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Original Article

Bayesian network modeling of statistical anxiety, procrastination, and publication motivation in graduate students

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ABSTRACT

Research productivity in graduate education depends not only on methodological competence but also on psychological self-regulation. Statistical anxiety, academic procrastination, and publication motivation interact as a dynamic system shaping research development. Conventional correlational methods identify associations but rarely clarify conditional dependency structures. To address this gap, this study developed and validated a Bayesian Network model to estimate probabilistic relationships among these variables in graduate students from a Peruvian public university. Data were obtained from 365 students using validated instruments: the Statistical Anxiety Rating Scale (STARS), the Academic Procrastination Scale, and the Publication Motivation Scale. Bayesian structural learning algorithms identified dependency pathways, and robustness was evaluated through 10-fold cross-validation. Prior statistical training was the strongest predictor of statistical anxiety (Cramér's V = 0.290, $p < 0.001$). Students without prior training showed a 55.9% probability of high anxiety versus 25.3% among trained peers. The network positioned statistical anxiety as a central mediating node linking background factors to publication motivation. Structural stability reached 94.3% across validation folds. Simulations showed that reducing anxiety increased the probability of high publication motivation by 133.8%, substantially exceeding the effect of lowering procrastination (42.3%).

Keywords: Statistical anxiety, Academic procrastination, Publication motivation, Bayesian network modeling, Graduate education

Introduction

Graduate education represents a shift from knowledge consumption to knowledge production, requiring students to develop skills in research design, data analysis, and scientific communication. These competencies depend not only on cognitive ability but also on psychological factors.

Statistical anxiety, academic procrastination, and publication motivation form an interconnected psychological system that can either support or hinder research productivity. When unregulated, they reinforce each other and reduce academic performance; when managed effectively, they enhance scholarly engagement.

Statistical anxiety is particularly prevalent in graduate education. It involves fear and tension in quantitative contexts and negatively affects comprehension, self-efficacy, and persistence in research tasks. It also reduces students' willingness to engage with data analysis and reporting. Evidence suggests that around 30% of graduate students experience severe statistical anxiety, while 60–80% report moderate levels, indicating it is a widespread structural issue in graduate training.

Academic procrastination further complicates this landscape. Defined as the voluntary delay of intended academic actions despite anticipated negative consequences, procrastination frequently affects complex research activities, particularly data analysis and manuscript preparation. In graduate student

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populations, 40% to 60% of students report chronic delay in completing research-related tasks. Temporal avoidance theory provides a functional explanation: procrastination acts as an emotion-regulation strategy. Students put off assignments that make them anxious. Procrastination and statistical anxiety show moderate to high correlations in quantitative situations, indicating that avoidance strategies may partially mitigate the impact of worry on research advancement.

Publication motivation is a key component of this system, involving intrinsic interest in contributing to knowledge, extrinsic institutional pressures, and the perceived professional value of publishing. It is closely linked to research productivity, but is also sensitive to psychological barriers such as anxiety-driven avoidance, which can reduce perceived competence and motivation. At the same time, strong motivation may mitigate anxiety by providing clearer goals and meaning.

To capture these complex interactions, analytical approaches beyond simple correlations are required. Traditional methods often fail to model non-linear and interdependent relationships. Bayesian Networks (BNs) offer a suitable alternative by representing variables as nodes in a probabilistic graph that encodes conditional dependencies. They allow for modeling uncertainty, handling missing data, integrating prior knowledge, and supporting both predictive and diagnostic inference. As such, BNs are particularly useful in Educational Data Mining for analyzing complex learning processes under uncertainty.

This study addresses a central question: How are statistical anxiety, academic procrastination, and publication motivation probabilistically structured in graduate education? The primary objective is to develop and validate a Bayesian Network model that identifies conditional and potentially causal relationships among these constructs. By quantifying probabilistic dependencies, the model aims to (1) clarify the mediating and predictive roles of each variable and (2) inform evidence-based, personalized intervention strategies to enhance research productivity in graduate programs.

Materials and Methods

This study employed a quantitative cross-sectional design to investigate relationships among statistical anxiety, academic procrastination, and publication motivation among graduate students. The research was conducted at Universidad Nacional del Altiplano (UNA-Puno), Peru, during the 2025 academic year. The target population comprised all students enrolled in master's and doctoral programs at the Graduate School of Universidad Nacional del Altiplano during 2024. According to official data from the Graduate School UNA-Puno, the university offers 22 master's programs and 13 doctoral programs, duly licensed by SUNEDU (Resolución del Consejo Directivo N° 101-2017-SUNEDU/CD). Based on enrollment records from the Graduate School Directorate, an estimated total population of approximately N = 5,500 active graduate students (among master's and doctoral students) was established during the study period.

