Predictors of Success and Retention: The Influence of Belonging and Self-Efficacy on First-Year Engineering Students

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This complete research paper examines the direct and indirect effects of self-efficacy and sense of belonging on first-year engineering students' academic performance (GPA) and their retention at the end of the first year. Using path analysis, we explore how these factors influence students' persistence in their study programs and the mediating role of GPA in this relationship. Strong belief in one's abilities (self-efficacy) and feeling part of the academic community (sense of belonging) are crucial for students pursuing STEM careers. These factors influence persistence, motivation, and identity development, particularly in engineering students, helping them overcome academic challenges and lack of technical experience. High self-efficacy fosters resilience, goal setting, and better academic outcomes, while low levels can lead to demotivation, feelings of inadequacy, and increased dropout risk, especially during the first year. Analyzing students' GPA is vital for understanding first-year retention, as it serves as an early indicator of academic performance and identifies students at risk. However, GPA alone is insufficient to capture the complexity behind academic success. Complementing GPA with measures of belonging and self-efficacy provides a deeper understanding and informs more effective support strategies. High self-efficacy and belonging are associated with better GPA outcomes, while low levels correlate with academic struggles and attrition. This study employs a quantitative approach using path analysis to evaluate the relationships between sense of belonging, self-efficacy, GPA, and retention at the end of the first year. The sample consists of 311 first-year engineering students from a prominent university in Chile. We collect data from a validated survey that measures sense of belonging and self-efficacy, and we obtain GPA from academic records. Retention at the end of the first year is assessed as a dichotomous variable (retained vs. not retained). Additionally, gender is included as a control variable to analyze its effect on sense of belonging, self-efficacy, and GPA. Results show that self-efficacy positively influences GPA both directly and indirectly through sense of belonging. While a general sense of belonging supports GPA, certain interaction-based dynamics negatively impact academic outcomes. The model explains 39% of the variance in GPA, emphasizing the importance of balancing individual and social factors. By identifying the role that sense of belonging and self-efficacy play in first-year students' academic performance and persistence, this research can help universities by aiding retention by developing targeted interventions that foster a more inclusive and supportive academic environment. Such interventions could significantly reduce dropout rates, enhance student engagement, and ultimately contribute to cultivating a more resilient and skilled engineering workforce, essential for meeting the demands of the rapidly evolving technological landscape.

Keywords: Academic Performance, Engineering Education, Path Analysis, Sense of Belonging, Self-Efficacy

Introduction

Academic performance is a critical indicator for analyzing the various factors associated with student success during their university journey. It is a complex concept, intrinsically linked to students' learning outcomes. Numerous studies have explored the relationship between academic performance and student retention or dropout rates, emphasizing the significance of this connection within the educational domain [1-3]. In higher education, STEM programs exhibit higher dropout rates compared to other fields. It is well-documented that a student's

first year is pivotal in determining whether they persist in their STEM program and successfully graduate or decide to leave [4-5].
First-year students undergo an adaptation process to a new academic environment, where they encounter greater responsibilities and significantly increased academic demands [6-7]. This transitional phase presents challenges that extend beyond academics to encompass personal and social dimensions. These challenges include managing time effectively, developing independent study habits, integrating into a new university community, and adapting to an environment that expects a high degree of autonomy. Additionally, students often experience academic stress and pressure, which can significantly influence their sense of belonging and self-efficacy, two critical factors for persistence and success in higher education.
The first-year dropout rate represents a significant challenge for academic institutions, particularly within STEM disciplines, as it is the most critical period for student retention in these fields [7-8]. Among the factors influencing retention, the sense of belonging plays a crucial role in a student's decision to persist or leave their program [9]. Thus, it is imperative to examine the challenges faced by first-year students to develop interventions that enhance understanding and foster persistence in engineering education.
This study aims to examine the relationship between sense of belonging, self-efficacy, and first-year engineering students' academic performance (GPA) and their impact on retention at the end of the first year. Specifically, it seeks to determine whether sense of belonging and self-efficacy is directly correlated with GPA and whether GPA serves as a mediating factor in the relationship between these constructs and student retention in their academic programs.

