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Research article

Relationship between academic engagement and burnout syndrome in Mexican students: a PLS-SEM analysis

Irving A. Ramírez-Muñoz[1], **Vanesa Avalos-Gaytán**[1,*], **Igor Barahona**[2], **Valeria Soto-Mendoza**[1], **and Gabriela Linares Acuña**[3]

[1]Universidad Autónoma de Coahuila, Centro de Investigación en Matemáticas Aplicadas, Unidad Saltillo, Mexico.
[2]King Fahd University of Petroleum and Minerals, Department of Information Systems and Operations Management, Dhahran, Saudi Arabia.
[3]Universidad Autónoma de Coahuila, Facultad de Psicología, Unidad Saltillo, Mexico.

ABSTRACT

Academic burnout is a growing concern in higher education, characterized by emotional exhaustion, cynicism, and a reduced sense of accomplishment. In contrast, academic engagement – defined as a positive, energetic, and committed state toward learning – has been identified as a protective factor and even an antidote to burnout. While most studies in this area have focused either on theoretical model development or on validating measurement instruments, few address both simultaneously. Moreover, research using Structural Equation Modeling (SEM) has predominantly been conducted in Europe and the United States, leaving Latin American contexts underexplored. A literature review revealed only nine studies on academic burnout in Mexico, underscoring the need for further investigation in the region. This study aims to bridge that gap by validating adapted versions of the Maslach Burnout Inventory-Student Survey (MBI-SS) and the School Engagement Measure, and by developing a SEM to examine how academic engagement influences burnout levels among students at a public university in northern Mexico. The findings are expected to contribute to the understanding of student well-being in Latin America and to offer validated tools for measuring and addressing academic burnout.

Keywords: burnout syndrome, academic engagement, structural equation model

1. Introduction

Burnout syndrome has its origins in the medical field [1]. However, today it has impacted several other contexts, so much so that the World Health Organization (WHO) included it in its International Classification of Diseases (ICD-11) in 2019 [2]. Originally defined within the context of healthcare professions, burnout was characterized as a combination of chronic emotional exhaustion, fatigue, and depersonalization toward patients [3]. Academic burnout has become an increasing concern in the educational field, particularly among university students [4]. In this setting, the condition has evolved to describe a stress response marked by negative attitudes and feelings towards school and the role of the student [3].

Although students are not legally considered employees, from a psychological standpoint, their academic activities can reasonably be regarded as a form of work. The primary distinction between formal employment and academic activity lies in the absence of a direct monetary exchange. However, this difference may be at-

E-mail address: vanesaavalos@uadec.edu.mx
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tenuated by the fact that students often maintain an active relationship with educational institutions and may receive financial support such as scholarships. Additionally, students are frequently exposed to performance pressure and demanding academic environments, both of which have been linked to declines in physical and mental health [5].

In contrast, engagement has emerged as a key construct for understanding the student experience, particularly in relation to academic performance, well-being, and retention. It is defined as a positive emotional state characterized by energy, dedication, and active involvement in academic activities [6]. Unlike burnout – marked by exhaustion, cynicism, and depersonalization – engagement is considered its positive counterpart and even a potential antidote [7]. Engagement comprises emotional, cognitive, and behavioral dimensions, reflecting the student's connection to their learning environment, academic tasks, peers, and instructors [8]. This commitment is shaped by individual factors such as self-efficacy, self-esteem, and positive emotions, as well as contextual elements including the quality of the university environment, academic workload, and time devoted to extracurricular activities [7, 6].

Numerous studies have shown that academic burnout and engagement are closely related, yet often opposing, constructs within the educational context [4, 9]. While burnout is characterized by emotional exhaustion, cynicism, and a diminished sense of personal accomplishment, engagement is associated with vigor, dedication, and deep absorption in academic activities [6, 4]. However, the relationship between burnout and engagement is not strictly dichotomous; rather, it may reflect a continuum in which students can experience elements of both to varying degrees.

Building on the preceding discussion, the main objective of this study is to examine the relationship between academic engagement and academic burnout among university students in northern Mexico. To this end, Partial Least Squares Structural Equation Modeling (PLS-SEM) is used to analyze the influence of emotional, cognitive, and behavioral engagement on burnout dimensions, namely emotional exhaustion, cynicism, and reduced academic efficacy. The remainder of the paper is structured as follows: the next section presents the literature review; Section 3 describes the materials and methods; Sections 4 and 5 discuss the results and provide the conclusions, respectively.

2. Literature review

Academic burnout has become a growing concern in educational settings (see Table 1), particularly in countries like China, where its prevalence among high school students has prompted research using the Job Demands-Resources (JD-R) model. This model helps explain how academic workload, teacher relationships, and personal resources (e.g., self-efficacy, self-esteem, optimism) contribute to either the development or prevention of burnout through protective factors [10].