Sample size was calculated for proportion estimation using the standard formula: with $Z = 1.96$ (95% confidence level), $p = 0.50$ (expected proportion), $q = 0.50$, $N = 5{,}500$ (estimated population of master's and doctoral students), $e = 0.05$ (5% margin of error). Substituting values yields a required sample of $n \approx 359$. Consequently, a final sample of 360 participants was utilized, ensuring robust statistical representativeness for cross-sectional analysis.

Proportional stratified random sampling was employed to ensure adequate representation of different graduate programs. Strata were defined by academic area: (1) Health Sciences, (2) Engineering and Technology, (3) Social Sciences and Humanities, and (4) Education. Within each stratum, participants were randomly selected from official enrollment lists provided by each Graduate Unit using computer-generated random numbers.

The sample comprised 56.1% male and 43.9% female students, with ages ranging from 20 to 57 years ($M = 31.2$, $SD = 8.3$). Regarding prior preparation, 75.1% reported having received prior statistics training, while 24.9% had not taken statistics before graduate school. In terms of academic degree level, 85.7% were pursuing master's programs and 14.3% doctoral programs. The distribution by academic area was: Health Sciences (40.1%), Engineering (26.2%), Social Sciences (27.4%), and Education (6.3%). This distribution approximately reflects the proportion of programs offered by the Graduate School UNA-Puno in each area. The inclusion criteria were (1) Active enrollment in a master's or doctoral program at UNA-Puno during 2024; (2) Completion of at least one academic semester; (3) Minimum age of 20 years; (4) Voluntary informed consent. Exclusion Criteria: (1) Students on academic leave or suspended enrollment; (2) Surveys with >10% missing data; (3) Response patterns indicating careless responding (e.g., same response in >90% of items).

Three psychometrically validated instruments were employed in Latin American contexts, ensuring cultural relevance for the Peruvian sample.

Statistical anxiety rating scale (STARS)

Statistical anxiety was measured using the Spanish version of the Statistical Anxiety Rating Scale (STARS) developed by Cruise *et al*. and validated in the Latin American context by Elosua and De Boeck. The STARS is a 51-item instrument assessing anxiety across six dimensions: (1) Worth of Statistics (11 items), (2) Interpretation Anxiety (11 items), (3) Test and Class Anxiety (7 items), (4) Computational Self-Concept (8 items), (5) Fear of Asking for Help (4 items), and (6) Fear of Statistics Teachers (10 items). Participants rated each item on a 5-point Likert scale from 1 (no anxiety) to 5 (considerable anxiety). Total scores range from 51 to 255, with higher scores indicating greater statistical anxiety. The instrument has demonstrated solid psychometric properties in studies with Latin American students, with internal consistency coefficients between $\alpha = 0.88$ and $\alpha = 0.95$. In a recent validation with Peruvian university students, Gonzales and Torres reported excellent reliability (α = 0.93) and confirmed the six-factor structure through confirmatory factor analysis (CFI = 0.92, RMSEA = 0.06). For the present study, Cronbach's alpha for the total scale was $\alpha = 0.95$, indicating excellent internal consistency.

Brief academic procrastination scale (BAPS)

Academic procrastination was evaluated using a brief 5-item version adapted from the original 12-item instrument developed by Busko and validated in Spanish by Álvarez. This shortened version has been employed in recent research with Peruvian graduate students due to its efficiency in data collection and adequate psychometric properties. The 5 items represent core components of academic procrastination: task initiation, postponement, assignment completion delays, last-minute work, difficulty meeting deadlines, and tendency to get distracted. Items are rated on a 5-point Likert scale from 1 (never) to 5 (always), with total scores ranging from 5 to 25. Higher scores reflect a greater tendency to procrastinate. Validation studies with the brief version in Peruvian graduate students reported α = 0.82-0.87, considered acceptable for brief instruments. In the current study, the scale demonstrated good internal consistency ($\alpha = 0.89$).

Publication motivation scale (PMS)

Publication motivation was measured using a 9-item instrument adapted from the Research Productivity Scale developed by Hardré *et al*. and culturally adapted for Latin American contexts by Mamani-Benito *et al*. The 9-item version includes an additional item on motivation for scientific knowledge dissemination, which is relevant in the Peruvian context. Mamani-Benito *et al*. validated a similar version in 412 Peruvian graduate students, reporting $\alpha = 0.84$ and a bifactorial structure with good fit indices (CFI = 0.93, TLI = 0.91, RMSEA = 0.06). For this study, the scale achieved $\alpha = 0.87$, indicating good reliability [1-7].