Literature Review

The persistence and academic success of first-year engineering students are influenced by various interrelated factors, such as sense of belonging, self-efficacy, and academic performance (GPA). These variables have been extensively studied in the literature due to their significant impact on students' adaptation, performance, and retention in STEM fields, which are often characterized by high dropout rates. This section examines recent studies that explore the relationship between sense of belonging, self-efficacy, and GPA, as well as the role of GPA as a mediator in academic retention.

Sense of belonging is defined as the subjective perception of being valued, accepted, and included as a legitimate group or community member [9]. This construct is critical to academic success, particularly in STEM disciplines, where social integration and environmental support are key determinants. Studies by Cwik and Singh [10] and Whitcomb, Maries, and Singh [11] highlight that students who perceive active inclusion in their academic environment are more likely to persist and succeed. This is especially pertinent during the first year, when students transition into a challenging educational environment. In alignment with these findings, Li and Singh [12] identified sense of belonging as a significant predictor of academic performance in physics courses. They suggest that creating intentional environments where faculty acknowledge and value students can directly enhance their sense of belonging and, consequently, their academic outcomes.

Similarly, self-efficacy, defined as the belief in one's ability to successfully perform a task or achieve a goal [13-14], has also been shown to be a crucial determinant of persistence and success in STEM. Whitcomb et al. [15] observed that students with high levels of self-efficacy are better equipped to tackle academic challenges and persist in their studies. Moreover, self-efficacy is a robust predictor of academic performance, particularly in STEM

fields known for their rigorous demands. One of the most relevant metrics for measuring academic performance is Grade Point Average (GPA). However, GPA is an indicator of academic achievement and a key mediator between sense of belonging, self-efficacy, and student retention in STEM [7, 16]. A high GPA can serve as tangible confirmation of students' abilities, reinforcing both their sense of belonging and self-efficacy. This feedback loop fosters greater commitment to their field of study and reduces the risk of dropout.

Whitcomb et al. [11] described how these factors interact to create a positive cycle: a strong sense of belonging and high self-efficacy increases the likelihood of achieving a high GPA, reinforcing students' confidence in their ability to overcome academic challenges. This cumulative effect enhances retention rates and academic success. Over the past five years, several studies have explored how sense of belonging influences academic performance. Sotardi [14] noted that a strong perception of institutional belonging improves academic outcomes by increasing social self-efficacy and the use of metacognitive strategies. Similarly, Edwards et al. [17] reported positive effects in general chemistry and calculus-based physics courses, demonstrating that a high sense of belonging boosts performance in both traditional assessments (e.g., final exams) and non-traditional ones (e.g., final projects), with an estimated improvement of 2–3% for every standard deviation increase in sense of belonging. These findings underscore the importance of inclusive interventions that foster equitable and supportive learning environments.

However, potential negative effects of a strong sense of belonging have also been identified. Ramadhani et al. [18] cautioned that group dynamics can strengthen social connections and create pressure to conform to group norms, potentially diverting focus from academic goals. Krause-Levy et al. [19] noted that a high sense of belonging in computer science courses might lose relevance or hinder academic performance as students' progress, particularly if it encourages excessive social dependency or diminishes academic autonomy. Academic performance is influenced by not only sense of belonging but also other factors, such as prior academic preparation [12], classroom climate, gender stereotypes, and social support from family and friends [20].

The literature suggests that sense of belonging and self-efficacy are key factors influencing academic performance and retention in engineering. However, their impact is highly context-dependent and shaped by how social dynamics are managed in educational settings. GPA is a critical mediator, reinforcing students' confidence and academic commitment. These interactions highlight the importance of designing pedagogical strategies that balance social inclusion with the development of academic autonomy to maximize benefits while mitigating potential negative effects. This framework provides a strong foundation for exploring how these factors can improve retention and success among first-year engineering students.

Methodology

This study employs a quantitative cross-sectional survey design. This section outlines the research design, data collection instrument, sample selection, and statistical methods for data analysis. The following section will discuss the results. The sample included 311 undergraduate engineering students from a private university in Chile, enrolled in the first year, selected non-probabilistically across nine STEM programs. The students' ages had a mean of 19.64 and a standard deviation of 1.95, with a gender distribution of 81.4% men and 18.6% women.