The most widely used instrument to assess academic burnout is the Maslach Burnout Inventory-Student Survey (MBI-SS), a student adapted version of the MBI-General Survey. It includes 15 items measuring emotional exhaustion, cynicism, and personal efficacy [11, 12].

Recent studies have explored the relationship between burnout, academic engagement, and affective traits such as attachment. High attachment-related anxiety has been shown to reduce academic engagement and increase burnout symptoms, which may influence students' decisions to persist or drop out of their studies [13]. While engagement is positively associated with academic performance and satisfaction, burnout is more strongly linked to dropout intentions.

Despite its importance, research on engagement faces methodological challenges, including overreliance on self-reported data and limited focus on outcomes. Scholars have called for more diverse methodologies, including observational approaches and culturally varied samples [8]. For example, a study with German university students found that 6.7% exhibited both high engagement and high burnout, suggesting a more complex relationship than previously assumed [7].

Cross-cultural studies in Finland [4], Spain [6], Canada [13], India, and Romania [9] consistently support a negative correlation between burnout and engagement. These findings highlight the potential of fostering academic engagement as a strategy to reduce burnout and improve student retention.

3. Materials and methods

This research utilizes the PLS-SEM technique to estimate and validate a causal model composed of latent variables. PLS-SEM focuses on maximizing the explained variance in endogenous constructs and is particularly suitable for complex models, non-normal data, and theory development contexts [20, 21].

3.1 Model specification

Let $\boldsymbol{\xi} = [\xi_1, \xi_2, \ldots, \xi_p]^\top$ denote the vector of exogenous latent variables and $\boldsymbol{\eta} = [\eta_1, \eta_2, \ldots, \eta_q]^\top$ denote the vector of endogenous latent variables. The structural model is represented as:

$$\boldsymbol{\eta} = \mathbf{B}\boldsymbol{\eta} + \boldsymbol{\Gamma}\boldsymbol{\xi} + \boldsymbol{\zeta} \tag{1}$$

where $\mathbf{B}$ is a $q \times q$ matrix of path coefficients among endogenous constructs (excluding diagonal elements), $\boldsymbol{\Gamma}$ is a $q \times p$ matrix representing the influence of exogenous constructs on endogenous constructs, and $\boldsymbol{\zeta}$ is a vector of structural disturbances.

For reflective measurement models:

$$\mathbf{x} = \boldsymbol{\Lambda}_x\boldsymbol{\xi} + \boldsymbol{\delta}, \quad \mathbf{y} = \boldsymbol{\Lambda}_y\boldsymbol{\eta} + \boldsymbol{\epsilon} \tag{2}$$

where $\mathbf{x}$ and $\mathbf{y}$ are vectors of observed indicators, $\boldsymbol{\Lambda}_x$ and $\boldsymbol{\Lambda}_y$ are loading matrices, and $\boldsymbol{\delta}$ and $\boldsymbol{\epsilon}$ are measurement errors.

Table 1. Related work comparison.

Authors	Instrument	Variables		Approach		Method	Population	Region	Sample size	Sampling technique
		Dependent	Independent	Validation	Model					
Yavus & Dogan (2014)[14]	MBI-SS	Academic burnout	Student's characteristics	X		Confirmatory factor analysis	High school students	Turkiye	1020	Not specified
Veiga et. al (2016)[15]	SES with Four-Dimensional Scale	Engagement	N/A	X		Confirmatory factor analysis	High school Students	Portugal	685	Convenience
Hederich-Martínez & Caballero-Domínguez (2016) [11]	MBI-SS	Academic burnout	N/A	X	X	Factor analysis	Students	Colombia	820	Not specified
Grilo et. al. (2019) [5]	Precursors of burnout	Academic burnout	Behavioral stress		X	PLS-SEM	Student volunteers	Arizona, USA	374	Convenience
Virga et al. (2020) [9]	PysCap, UWES-S MBI-SS, UBOS	Engagement	Psychological capital, academic performance, and boredom		X	PLS-SEM	University students	India and Romania	420	Convenience
De la Fuente et. al.(2020)[6]	AEQ, EEC-Short MBI-SS,UWE	Engagement & burnout	Achievement emotions, coping mechanisms		X	SEM and logistic regression	Students	Spain	642	Convenience
Brubaker et. al. (2020) [3]	PSS, PSQI and MBI-SS	Perceived stress, burnout levels, and sleep quality	Intervention		X	Quasi-experimental	Medical students	Ohio, USA	57	Convenience
Bumbacco and Schafre (2020)[13]	EDA and SBI	Engagement and academic burnout	Attachment		X	Qualitative correlational study	First year college students	Canada	290	Intencional
Kiema-Junes et. al. (2020)[4]	UWES-S and SBI-9	Burnout and engagement	Self-perceived social skills		X	Linear regression	Students	Finland	351	Not specified
Smith & Emerson (2021) [16]	Connor Resilience GHQ-12 and MBI-SS	Academic burnout and psychological distress	Resilience		X	SEM	Undergraduate accounting students	USA	443	Convenience
Teuber et. al. (2021)[10]	QARCA-C and MBI-SS	academic burnout	workload, academic demands, teacher-student relationships and optimism		X	SEM	High school students	China	1083	Not specified
Reyna-Castillo et al. (2022)[17]	MBI-SS and EMEDO	Academic burnout	Sociodemographic antecedents	X	X	PLS-SEM	Students	Mexico and Colombia	235	Convenience
Fiorilli et al. (2022) [18]	Burnout BAT-C-Short	Burnout	Gender and employment status		X	MANOVA	Students	Italy	494	Snowball
Olson et. al. (2023) [7]	UWES-S 9 and MBI-SS	Engagement and student burnout	Work overload and academic satisfaction		X	SEM, Regression analysis	University students	Germany	3451	Convenience
Gutu et al. (2024) [19]	Instrument made by the authors	Level of engagement	Higher Education digitalization and academic leadership		X	PLS-SEM	Students	Romania	2272	Not specified
This work (2025)	MBI-SS and School Engagement Measure-MacArthur	Academic burnout	Academic engagement	X	X	PLS-SEM and Confirmatory factor analysis	Higher education students, anonymous and voluntary	Mexico	552	Convenience