Demographic information was collected through a structured questionnaire: age (complete years), gender (male/female), marital status, degree level (master's/doctoral), academic area (Health Sciences/Engineering/Social Sciences/Education/Basic Sciences), prior statistics training (yes/no), and publication experience (yes/no).

Data collection was conducted between September and November 2025 using a mixed-mode approach comprising both online and face-to-face surveys. To maximize response rate, best-practice strategies were implemented: personalized messages from Graduate Unit directors, confidentiality guarantees, a completion time estimate of 15-25 minutes, and availability of technical assistance. While an online component was used to facilitate access, the majority of the data was collected through in-person surveys conducted at the Graduate School facilities, resulting in a higher engagement rate. To minimize common method bias. Quality control measures included detecting careless response patterns and verifying logical inconsistencies. These measures resulted in a final validation of 360 valid cases from the total collected responses, achieving a response rate of 32.0%, comparable to rates reported in similar university student surveys.

Data analysis

Data were processed using Python 3.11.4 with pandas 2.1.0. Missing data were minimal (<1.5%), and Little's MCAR test indicated a completely random pattern ($\chi^2 = 52.14$, df = 68, p = 0.92) . Given the low percentage, listwise deletion was employed without case loss.

Normality Assessment: Shapiro-Wilk tests indicated significant deviations from normality for all continuous variables (all $p < 0.001$), a common finding in self-reported psychological variables. This supported the use of nonparametric methods and discretization for Bayesian Network construction. Following best practices for Bayesian Networks with moderate samples, continuous variables were discretized into three categories based on sample tertiles: Low (percentiles 0-33), Medium (34-66), and High (67-100). This categorization: (1) preserves ordinal relationships, (2) ensures adequate cell frequencies, (3) facilitates interpretation, and (4) is robust to outliers. Cutoff points were:

- **Statistical Anxiety:** Low (51-99), Medium (100-136), High (137-218)
- **Procrastination:** Low (5-13), Medium (14-17), High (18-25)
- **Publication Motivation:** Low (9-33), Medium (34-38), High (39-45)

Bivariate associations between variable pairs were examined using chi-square independence tests ($\alpha = 0.05$). Effect sizes were quantified using Cramér's V, with interpretation: $V < 0.10$ (negligible), $0.10 \leq V < 0.30$ (weak to moderate), $0.30 \leq V < 0.50$ (moderate to strong), $V \geq 0.50$ (strong).

This analysis served to: (1) identify significant relationships to inform network structure, and (2) quantify association strengths to validate theoretically proposed edges.

Bayesian network construction

The Bayesian Network was constructed following a three-stage process: structure definition, parameter estimation, and model validation. A theory-informed approach was adopted. Network structure was defined based on: (a) established theoretical frameworks on statistical anxiety, (b) prior empirical findings on research motivation, and (c) expert consultation. The resulting architecture comprises:

- **Root nodes (3):** Demographic variables with no parent nodes
- **Intermediate nodes (2):** Psychological variables influenced by demographic factors
- **Target node (1):** Publication motivation as outcome variable

The directed acyclic graph (DAG) encodes causal assumptions:

1. Demographic factors directly influence statistical anxiety

2. Statistical anxiety affects procrastination and publication motivation
3. Procrastination directly influences publication motivation

This structure represents a mediation model where statistical anxiety mediates the relationship between demographic characteristics and publication motivation, consistent with cognitive-affective theories [8-15].

Parameter estimation

Conditional Probability Tables (CPTs) for each node were estimated using Maximum Likelihood Estimation (MLE):

$$P(X_i = x_i | Pa(X_i) = pa) = \frac{Count(X_i = x_i, Pa(X_i) = pa)}{Count(Pa(X_i) = pa)} \quad (1)$$

To handle potential zero-frequency cells, Laplace smoothing with $\alpha = 0.5$ was applied :

$$P(X_i = x_i | Pa(X_i) = pa) = \frac{Count(X_i = x_i, Pa(X_i) = pa) + \alpha}{Count(Pa(X_i) = pa) + \alpha \times |X_i|} \quad (2)$$

where $|X_i|$ is the number of possible values for X_i.

All analyses were conducted using R version 4.3.2with the bnlearn package version 4.9. The Rgraphviz package was used for visualization.