This study administered a validated survey to assess self-efficacy, general sense of belonging, and sense of belonging in interactions. The survey consisted of 24 Likert-type items, where respondents indicated their level of agreement on a 5-point scale (1: strongly disagree to 5: strongly agree). Additionally, the survey included a section to collect sociodemographic information. The instrument was proposed by [21], and the reliability of the scales was evaluated using McDonald's Omega and Cronbach's Alpha, yielding acceptable indices as shown in Table 1.

Table 1. Reliability and Information of the Scales.

Scale	**Coefficient**		**N° items**
	ω	α	
Self-efficacy	0.919	0.919	8
Sense of belonging - general	0.896	0.894	8
Sense of belonging - interactions	0.895	0.085	8

The three dimensions—sense of belonging - interactions (SB-i), sense of belonging - general (SB-g), and self-efficacy—offer a comprehensive view of students' academic and social experiences. SB-i emphasizes the quality of social interactions, focusing on respect from professors and peers (e.g., "Professors here respect me"), comfort in academic participation (e.g., "I feel comfortable contributing to class discussions"), and the ease of forming study groups or seeking help (e.g., "It would be easy for me to join study groups with other students if I wanted to"). In contrast, SB-g captures a broader sense of connection and integration within the university, including identification with the institution (e.g., "I feel like I belong to this university") and perceiving the university as a welcoming and inclusive environment (e.g., "The students of this university are friendly to me"). Lastly, self-efficacy reflects students' confidence in their ability to overcome academic challenges, solve problems (e.g., "I can solve most problems if I put in the necessary effort"), and achieve their goals (e.g., "It is easy for me to stick to my objectives and achieve my goals"). These dimensions provide key insights into the interplay between personal confidence, social dynamics, and institutional belonging in shaping academic success.

Disclaimer on gender classification. We acknowledge that gender is a social construct, and a broad spectrum of gender identities exists. While our survey included options beyond the binary, due to the limitations inherent in our non-probabilistic sample and the population's demographic distribution, our study only includes binary gender classifications (male and female). This limitation is noted for transparency, and future research should aim to incorporate more diverse gender representations.

Data analysis and ethical considerations. Faculty members distributed the questionnaire and allocated class time for students to complete it. The process began with informed consent, assurances of confidentiality, and contact information for the research group. The questionnaire was created and administered using Google Forms, and the data collected was anonymized and securely backed up. The results of the validated instrument were analyzed using JASP version 0.19.0. The analysis involved assessing normality, calculating descriptive statistics and correlations, and conducting a path analysis to test the underlying hypotheses. A mediation model analysis was performed to estimate direct and indirect effects. The Maximum Likelihood (ML) estimator with robust standard errors was utilized, and 95% confidence intervals were calculated. Finally, the model's explanatory power was assessed using the coefficient of determination (R^2).

Results

The main objective of this study is to analyze both the direct and indirect effects among the constructs of self-efficacy, sense of belonging, and two measures of academic success: GPA and the number of enrolled courses. Our approach begins with presenting descriptive statistics and normality results, followed by an analysis of correlations and path analysis, with gender as a controlled variable. Table 2 shows the description of the variables to understand the results better.

Table 2. Data dictionary of key study variables.

Variable	Definition	Description
GPA	Grade Point Average: an indicator of academic performance.	The scale standard for Chilean institutions is 1-7.
Enrolled Courses	The number of courses a student is enrolled in during the academic period.	Commonly, students take a maximum of 6 courses per semester.
Self-Efficacy	The student's belief in their ability to overcome academic challenges and achieve goals.	Likert-type items on a 5-point scale (1 = Strongly Disagree, 5 = Strongly Agree).
Sense of Belonging – General (SB-g)	A broad measure of the student's overall connection and identification with the university.	Likert-type items on a 5-point scale (1 = Strongly Disagree, 5 = Strongly Agree).
Sense of Belonging – Interactions (SB-i)	The perceived quality of social interactions within the academic environment, including relationships with peers and faculty.	Likert-type items on a 5-point scale (1 = Strongly Disagree, 5 = Strongly Agree).
Retention	Indicates students who continue their studies from the first to the second year of the program.	Dichotomous variable with categories such as "Retained" vs. "Not Retained."
Gender	The self-identified gender of the student.	Gender is treated as a binary variable (Male, Female).
Age	The age of the student in years.	A continuous variable.

