	I pick up my mess without others having to do it for me.	Management of elements to solve tasks	1	2	3	4	5
27	I finish my college assignments on time.	Conscious monitoring of responsibilities	1	2	3	4	5
28	I maintain good study habits.	Supervisory attentional system	1	2	3	4	5
29	My moods are stable.	Deliberate regulation of emotions	1	2	3	4	5
30	At the end of a university activity, I verify that I have achieved what I planned.	Verification of the fulfillment of objectives	1	2	3	4	5
31	I can regulate my emotions.	Deliberate regulation of emotions	1	2	3	4	5

Appendix 2

University Student Engagement Inventory: USEI (Marôco et al., 2016).
Instructions: Using the response scale, indicate how often the following statements apply to you:

1. I pay attention in class.				
Never	A few times	Sometimes	Most of the time	Always
2. I follow the school's rules.				
Never	A few times	Sometimes	Most of the time	Always
3. I usually do my homework on time.				
Never	A few times	Sometimes	Most of the time	Always
4. When I have doubts I ask questions and participate debates in the classroom.				
Never	A few times	Sometimes	Most of the time	Always
5. I usually participate actively in group assignments.				
Never	A few times	Sometimes	Most of the time	Always
6. I don't feel very accomplished at this school.				
Never	A few times	Sometimes	Most of the time	Always
7. I feel excited about the school work.				
Never	A few times	Sometimes	Most of the time	Always
8. I like being at school.				
Never	A few times	Sometimes	Most of the time	Always
9. I am interested in the school work.				
Never	A few times	Sometimes	Most of the time	Always
10. My classroom is an interesting place to be.				
Never	A few times	Sometimes	Most of the time	Always
11. When I read a book, I question myself to make sure I understand the subject I'm reading about.				
Never	A few times	Sometimes	Most of the time	Always

12. I talk to people outside the school on matters that I learned in class.				
Never	A few times	Sometimes	Most of the time	Always
13. If I do not understand the meaning of a word, I try to solve the problem, for example by consulting a dictionary or asking someone else.				
Never	A few times	Sometimes	Most of the time	Always
14. I try to integrate the acquired knowledge in solving new problems.				
Never	A few times	Sometimes	Most of the time	Always
15. I try to integrate subjects from different disciplines into my general knowledge.				
Never	A few times	Sometimes	Most of the time	Always

Appendix 3

Demographic questions (drawn from the NSSE survey, Kuh, 2009)

1. Age

_____

2. What is your class level?

First-year, Semester 1
First-year, Semester 2
Senior year, Semester 1
Senior year, Semester 2

3. What types of courses have you taken at this institution this current school year?

Mostly in-person courses
Mostly remote courses (online, web-based, Zoom, etc.)
Mostly hybrid or blended courses that combine in-person and remote instruction
A balanced mix of the above course types

4. What have most of your grades been up to now at this institution?

A
A-
B+
B
B-
C+
C
C- or lower

5. Did you begin college at this institution or elsewhere?

Started here
Started elsewhere

6. Since graduating from high school, which of the following types of schools have you attended other than the one you are now attending? (Select all that apply.)

Vocational or technical school
Community or junior college
4-year college or university other than this one
None
Other _____

7. What is the highest level of education you ever expect to complete?

Some college but less than a bachelor's degree
Bachelor's degree (B.A., B.S., etc.)
Master's degree (M.A., M.S., etc.)
Doctoral or professional degree (Ph.D., J.D., M.D., etc.)

8. What is the highest level of education completed by your parent(s), guardian(s), or those who raised you?

Did not finish high school
High school diploma or G.E.D.
Attended college but did not complete degree
Associate's degree (A.A., A.S., etc.)
Bachelor's degree (B.A., B.S., etc.)

Master's degree (M.A., M.S., etc.)
Doctoral or professional degree (Ph.D., J.D., M.D., etc.)
I prefer not to respond

9. How would you describe your gender identity? (Select all that apply.)

Woman
Man
Trans/Transgender
Agender or gender neutral
Demigender
Genderqueer, non-binary, gender non-conforming, or genderfluid
Two-spirit
Cis/Cisgender
Questioning or unsure
Another gender identity, please specify:
_____
I prefer not to respond

10. How would you describe your sexual orientation? (Select all that apply.)

Straight or heterosexual
Bisexual
Lesbian
Gay
Queer
Pansexual or polysexual
Ace, gray, or asexual
Demisexual
Questioning or unsure
Another sexual orientation, please specify:
_____
I prefer not to respond

11. How would you describe yourself? (Select all that apply.)

Asian
Black or African American
Hispanic, Latina/o, Latine, or Latinx
Indigenous, American Indian, Native American, or Alaska Native
Middle Eastern or North African
Native Hawaiian or Pacific Islander
White
Another race or ethnicity
I prefer not to respond

12. Are you an international student?

Yes
No

13. Do you have a disability or condition that impacts your learning, working, or living activities?

Yes
No
I prefer not to respond

14. Which of the following impacts your learning, working, or living activities? (Select all that apply.)

Blind or low vision/ Deaf or hard of hearing
Mobility condition that affects walking
Mobility condition that does not affect walking
Speech or communication disorder
Traumatic or acquired brain injury (TBI)
Anxiety
Attention deficit or hyperactivity disorder (ADD or ADHD)
Autism spectrum
Depression
Post-Traumatic Stress Disorder (PTSD)
Another mental health or developmental disability (schizophrenia, eating disorder, etc.)
Chronic medical condition (asthma, diabetes, Crohn's disease, etc.)
Learning disability
Intellectual disability
Disability or condition not listed

15. Are you a student-athlete on a team sponsored by your institution's athletics department?

Yes
No