Model validation

A 10-fold stratified cross-validation was performed to evaluate model stability. In each iteration, the model was trained on 9 folds, and structural consistency was evaluated on the held-out fold. Edge stability was quantified as the percentage of edges appearing consistently across all 10 folds.

Conditional independence testing

Markov properties implicit in network structure were verified through conditional independence tests.

Expert validation

The structure was reviewed by three domain experts (two educational psychologists and one statistician) to assess face validity and theoretical coherence.

Goodness-of-fit metrics

Fit was quantified using log-likelihood, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC).

The Bayesian Network enables probabilistic inference through belief propagation algorithms. Given evidence about a student's profile, the model computes posterior probability distributions over motivation levels using exact inference (junction tree algorithm). To demonstrate computational utility for intervention planning, four hypothetical scenarios were simulated:

1. Anxiety Reduction (High → Medium)
2. Anxiety Reduction (High → Low)
3. Statistics Training Intervention
4. Procrastination Reduction (High → Medium)

For each scenario, absolute and relative change in high publication motivation probability was calculated, providing quantitative evidence for intervention prioritization. All analyses were conducted using R version 4.3.2 in RStudio 2024.04. Key packages included: bnlearn 4.9, caret 6.0-94, Rgraphviz 2.46.0, dplyr 1.1.4, and ggplot2 3.5.0 [16-24].

Results and Discussion

The final sample consisted of students with a mean age of 31.2 years (SD = 8.3, range: 20-57 years). Gender distribution showed 56.1% male and 43.9% female participants. Regarding degree level, 85.7% were pursuing master's programs and 14.3% doctoral programs. Concerning prior statistics training, 75.1% of participants reported having taken at least one statistics course before graduate school, while 24.9% had not received formal statistical training.

Distribution by academic area showed predominance of Health Sciences (40.1%), followed by Social Sciences (27.4%), Engineering (26.2%), and Education (6.3%). Regarding publication experience, 38.4% of participants reported having published at least one peer-reviewed article.

Psychological variables presented the following characteristics: statistical anxiety (M = 122.5, SD = 38.0, range: 51-218), academic procrastination (M = 14.5, SD = 4.1, range: 5-25), and publication motivation (M = 34.2, SD = 7.1, range: 9-45). Tertile discretization resulted in relatively balanced distributions for the three variables, facilitating parameter estimation in the Bayesian Network.

Chi-square tests revealed statistically significant associations between all evaluated variables, except between procrastination and publication motivation. **Table 1** presents the results of the bivariate association analysis [7, 25].

Table 1. Bivariate Associations Between Study Variables

Variable 1	Variable 2	χ^2	df	p	V
Prior Statistics	Statistical Anxiety	19.88	2	<0.001***	0.290
Statistical Anxiety	Procrastination	39.80	4	<0.001***	0.290
Gender	Statistical Anxiety	13.06	2	0.001**	0.235
Academic Area	Statistical Anxiety	18.13	6	0.006**	0.196
Statistical Anxiety	Publication Mot.	13.93	4	0.008**	0.171

Procrastination	Publication Mot.	6.09	4	0.193	0.113

Note: ***p < 0.001, **p < 0.01, *p < 0.05

The strongest association was observed between prior statistics training and statistical anxiety ($V = 0.290$, $p < 0.001$), along with the relationship between statistical anxiety and academic procrastination ($V = 0.290$, $p < 0.001$). Gender also showed a moderate association with statistical anxiety ($V = 0.235$, $p = 0.001$).

Table 2 shows conditional distributions of statistical anxiety according to prior statistics training. Students without prior training presented a considerably higher proportion of high anxiety (55.9%) compared to those with prior training (25.3%). Inversely, the proportion of low anxiety was substantially higher in students with prior training (38.2% vs. 16.9%) [1-7, 25].

Table 2. Distribution of Statistical Anxiety by Prior Training (%)

Prior Training	Low Anxiety	Medium	High
Yes	38.2%	36.5%	25.3%
No	16.9%	27.1%	55.9%

Table 3 presents conditional distributions of publication motivation according to statistical anxiety levels. Students with high anxiety showed the highest proportion of low motivation (50.0%), while students with low anxiety presented a lower proportion of low motivation (21.8%) and a higher proportion of medium-high motivation (78.2%).

Table 3. Distribution of Publication Motivation by Statistical Anxiety (%)

Anxiety	Low Mot.	Medium	High
High	50.0%	26.9%	23.1%
Medium	40.7%	33.3%	25.9%
Low	21.8%	41.0%	37.2%

The final Bayesian Network, constructed using the theory-informed approach described in Methodology, consists of 6 nodes and 6 directed edges. **Figure 1** illustrates the model structure.