For formative constructs:

$$\boldsymbol{\xi} = \mathbf{W}_x^\top \mathbf{x}, \quad \boldsymbol{\eta} = \mathbf{W}_y^\top \mathbf{y} \tag{3}$$

where $\mathbf{W}_x$ and $\mathbf{W}_y$ are weight matrices estimated to maximize the R^2 of the endogenous latent constructs.

3.2 Estimation procedure

PLS-SEM was performed using SmartPLS (v4.1), employing a three-stage iterative algorithm:

1. Initial approximation of latent variable scores based on proxies,
2. Estimation of inner model relationships using weighted least squares,
3. Update of weights and loadings until convergence is achieved.

Bootstrapping with 5,000 subsamples was used to assess the significance of path coefficients and measurement parameters.

3.3 Measurement model evaluation

For reflective indicators, the following criteria were used:

- Indicator reliability: Outer loadings $\lambda_i \geq 0.70$
- Internal consistency: Composite reliability (CR) ≥ 0.70
- Convergent validity: Average Variance Extracted (AVE) ≥ 0.50

$$\text{AVE} = \frac{1}{k} \sum_{i=1}^{k} \lambda_i^2 \tag{4}$$

For formative constructs, multicollinearity was assessed via Variance Inflation Factor (VIF), ensuring VIF < 5, and significance of outer weights was tested using bootstrapped t-statistics.

3.4 Structural model evaluation

The structural model was evaluated through:

- Coefficient of determination (R^2) for endogenous constructs,
- Effect size (f^2) for each path:

$$f^2 = \frac{R^2_{\text{included}} - R^2_{\text{excluded}}}{1 - R^2_{\text{included}}} \tag{5}$$

- Predictive relevance (Q^2) using the blindfolding procedure,
- Model fit using Standardized Root Mean Square Residual (SRMR), with threshold < 0.08.

3.5 Mediation and multigroup analysis

Mediation effects were examined by calculating the product of coefficients ($\beta_{ab} = \beta_a \cdot \beta_b$), and significance was tested via bootstrapped confidence intervals. Multigroup analysis (PLS-MGA) was conducted to explore differences in path coefficients across predefined subgroups using non-parametric techniques.

4. Participants and procedure

The study focused on students from a public university in Northern Mexico. A sample of size $n = 552$ students was collected, with 343 identifying as women, 202 as men, and only 7 as non-binary, representing 62.1%, 36.5%, and 1.3%, respectively. The average age was 19 years with a standard deviation of ± 5.4 years. The sample was obtained using a convenience sampling method. Participation was anonymous and voluntary; however, participants were given the option to register an email address if they wished to receive their results. To collect the information, assistance from specific teachers was requested, as well as support from the university tutoring department and the official announcements department.

4.1 Instruments and their validation

MBI - Student Survey [11] and School Engagement Measure - MacArthur [22] were adapted and used for this work. They were also validated by calculating the Cronbach's alpha coefficient [23]. Then we conducted an exploratory factor analysis (EFA) as suggested [24].

MBI - student survey

To determine levels of burnout, a translated and adapted version of the MBI-SS [11] was used. This questionnaire consists of six items measuring academic personal efficacy (e.g., "I can effectively solve problems related to my field of study."), five items measuring emotional exhaustion (e.g., "The academic activities in my field have left me emotionally drained."), and four items measuring cynicism (e.g., "I have become distanced from my field of study because I think it will not be useful for my professional development.").