Table 3 shows the descriptive data for the four scales assessed. These data reveal that the standard deviations for all the variables measured were relatively low, suggesting consistent responses and moderate variability among participants. The variable with the lowest dispersion is self-efficacy (SD=0.78), unlike enrolled courses with the highest dispersion (SD=1.73). The skewness and kurtosis values confirm that the distributions of the variables are within an acceptable range, thereby allowing for the use of normality assumptions in the analyses.

Table 3. Description Data of the Scales.

Scale	Mean	Std. Deviation	Kurtosis	Skewness
Self-efficacy	4.00	0.78	-1.76	4.21
Sense of belonging - general	3.85	0.88	-1.18	1.54
Sense of belonging - interactions	3.86	0.83	-1.29	2.13
Enrolled Courses 2024	3.75	1.73	-1.12	0.46
GPA	5.14	0.89	-1.02	1.58

A correlation analysis examined the relationship between the variables of interest. The results indicate statistically significant correlations among the analyzed variables (Table 4).

Specifically, self-efficacy significantly correlates with sense of belonging – general ($r = 0.842$, $p < 0.001$) and sense of belonging – interactions ($r = 0.849$, $p < 0.001$). Similarly, enrolled courses show significant correlations with self-efficacy ($r = 0.181$, $p < 0.001$), sense of belonging - general ($r = 0.172$, $p = 0.002$), and sense of belonging - interactions ($r = 0.123$, $p = 0.03$). Finally, GPA is significantly associated with enrolled courses ($r = 0.364$, $p < 0.001$), self-efficacy ($r = 0.159$, $p = 0.005$), and sense of belonging - general ($r = 0.112$, $p = 0.049$).

Table 4. Correlation analysis results showing the relationships among self-efficacy, sense of belonging (general and interactions), GPA, and enrolled courses, with statistical significance levels indicated.

		GPA	Enrolled Courses 2024	Self-Efficacy	SB General	SB Interactions
GPA	CC	--				
	Sig. (2-sided)					
	N	311				
Enrolled Courses 2024	CC	.364**	--			
	Sig. (2-sided)	<.001				
	N	311	311			
Self-Efficacy	CC	.159**	.181**	--		
	Sig. (2-sided)	0.005	0.001			
	N	311	311	311		
SB General	CC	.112*	.175**	.842**	--	
	Sig. (2-sided)	0.049	0.002	<.001		
	N	311	311	311	311	
SB Interactions	CC	0.071	.123*	.849**	.859**	--
	Sig. (2-sided)	0.212	0.03	<.001	<.001	
	N	311	311	311	311	311

****The correlation is significant at the 0.01 level (two-sided). *The correlation is significant at the 0.05 level (two-sided).**

Except for the relationship between sense of belonging—interactions and GPA, all other correlations were found to be statistically significant. This indicates that the observed relationships between the variables are unlikely to be due to chance and can be interpreted as consistent patterns within the studied group. The obtained correlations strongly support the proposed path analysis and the hypothesized relationships. The significant correlations between self-efficacy, sense of belonging, GPA, and enrolled courses indicate that these variables are closely related, justifying their inclusion in the model.

The path analysis examines the effects of self-efficacy (SEff) and sense of belonging interactions (SB-i) on GPA, using standardized coefficients controlled by gender and age (Figure 1). The model includes direct and indirect effects, with self-efficacy influencing GPA directly and through SB-i. The analysis also explains 39% of the variance in GPA ($R^2 = 0.39$), providing insights into the relationships between self-efficacy, social belonging, and academic performance.

As detailed in Figure 1, the analysis shows that self-efficacy (SEff) predicts GPA through direct and indirect pathways. The direct effect of self-efficacy on GPA is moderate and statistically significant ($\beta = 0.352$, $p < 0.001$, 95% CI [0.151, 0.553]), demonstrating the

importance of self-efficacy in fostering academic performance. Additionally, self-efficacy has a strong and statistically significant direct effect on SB-i (β = 0.846, p < 0.001, 95% CI [0.788, 0.905]), showing that students with higher self-efficacy tend to perceive a stronger sense of belonging. SB-i, in turn, has a significant direct effect on GPA (β = -0.215, p = 0.001, 95% CI [-0.416, -0.014]), indicating that certain social belonging interactions negatively influence academic performance (Figure 1).