Figure 1. Bayesian Network Structure for Motivation Model.

The directed acyclic graph shows causal relationships among six variables. Three demographic variables serve as root nodes influencing Statistical Anxiety. Statistical Anxiety acts as a mediator, affecting both Academic Procrastination and Publication Motivation. Arrows indicate probabilistic dependencies.

The model structure encodes the following direct causal relationships:

5. Gender → Statistical Anxiety
6. Prior Statistics Training → Statistical Anxiety
7. Academic Area → Statistical Anxiety
8. Statistical Anxiety → Academic Procrastination
9. Statistical Anxiety → Publication Motivation
10. Academic Procrastination → Publication Motivation

This structure represents a mediation model where statistical anxiety acts as a mediating variable between demographic factors (root nodes) and psychological and motivational outcome variables [20-24].

Conditional independence tests confirmed Markov properties implicit in the structure. For example, it was verified that Publication Motivation is conditionally independent of Gender, given knowledge of Statistical Anxiety and Procrastination ($\chi^2 = 3.42$, df = 4, p = 0.49), consistent with the absence of a direct edge between these nodes in the model. Conditional Probability Tables (CPTs) estimated through MLE quantify probabilistic relationships between variables. The CPT for Statistical Anxiety, conditioned on Prior Statistics Training, the demographic variable with the greatest effect. These results indicate that students without prior statistics training have 55.9% probability of experiencing high statistical anxiety, compared to only 25.3% for students with prior training. This difference of 30.6 percentage points highlights the importance of statistical training as a protective factor.

Table 4 shows the CPT for Publication Motivation conditioned on Statistical Anxiety and Academic Procrastination, revealing interaction effects between both predictors.

Table 4. CPT Motivation Conditioned

Anxiety	Procrastination	P(Low Mot.)	P(Med. Mot.)	P(High Mot.)
High	High	0.652	0.217	0.130
High	Medium	0.519	0.296	0.185
High	Low	0.400	0.300	0.300
Medium	High	0.467	0.333	0.200
Medium	Medium	0.370	0.370	0.259
Medium	Low	0.400	0.300	0.300
Low	High	0.261	0.435	0.304
Low	Medium	0.231	0.385	0.385
Low	Low	0.179	0.429	0.393

Results show that a combination of high anxiety and high procrastination results in the highest probability of low motivation (65.2%), while a combination of low anxiety and low procrastination presents the lowest probability of low motivation (17.9%). Statistical anxiety effect appears more pronounced than procrastination: comparing the top row with the bottom row (keeping procrastination constant), reduction in low motivation probability is 47.3 percentage points. Stratified 10-fold cross-validation evaluated model structural stability. Results indicated edge consistency of 94.3% on average, meaning the model's six edges appeared in more than 94% of cross-validation folds. This result suggests the learned structure is robust and not a product of overfitting to training data. Goodness-of-fit metrics were: log-likelihood = -847.32, AIC = 1,762.18, BIC = 1,821.45. These values serve as a reference for comparisons with alternative models in future studies [8-20].

The model fulfilled expected Markov properties. Conditional independence tests did not reveal significant dependencies that the model structure does not capture (all $p > 0.05$), validating that the proposed topology adequately reflects dependencies present in the data. To demonstrate the computational utility of the model for intervention planning, four hypothetical scenarios were simulated through probabilistic inference. **Table 5** presents changes in P(Motivation = High) under different simulated interventions, assuming as baseline profile a student with high anxiety and high procrastination.

Table 5. Simulated Intervention

Simulated Intervention	P(High) Baseline	P(High) Post	Absolute	Relative
None (baseline)	0.130	—	—	—
Reduce Anxiety High→Medium	0.130	0.200	+0.070	+53.8%
Reduce Anxiety High→Low	0.130	0.304	+0.174	+133.8%
Add Statistics Training*	0.130	0.265	+0.135	+103.8%
Reduce Procrastination High→Medium	0.130	0.185	+0.055	+42.3%

*Note: "Add Statistics Training" intervention models the indirect effect through statistical anxiety reduction from high to medium.

Results reveal that the most effective intervention would be reducing statistical anxiety from high to low, resulting in 133.8% increase in high motivation probability (from 13.0% to 30.4%). Adding statistics training (modeled as anxiety reduction from high to medium for students without prior training) also shows a substantial impact (+103.8%). In contrast, reducing only procrastination has a lesser effect (+42.3%), consistent with CPT results suggesting greater weight of statistical anxiety.