The results in Table 2a show that all Cronbach's alpha values exceed 0.70, indicating that the items exhibit good reliability to measuring each factor [25]. On the other hand, Table 2b reports a KMO value of 0.89 and a $p - value$ of 0.001 in Bartlett's test [26], which suggests that applying an EFA is appropriate. Table 3 presents the factor loadings of the questionnaire items where *ago* refers to *emotional exhaustion* items, *cin* refers to *cynicism* items and, *efi* refers to *academic efficacy* items, with its associated number of item. It can be seen that all the items have satisfactory loadings, exceeding 0.40. Item *cin4* shows loadings in two factors, and only item *efi5* did not load significantly on any factor. These results confirm that the items appropriately measure the theoretical factors proposed in the MBI-SS and that the

Table 2. Results to Cronbach's alpha and the exploratory factor analysis for the MBI-SS.

(a) Cronbach's alpha coefficients for each factor in the MBI-SS.

Factor	Cronbach's Alpha
Exhaustion (ago)	0.8602
Efficacy (efi)	0.7792
Cynicism (cin)	0.8404

(b) Results from the exploratory factor analysis (EFA) for the MBI-SS.

Statistic	Value
KMO Overall	0.89
Bartlett's Test χ^2	3436.32 ($p < 0.001$)
Total variance explained	51%
RMSR	0.02
RMSEA (90% CI)	0.043 (0.033, 0.054)
Tucker-Lewis Index (TLI)	0.967

Table 3. Factor loadings for the MBI-SS.

Item →	*ago1*	*ago2*	*ago3*	*ago4*	*ago5*	*cin1*	*cin2*	*cin3*	*cin4*	*efi1*	*efi2*	*efi4*	*efi6*
-Emotional exhaustion	0.67	0.68	0.72	0.81	0.70				0.47				
-Personal efficacy										0.56	0.72	0.72	0.73
-Cynicism						0.64	0.65	0.77	0.61				

instrument can be reliably used for this purpose.

School engagement measure - MacArthur

Regarding academic engagement, a translation and adaptation of the MacArthur School Engagement Measure (SEM-MacArthur) was also carried out [22]. This questionnaire consists of five items measuring behavioral engagement (e.g. "I follow the rules at my faculty"), six items measuring emotional engagement (e.g., "I feel happy about the work I have to do"), and eight items assessing cognitive engagement (e.g., "I review my activities and school attitude for mistakes").

Table 4a shows that the emotional and cognitive factor scores exceed the required threshold of 0.70. Only the behavioral factor falls below this threshold (0.67). However, when item *com2* corresponding to this factor is removed, the coefficient increases to 0.71, suggesting that this item presents internal consistency issues and must be eliminated. Furthermore, the results in Table 4b show a KMO value of 0.90 and a significant result in Bartlett's sphericity test ($p < 0.001$), indicating that the conduct of an EFA is appropriate. Finally, Table 5 shows that the vast majority of questionnaire items load exclusively onto a single factor, only the items "*com2*" and "*efi6*" did not exhibit adequate loadings during the exploratory factor analysis (EFA), leading to their removal from the instrument. As a result, the final version of the scale includes 17 of the 19 items originally proposed.

Overall, these findings provide strong empirical support for the validity and reliability of the School Engagement Measure in the studied sample. The instrument demonstrates adequate internal consistency, a well-defined factor structure, and appropriate conditions for the application of exploratory factor analysis, thus confirming its suitability for assessing academic engagement in this context.

5. Results and discussion

Two key constructs emerge from the Structural Equation Modeling (SEM) proposed: academic engagement and academic burnout, which are discussed in the following subsections.

5.1 Academic burnout

Regarding academic burnout, it is composed of three factors: academic personal efficacy, emotional exhaustion, and cynicism. Given the number of items and the fact that all MBI-SS questions use a Likert scale from 0 to 6, theoretical maximum scores for efficacy, exhaustion, and cynicism would be 36, 30, and 24 points, respectively. Table 6 presents the descriptive statistics obtained from the university student sample.

For the personal academic efficacy factor, the students reported a mean score of 26.45 points and a median of 28 points, with a standard deviation of approximately 7 points. This suggests that most university students perceive themselves as highly effective in their academic activities. In contrast, the emotional exhaustion factor showed a mean of 17.78 and a median of 19, with a standard deviation of 7.86, indicating that students are moderately emotionally exhausted, although with considerable variability. Finally, the cynicism fac-

Table 4. Results to Cronbach's alpha and the exploratory factor analysis for the MBI-SS.

(a) Cronbach's alpha coefficients for each factor in SEM-MacArthur.

Factor	Cronbach's Alpha
Behavioral (com)	0.6703
Emotional (emo)	0.8970
Cognitive (cog)	0.8261

(b) Results from the exploratory factor analysis for the School Engagement Measure.