Self-efficacy also significantly indirectly affects GPA through SB-i (β = -0.182, p = 0.037, 95% CI [-0.353, -0.011]). This negative indirect effect suggests that sense of belonging interactions reduce the positive influence of self-efficacy on academic performance.

Regarding the total effects, self-efficacy maintains a significant overall impact on GPA (β = 0.170, p = 0.002, 95% CI [0.063, 0.277]). These findings emphasize the multifaceted influence of self-efficacy on academic outcomes and underscore the importance of addressing both individual and social factors to fully support students' academic success.

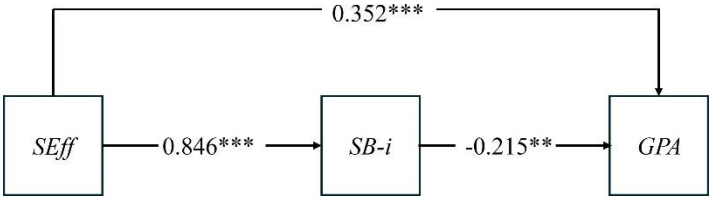

Figure 1. Path diagram illustrates the direct and indirect effects of Self-Efficacy and Sense of Belonging on GPA. Effects of self-efficacy (SEff), sense of belonging – interactions (SB-i) on GPA, with standardized coefficients controlled by gender and age, 95% confident interval, explained variance of the dependent variable (AC), and statistical significance (**p <0.01; *** p < 0.001).

Table 5. Parameter estimates.

						95% Confidence Interval	
Effect	**Variables**	**Estimate**	**Std. Error**	**z-value**	**p**	**Lower**	**Upper**
Direct	SEff → GPA	0.352	0.103	3.433	< .001	0.151	0.553
Indirect	SEff → SB-i GPA	-0.182	0.087	-2.087	0.037	-0.353	-0.011
Total	SEff → GPA	0.170	0.055	3.109	0.002	0.063	0.277

In summary, this study's findings underscore the complex interplay between self-efficacy, sense of belonging, and academic outcomes. The observed direct and indirect effects highlight the importance of fostering self-efficacy and carefully managing social belonging dynamics to optimize academic performance. While self-efficacy positively influences GPA, the mediating role of sense of belonging interactions suggests a nuanced relationship that warrants further investigation. These results provide valuable insights for developing targeted interventions to support first-year engineering students' academic success and retention.

Discussion

The results of this study illuminate the complex interactions between self-efficacy, sense of belonging, and academic performance among engineering students, highlighting both direct and indirect effects. Self-efficacy was identified as a key predictor of grade point average (GPA), showing a positive and statistically significant direct effect (β = 0.352, p < 0.001). This finding is consistent with previous research, such as that by Sotardi [14], which

emphasizes how social self-efficacy and metacognitive strategies bolstered by a sense of institutional belonging can significantly enhance academic performance. Additionally, the strong correlation between self-efficacy and the two dimensions of sense of belonging ($r = 0.84$, $p < 0.001$) indicates that students with higher self-perception are more likely to feel connected to their educational environment.

The path analysis, while controlling gender and age, enables a more straightforward interpretation of the observed dynamics. Considering the documented differences in self-efficacy and sense of belonging across these demographic factors, it was particularly important to account for gender and age. Research shows that these variables can moderate academic experiences, influencing the dynamics analyzed in this study [20]. This approach minimizes potential biases linked to these demographic variables. It is especially important when demographic differences might affect students' academic and social experiences. Within this framework, sense of belonging - interactions negatively affected GPA ($\beta = -0.215$, $p = 0.001$). This result underscores that, while social connections are generally beneficial, certain dynamics may become counterproductive, possibly due to distractions, pressure to conform to group norms, or an overreliance on interpersonal relationships, as suggested by Ramadhani et al. [18]. This negative effect was also observed in the indirect relationship, where self-efficacy showed an adverse impact on GPA mediated by sense of belonging - interactions ($\beta = -0.182$, $p = 0.037$). These findings highlight the importance of carefully managing social interactions in academic contexts to maximize their benefits without compromising performance.