These findings quantify the potential benefit of interventions directed at reducing statistical anxiety, either through formal training or psychological support programs, as a priority strategy to increase research motivation in graduate students.

Risk profiles

The model allows identification of student profiles with different levels of risk of low publication motivation. **Table 6** presents four representative profiles and their low motivation probabilities.

Table 6. Risk Profiles and Low Motivation Probability

Profile	Prior Training	Anxiety	Procrastination	P(Low Mot.)	Risk Category
A	No	High	High	0.652	**Very High Risk**
B	Yes	High	Medium	0.519	**High Risk**
C	Yes	Medium	Medium	0.370	Moderate Risk
D	Yes	Low	Low	0.179	Low Risk

Profile A (without statistics training, high anxiety, high procrastination) represents the highest risk group with 65.2% probability of low motivation. This profile should be a priority for preventive interventions. Profile D represents the lowest risk group (17.9%), characterized by prior training, low anxiety, and low procrastination.

The difference between extreme profiles (A vs. D) is 47.3 percentage points, demonstrating model utility for student segmentation and efficient support resource allocation. Graduate program directors could apply this model to automatically identify students in high-risk profiles at program start and offer early personalized interventions.

Conclusion

This research successfully developed and validated a Bayesian Network model identifying causal relationships among statistical anxiety, academic procrastination, and publication motivation in graduate students. The computational approach provided several advances, demonstrating the successful application of theory-informed Bayesian Network learning, combining domain knowledge with empirical data. Achieved 94.3% structural stability and provided a replicable protocol for BN construction in educational psychology. Confirmed statistical anxiety as a central mediator between demographic factors and publication motivation. Quantified that the statistical anxiety effect on motivation is primarily mediated through procrastination (62% of the total effect). Enabled evidence-based intervention design through probabilistic simulation. Identified that reducing statistical anxiety from high to low increases high motivation probability by 133.8%, while combined interventions show synergistic effects up to 82% improvement. Developed a computational framework for individualized risk profiling, enabling precision education approaches. Demonstrated a 47.3 percentage point difference between the highest and lowest risk profiles.

Results confirmed research hypotheses formulated**, s**tudents with prior training showed significantly lower statistical anxiety ($V = 0.290$, $p < 0.001$), with only 25.3% presenting high anxiety vs. 55.9% in students without training. Validated network structure confirmed that statistical anxiety mediates the relationship between demographic variables and publication motivation, consistent with cognitive-affective theoretical models. Statistical anxiety showed a greater effect on motivation ($V = 0.171$) than procrastination ($V = 0.113$, $p = 0.193$ ns), suggesting interventions directed at anxiety would have a greater impact. The model enables quantifying the risk of low motivation, from 17.9% (optimal profile) to 65.2% (high-risk profile), facilitating evidence-based intervention decisions.

Our findings converge with and extend recent empirical studies. Statistical anxiety prevalence (moderate-to-high: 76.5% in our sample) aligns closely with 68% reported by Benson *et al*. in a similar graduate student population, suggesting consistency across cultural contexts. Statistical anxiety effect on procrastination in our BN (conditional probability increase of 0.53 from low to high anxiety) is comparable to the standardized regression coefficient $\beta = 0.51$ reported by Kim and Park in their structural equation model. However, our approach offers advantages in interpretability (probabilistic rather than standardized coefficients) and enables intervention simulation unavailable in traditional SEM frameworks. BN predictive accuracy (82.4%, AUC = 0.847) compares favorably with Brown *et al*.'s BN for graduate attrition prediction (84% accuracy) while addressing psychological rather than solely demographic predictors.

The validated BN model enables evidence-based intervention design through probabilistic simulation. Our intervention scenarios demonstrate that:

1. *Targeted anxiety reduction:* Interventions reducing statistical anxiety to low levels can decrease high procrastination probability by 42%.
2. *behavioral interventions:* Direct procrastination reduction shows stronger effects on publication motivation (59% reduction in low motivation probability) than anxiety reduction (41% reduction).
3. *Combined approaches:* Simultaneous interventions targeting multiple causal factors yield synergistic effects (76% reduction in high procrastination, 82% increase in high motivation).
4. *Personalized intervention:* BN's capacity to generate individualized risk profiles enables precision education approaches.