Statistic	Result
KMO Overall	0.90
Bartlett's Test χ^2	4007.16 ($p < 0.001$)
Total variance explained	45%
RMSR	0.03
RMSEA (90% CI)	0.044 (0.036, 0.052)
Tucker-Lewis Index (TLI)	0.952

Table 5. Factor loadings for the School Engagement Measure.

Item →	*com1*	*com2*	*com3*	*com4*	*com5*	*emo1*	*emo2*	*emo3*	*emo4*	*emo5*	*emo6*
-Behavioral	0.47		0.65	0.65	0.49						
-Emotional						0.82	0.73	0.72	0.69	0.83	
Item →	*cog1*	*cog2*	*cog3*	*cog4*	*cog5*	*cog6*	*cog7*	*cog8*			
-Cognitive	0.52	0.59	0.61	0.72	0.78	0.59	0.46	0.47			

Table 6. Descriptive statistics of the factors in MBI-SS.

Factor	Efficacy	Exhaustion	Cynicism
Items	6	5	4
Mean	26.45	17.78	6.48
Median	28	19	4.5
Standard deviation	7.02	7.86	6.51
Skew	-0.88	-0.33	0.97
Kurtosis	0.23	-0.89	0

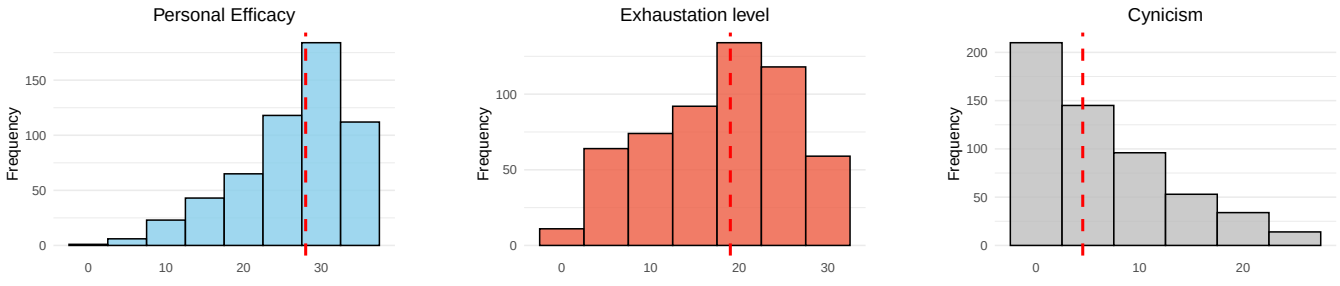

Figure 1. Histograms of the factors Efficacy, Exhaustion and Cynicism in students.

tor revealed a mean of 6.48 and a median of 4.5, accompanied by a standard deviation of 6.51. Although these results imply that most students exhibit low levels of cynicism, the relatively high standard deviation suggests that a smaller subgroup reports significantly higher levels of cynicism, as we can see in Figure 1.

Figure 1 displays the histograms of the score distributions for each factor of MBI-SS. It is visually evident and supported by the skewness and kurtosis values in Table 6 that none of the factors follows a normal distribution. Therefore, all group comparisons will be conducted using nonparametric tests.

Regarding academic burnout, the literature (Section 2) indicates that, for a student to be considered to experience a severe and significant level of burnout, three criteria must be met: low academic efficacy, high emotional exhaustion, and high cynicism. However, the syndrome may also be present in moderate or mild forms when one or two of these conditions are observed. In contrast, a student is considered free of academic burnout when they exhibit high levels of academic efficacy along with low levels of cynicism and emotional exhaustion. In this regard, Figure 2 illustrates the levels of academic burnout in the student sample from the Universidad Autonoma de Coahuila. Based on the criteria mentioned above, almost half of the students (47.6%) exhibit some level of academic burnout. In addition, at least 1 in 4 students (28.1%) show moderate to high levels of burnout syndrome, which puts them at risk of experiencing its negative consequences.

5.2 Academic engagement

Academic engagement is composed of three factors: behavioral engagement, cognitive engagement, and emotional engagement. It is important to note that the response scale for this questionnaire was a Likert-type scale ranging from 1 to 5. Theoretical maximum scores for each dimension are 25, 40, and 30, respectively. Table 7 presents the descriptive statistics for the academic engagement factors observed in the university student sample.

Table 7 reports that the behavioral engagement factor has a mean of 16.4, a median of 17, and a standard deviation of 2.38. These results suggest a high level of behavioral engagement with low variability, indicating consistency across responses. The negative skewness suggests a higher concentration of students scoring above the mean in this dimension. For the cognitive engagement factor, the mean score of 25.69 and median of 25.5 indicate a moderately high level of engagement. However, the standard deviation of 6 points reflects greater variability in responses compared to the other two dimensions, suggesting a broader range of cognitive involvement among students. Regarding emotional engagement, the mean of 20.38 and median of 20 indicate comparatively higher levels relative to the other factors. The standard deviation of 4 points denotes moderate dispersion, while a skewness value of -0.14 suggests a slight leftward asymmetry, implying that higher scores are more frequent.