In contrast, sense of belonging - general showed a low but significant positive correlation with GPA ($r = 0.112$, $p = 0.049$), suggesting that a broader sense of inclusion and institutional connection may act as a catalyst for learning and motivation. Studies such as Edwards et al. [22] have emphasized how inclusive interventions can improve sense of belonging and academic outcomes. These findings reinforce the need to foster educational environments that promote a sense of inclusion, particularly in highly demanding academic contexts.

The model analyzed explains 39% of the variance in GPA, underscoring the relevance of considering individual and social factors when studying academic performance. Including controls for gender and age strengthens the validity of the findings, demonstrating that the observed effects are not biased by these variables. This level of analytical detail is crucial for designing educational strategies that comprehensively address students' needs.

In conclusion, this study emphasizes the importance of balancing individual and social factors to promote academic success. Educational institutions should focus on strengthening self-efficacy and fostering an inclusive sense of belonging while managing social dynamics that may have adverse effects. Future research could explore how these relationships vary by gender, academic level, and discipline to develop more targeted and effective interventions. This approach will create educational environments that optimize students’ academic and social experiences, as highlighted in recent literature [17, 19].

Conclusions

This study aimed to analyze the direct and indirect effects among the constructs of self-efficacy, sense of belonging, and two key indicators of academic success: Grade Point Average (GPA) and the number of enrolled courses. To achieve this goal, the research employed a methodology that included descriptive statistics, correlation analysis, and path analysis, with controls for variables such as gender and age. This approach allowed for an in-

depth exploration of the relationships between the variables of interest and the mediating effects of sense of belonging in the relationship between self-efficacy and academic performance.

The results revealed statistically significant correlations among the analyzed variables. Self-efficacy was positively associated with both general sense of belonging and belonging based on interactions. Additionally, these variables were significantly correlated with GPA and the number of enrolled courses, highlighting the critical role of individual and social factors in academic performance.

The path analysis provided further insights into these relationships, showing that self-efficacy has a direct positive effect on GPA ($\beta = 0.352$, $p < 0.001$). Moreover, self-efficacy indirectly influences academic performance through sense of belonging based on interactions ($\beta = -0.182$, $p = 0.037$). Interestingly, social interactions associated with sense of belonging were found to have a direct negative effect on GPA ($\beta = -0.215$, $p = 0.001$). This finding suggests that certain aspects of students' social environments might adversely impact their academic performance. Overall, the model explained 39% of the variance in GPA, underscoring the importance of considering both individual and social factors in analyzing academic success.

Despite the significant findings, the study presents some limitations that warrant consideration. The sample was limited to first-year engineering students, which may restrict the generalizability of the results to other educational contexts or disciplines. Furthermore, the cross-sectional design of the study does not allow for definitive causal inferences between the analyzed variables. While negative effects associated with interaction-based sense of belonging were identified, the specific factors driving this impact were not explored in depth, leaving room for future research.

Future studies should address these limitations by employing longitudinal designs to examine how the relationships among self-efficacy, sense of belonging, and academic performance evolve. It would also be valuable to design and implement interventions that strengthen self-efficacy and optimize social interactions to maximize students' academic success. This consideration is particularly relevant given that the university currently covers the academic-theoretical aspect through an early alert system based on the grades obtained in the first assessments of first-year students. With this information, the university provides academic tutoring exclusively for students flagged by the system—those who failed their first assessment in at least one subject. Additionally, replicating this study across different disciplines and educational levels could provide broader insights and validate the generalizability of the findings. Finally, a detailed analysis of the specific components of sense of belonging could help identify the social dynamics that negatively affect academic performance and propose more effective solutions.

In conclusion, this study highlights the importance of self-efficacy and sense of belonging in academic success, providing a solid foundation for designing strategies to improve students' performance and retention in high-demand educational contexts such as engineering. The findings offer valuable insights for developing interventions addressing individual and social factors, contributing to better academic outcomes and enhancing student experience.

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