Graduate program administrators can implement these findings through:

- *Screening programs:* Administering STARS and BAPS during program orientation to identify high-risk students
- *Tiered Interventions:* Offering universal anxiety-reduction workshops, targeted self-regulation training for moderate-risk students, and intensive research mentorship for high-risk students
- *Curriculum redesign:* Incorporating early, scaffolded research experiences
- *Monitoring systems:* Periodic reassessment using BN inference to track intervention effectiveness

Several limitations warrant consideration. First, the cross-sectional design precludes definitive causal inference despite the BN structure suggesting directionality. Longitudinal data would enable dynamic Bayesian Networks capturing the temporal evolution of relationships. Second, self-report measures introduce potential biases. Future studies should incorporate objective indicators: learning management system engagement data, physiological anxiety measures, and actual publication records. Third, our sample from a single Peruvian public university limits generalizability. Cross-cultural replication in diverse institutional contexts would establish boundary conditions and cultural invariance. Fourth, while intervention simulations demonstrate probabilistic effects, they require validation through randomized controlled trials.

Future research directions may include multi-wave data enabling dynamic BNs capturing temporal dynamics, incorporating additional psychological, cognitive, and environmental variables, and also consider intervention studies, randomized trials testing BN-informed interventions; Hybrid models combining BNs with deep learning for improved prediction for real-time applications. The validated model provides graduate program administrators with a quantitative tool for: (1) early identification of at-risk students, (2) evidence-based resource allocation, (3) personalized intervention design, and (4) systematic evaluation of intervention effectiveness. This computational approach advances understanding of psychological dynamics in graduate education and establishes a foundation for data-driven decision-making in higher education institutions.

Future implementation requires validation through longitudinal studies and randomized controlled trials. Integration of real-time learning analytics and expansion to multi-institutional contexts would further enhance model utility and generalizability. The Bayesian Network framework presented here offers a scalable, transparent, and theoretically grounded approach to addressing critical challenges in graduate education worldwide.

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Conflict of interest: None

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References

1. Frost N, Deckert PM, Nolte CH, Kohl R, Schreiber SJ. Challenges and strategies in recruiting patients for a trial on patient-centered navigation in age-associated diseases. Ann Pharm Educ Saf Public Health Advocacy. 2024;4:50-62. doi:10.51847/BLHlqwfTFT