In summary, all three academic engagement factors exhibit left skewed or near symmetric distributions, with overall scores clustering in the moderate-to-high range. This indicates that the majority of students in the sample demonstrate medium to high levels of academic engagement. This trend is also observable in Figure 3.

5.3 The SEM of academic burnout and academic engagement

Figure 4 presents the proposed model, which follows a hierarchical structure. In this model, the factors Behavioral, Cognitive, and Emotional operate sequentially to explain the higher-order construct of Academic Engagement, which in turn negatively predicts Academic Burnout, a second-order construct composed of personal efficacy, exhaustion, and cynicism.

First, the model indicates that students who pay attention in class, complete assignments on time, and remain focused during school hours are more likely to exhibit stronger cognitive engagement ($\beta = 0.524,\ p < 0.001$). This suggests that adherence to academic norms and personal responsibility enhances students' willingness to engage in deeper, reflective academic processes.

Furthermore, the cognitive engagement factor, which includes behaviors such as studying outside of class, reading supplementary materials, and discussing academic topics with others, exerts a significant positive effect on emotional engagement ($\beta = 0.417,\ p < 0.001$). This implies that students who invest in constructing knowledge beyond assigned tasks are also more likely to experience positive emotions in their academic life, such as satisfaction, interest, and enjoyment.

Finally, emotional engagement significantly reduces academic burnout levels ($\beta = -0.871,\ p < 0.001$). Specifically, students who report feeling happy, motivated, and satisfied with their academic activities tend to show lower levels of cynicism and exhaustion, and higher levels of personal efficacy.

These findings support the hypothesis that affective well-being within the university environment serves as a key protective factor against the psychological strain associated with academic demands.

5.3.1 The SEM comparison between gender and semester

Regarding the potential differences between the groups analyzed in this study, a multigroup analysis (MGA) was conducted using the *SEMinR* package in R [27]. This approach allows for the comparison of structural equation models (SEMs) across different groups to identify statistically significant differences. In this case, Table 8 presents the results of the MGA comparing gender (209 males vs. 343 females) and semester (360 students before their fifth semester vs. 192 students in their fifth semester or later).

For the gender comparison, the overall estimate mean (0.0231) is relatively small, and while the beta

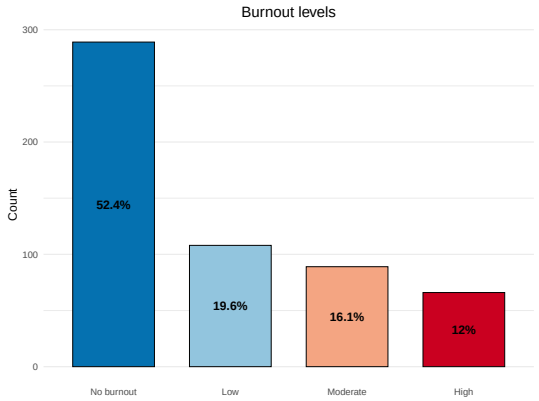

Figure 2. Levels of academic burnout in the university sample.

Table 7. Descriptive statistics of the factors in the School Engagement Measure.

Factor	Behavioral	Cognitive	Emotional
Items	4	8	6
Mean	16.43	25.69	20.38
Median	17	25.5	20
Standard deviation	2.38	6.03	4
Skew	-0.58	-0.02	-0.14
Kurtosis	-0.01	-0.11	-0.5

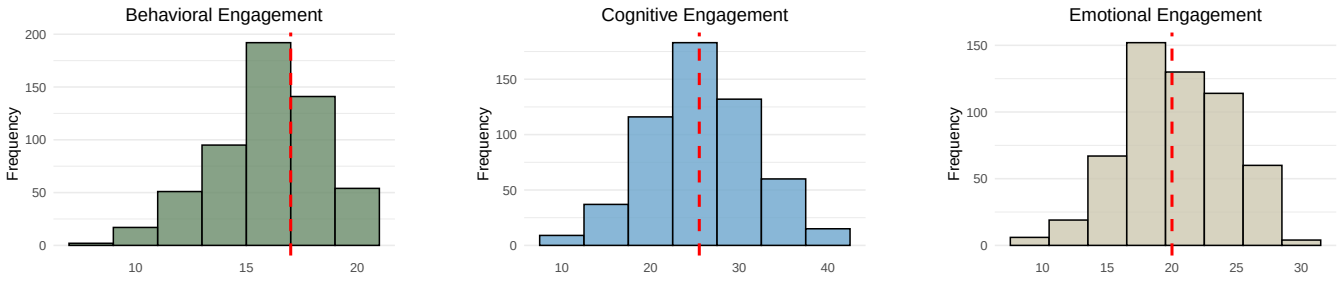

Figure 3. Histograms of the factors Behavioral, Cognitive and Emotional Engagement in the Student Engagement Measure.