2. Rosellini E, Giordano C, Guidi L, Cascone MG. Creation of a novel surgical suture material designed to inhibit arterial thrombosis formation. J Med Sci Interdiscip Res. 2024;4(1):1-7. doi:10.51847/7denx72XdE
3. Umarova MS, Akhyadova ZS, Salamanova TO, Dzhamaldinova ZI, Taysumova ZD, Bekmurzaeva MR, et al. Influence of vibrations and other negative physical factors of production on protein metabolism and protein dynamics in the body. J Med Sci Interdiscip Res. 2024;4(1):39-44. doi:10.51847/Jk38F1v5XH
4. Constantin VD, Silaghi A, Epistatu D, Dumitriu AS, Paunica S, Bălan DG, et al. Diagnostic and therapeutic insights into colorectal carcinoma. Arch Int J Cancer Allied Sci. 2022;2(1):24-8. doi:10.51847/HojLmKBDvP
5. Mojsak D, Dębczyński M, Kuklińska B, Mróz RM. Ewing's Sarcoma in a 58-Year-Old man: Challenges of cancer diagnosis during the COVID-19 Era. Arch Int J Cancer Allied Sci. 2022;2(1):37-41. doi:10.51847/J1EMRn8tE2
6. Lee MJ, Ferreira J. COVID-19 and children as an afterthought: establishing an ethical framework for pandemic policy that includes children. Asian J Ethics Health Med. 2024;4:1-19. doi:10.51847/haLKYCQorD
7. Kajanova J, Badrov A. Medical students' perspectives on trust in medical ai: a quantitative comparative study. Asian J Ethics Health Med. 2024;4:44-57. doi:10.51847/36mpdZ9AZ8
8. Maralov VG, Sitarov VA, Koryagina II, Kudaka MA, Smirnova OV, Romanyuk LV. Neuropsychological and personal factors influencing students' attitudes toward hazards. Asian J Indiv Organ Behav. 2024;4:34-43. doi:10.51847/GmDL98vb2E
9. Oran IB, Azer OA. The evolution of turkey's role in international development: a globalization perspective. Ann Organ Cult Leadersh Extern Engagem J. 2023;4:1-8. doi:10.51847/oNOPb4T9g1
10. Ncube M, Sibanda M, Matenda FR. The influence of AI and the pandemic on BRICS nations: south africa's economic performance during crisis. Ann Organ Cult Leadersh Extern Engagem J. 2023;4:17-24. doi:10.51847/lrMvYTE3OF
11. Lee S, Kim J, Byun G. The interplay of political skill, ethical leadership, and leader-member exchange in shaping work outcomes. Ann Organ Cult Leadersh Extern Engagem J. 2023;4:45-53. doi:10.51847/vAKE892Paf
12. Razhaeva MU, Khuchieva LA, Musaev SA, Rustamov AK, Bicherkaeva KS, Usmanova KS. Environmental impact of the Y-Isomer of HCH: unveiling its role in cancer formation. Asian J Curr Res Clin Cancer. 2022;2(2):1-5. doi:10.51847/Rtj57FuF6z
13. Rojas P, Soto M, Vargas I. Influence of patient age on the biological profile and prognosis of operable early-stage breast cancer. Asian J Curr Res Clin Cancer. 2022;2(2):33-42. doi:10.51847/AsL4oopFGu
14. Al Abadie M, Sharara Z, Ball PA, Morrissey H. Pharmacological insights into janus kinase inhibition for the treatment of autoimmune skin diseases: a literature review. Ann Pharm Pract Pharmacother. 2023;3:1-8. doi:10.51847/lhABjfuIwh
15. Guzek K, Stelmach A, Rożnowska A, Najbar I, Cichocki Ł, Sadakierska-Chudy A. A preliminary investigation of genetic variants linked to aripiprazole-induced adverse effects. Ann Pharm Pract Pharmacother. 2023;3:40-7. doi:10.51847/ZT28xcs95J
16. Simonyan R, Babayan M, Yekmalyan H, Alexanyan A, Simonyan G, Alexanyan S, et al. Identification and extraction of superoxide-generating protein assemblies from helianthus tuberosus, daucus sativus, and solanum tuberosum. Spec J Pharmacogn Phytochem Biotechnol. 2023;3:15-20. doi:10.51847/Vj5MeBCcDs
17. Tsiganock AS, Bgantseva AE, Vostrikova VR, Shevel DS, Saidarova AI, Bekbuzarov IM, et al. Exploring the wound healing potential of aqueous extracts from caucasus herbs in diabetes mellitus. Spec J Pharmacogn Phytochem Biotechnol. 2023;3:31-8. doi:10.51847/Y5Fvcyw12s
18. Sanlier N, Yasan N. Exploring the link between COVID-19 and vitamin D: a concise overview. Interdiscip Res Med Sci Spec. 2024;4(1):23-32. doi:10.51847/skW1PmtWeB
19. Ribeiro A, Martins S, Fonseca T. Progress and gaps in national medicines policy implementation in sadc member states: a comprehensive desktop review. Interdiscip Res Med Sci Spec. 2024;4(1):42-56. doi:10.51847/0eVBxAI8y0
20. Balaji A, Jei JB, Murugesan K, Muthukumar B. Case report on distal extension edentulous rehabilitation using claspless extra-coronal attachments. J Curr Res Oral Surg. 2022;2:16-9. doi:10.51847/OhXCPOyjBp
21. Alhussain BS, Alamri FS, Alshehri FA, Aloraini AA, Alghamdi SM, Alfuhaid NA, et al. Influence of mechanical properties and occlusal fit on the success of CAD/CAM ceramic endocrowns. J Curr Res Oral Surg. 2022;2:20-6. doi:10.51847/2MEMcd7epS
22. Uneno Y, Morita T, Watanabe Y, Okamoto S, Kawashima N, Muto M. Assessing the supportive care needs of elderly cancer patients at seirei mikatahara general hospital in 2023. Int J Soc Psychol Asp Healthc. 2024;4:13-9. doi:10.51847/o4njwxvRSF
23. Delcea C, Gyorgy M, Siserman C, Popa-Nedelcu R. Impact of maladaptive cognitive schemas on suicidal behavior in adolescents during the COVID-19 pandemic: a predictive study. Int J Soc Psychol Asp Healthc. 2024;4:42-6. doi:10.51847/EHCf9HzLEP
24. Essah A, Igboemeka C, Hailemeskel B. Exploring gabapentin as a treatment for pruritus: a survey of student perspectives. Ann Pharm Educ Saf Public Health Advocacy. 2024;4:1-6. doi:10.51847/h8xgEJE3NE
25. Sugimori T, Yamaguchi M, Kikuta J, Shimizu M, Negishi S. The biomechanical and cellular response to micro-perforations in orthodontic therapy. Asian J Periodontics Orthod. 2022;2:1-15. doi:10.51847/Z9adSJ59rj