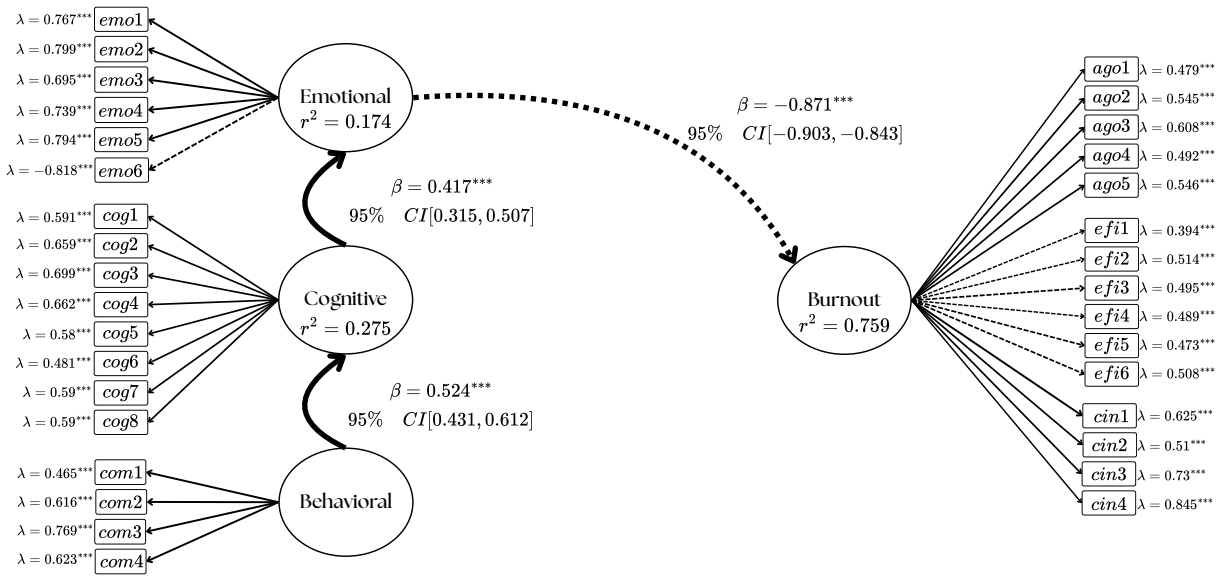

Figure 4. Levels of academic burnout in the university sample.

coefficient for male students (0.0290) is slightly higher than that for female students (0.0186), this difference is not substantial within the context of the model. The average p-value of 0.4801 indicates that, overall, the differences between the SEMs for male and female students are not statistically significant in this context.

For the comparison between the early and late semesters, Table 8 shows that the estimated mean (0.0231) is similar to that observed in the gender comparison, indicating that the average difference between these two semester groups is also small. Students in the first semesters (0.0230) exhibit a slightly weaker structural relationship compared to those in the later semesters (0.0465), suggesting a change in academic dynamics as students progress through their studies. However, the $p - values$ for this comparison confirms that there is no significant statistical evidence to support meaningful differences in the SEM relationships across these two groups. In other words, although students in higher semesters tend to exhibit slightly stronger effects, these differences are not statistically significant.

6. SEM & AI

This research, which focuses on analyzing academic burnout and engagement through SEM, can be enriched by incorporating artificial intelligence (AI)-based tools from both theoretical and practical perspectives. Two complementary approaches emerge from recent studies on intelligent technology adoption: the use of automated care systems in digital health [28] and the application of smart technologies in tourism experiences enhanced by augmented reality [29].

First, AI can be conceived as a key component in the development of adaptive dashboards for personalized academic support, inspired by digital medical platforms such as "eDoctor apps". These systems could be integrated with data collected via the MBI-SS and SEM-MacArthur instruments, generating a dynamic psychoeducational profile for each student. This profile would enable real-time monitoring of latent variables such as academic efficacy, emotional exhaustion, and cynicism—core constructs in our academic burnout model. The descriptive and structural analyses in this study revealed that students with higher engagement levels report significantly lower exhaustion and cynicism. Consequently, an AI-enhanced platform that optimizes these factors through personalized interventions could serve as a preventive tool, especially beneficial for institutions managing large student cohorts with limited human resources. Second, following Namahoot's proposal [29], the adaptation of AI-based "smart assistant" models—similar to virtual tourist guides—to academic contexts is proposed. In this setting, these assistants would serve as "cognitive and emotional tutors", supporting students throughout their academic journeys. Such emotional support would be particularly valuable for students reporting low efficacy or high cynicism, clearly identifiable segments in our structural model.

Both proposals position artificial intelligence as a mediating technology that, beyond its informational role, plays an active part in promoting academic well-being. Future research should evaluate the technical feasibility and user acceptance of such resources among students and faculty, incorporating variables such as attitude toward AI, intention to use, and perceived usefulness into extended SEM models. This would enable the development of evidence-based intervention pathways that foster ethical and personalized use of AI in higher education environments.

Table 8. MGA results comparing gender and semester.

Group	Estimate mean	β-group 1	β-group 2	p-value	p-value min
Male vs. Female	0.0231	0.0290	0.0186	0.4801	0.3002
First vs. Last semesters	0.0231	0.0230	0.0465	0.5222	0.0837

7. Conclusions and future work

This study examined the structural relationships between academic engagement and academic burnout among university students in Northern Mexico, using a second-order PLS-SEM. By conceptualizing academic engagement through its behavioral, cognitive and emotional dimensions, and academic burnout through emotional exhaustion, cynicism, and reduced academic efficacy, the model explained a substantial 75.9% of the variance in burnout. The results provide compelling evidence for the protective effect of emotional engagement against burnout, as demonstrated by the strong negative path coefficient ($\beta = -0.871$; 95% CI $[-0.903, -0.843]$) linking emotional engagement with burnout levels.

The findings corroborate theoretical models such as the JD-R and Conservation of Resources (COR) frameworks, suggesting that emotionally invested students exhibit lower susceptibility to burnout [10], [9]. Notably, cognitive engagement emerged as a positive antecedent of emotional engagement, indicating that students who go beyond basic academic requirements—by reflecting critically and engaging in peer discussions—also tend to report more positive academic emotions. These insights align with prior research emphasizing the mediating role of engagement in the relationship between personal resources (e.g., psychological capital) and burnout [13], [7], [9].

Multigroup analysis revealed no statistically significant differences across gender or semester level, suggesting the robustness of the model across demographic subgroups. However, the absence of significant moderation by these variables opens the door for future exploration of alternative moderators, such as socioeconomic status, attachment style, psychological capital, and institutional support systems.

In practical terms, the structural model validated in this study provides a foundation for future work. Pertinent research efforts may focus on operationalizing these findings through the development of predictive models—such as binary or ordinal logistic regression—to classify students at risk of burnout based on engagement profiles. Furthermore, longitudinal studies are recommended to capture the dynamic evolution of burnout and engagement over time, as cross-sectional designs may obscure causal inferences.

Additionally, the implementation of targeted interventions aimed at fostering emotional engagement—such as mentorship programs, positive psychology training, or resilience workshops—should be prioritized and empirically evaluated within Mexican universities. These initiatives are particularly relevant in the context of Mexico's ongoing educational transformation, where digitalization and shifting pedagogical models are altering traditional student-instructor dynamics. Institutional support for these programs is essential, as engagement can be significantly disrupted by socioeconomic disparities, limited student services, and inconsistent technological infrastructure—challenges that are especially salient in public universities across the country.

For higher education practitioners and decision-makers in the Mexican education system, the results of this study offer actionable insights for designing policies and allocating resources to strengthen protective factors against academic burnout. The validated SEM framework not only deepens theoretical understanding but also enables predictive diagnostics that can be embedded into institutional early-alert systems. By identifying students at risk through engagement profiles, universities can deliver timely, data-driven interventions, thereby enhancing student retention, academic success, and psychological well-being. In a national context where dropout rates and mental health issues are pressing concerns, these findings provide a critical roadmap for implementing evidence-based strategies that promote both educational quality and equity. Thus, this research directly aligns with Mexico's educational policy goals of improving inclusion, academic performance, and long-term student development.

Ethics statement

This study used anonymized data collected via an online survey. No personally identifiable information was collected. Ethical approval was deemed unnecessary according to the guidelines of UADEC (https://www.uadec.mx/transparencia/acceso-a-la-informacion/53-aviso-de-privacidad-y-derechos-arco/).

CRediT authorship contribution statement

Irving A. Ramírez Muñoz: Conceptualization, Methodology, Software, Validation, Formal analysis, data curation, Visualization, Writing-original draft, Writing-review & editing. **Vanesa Avalos-Gaytán:** Conceptualization, Methodology, Software, Validation, Formal analysis, data curation, Visualization, Writing-

original draft, Writing-review & editing. **Igor Barahona:** Conceptualization, Methodology, Software, Validation, Formal analysis, data curation, Visualization, Writing-review & editing. **Valeria Soto-Mendoza:** Formal analysis, Visualization, Writing-review & editing. **Gabriela Linares-Acuña:** Formal analysis, Visualization, Writing-review & editing.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors utilized Grammarly and ChatGPT to refine sentence structure and enhance readability. No content was generated by AI; all scientific insights and original ideas are the author's own.

Declaration of competing interest

All authors declare that there are no potential conflicts of interest—financial or personal—that could have influenced the results or interpretations of this work.

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