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Latent profiles of perceptions of formative experiences associated with mathematics anxiety among prospective teachers

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ABSTRACT

This study explored latent class patterns in 100 Chilean prospective mathematics teachers' perceptions of formative experiences associated with mathematics anxiety (MA) and examined whether the classes differed in MA, affect, and beliefs. Responses to three open-ended questions were inductively coded into thematic categories and transformed into dichotomous indicators for separate latent class analyses. Model-selection evidence was mixed: conservative criteria favored one-class models, whereas other indices variably supported more complex solutions. Two-class solutions were retained as exploratory descriptive representations. They distinguished patterns involving assessment and self-perceived learning, pedagogical interaction and teaching methodology, and anxiety relief through academic support or self-regulation. Two nominally significant unadjusted group differences were observed, but neither remained significant after Holm correction. The findings suggest heterogeneous interpretations of formative experiences associated with MA; however, limited class stability warrants cautious interpretation and independent replication.

Keywords: mathematics anxiety, initial teacher education, exploratory latent classes, self-efficacy, self-regulation

INTRODUCTION

Mathematics anxiety (MA) has received increasing attention in educational research because of its relationship with self-efficacy beliefs, attitudes toward mathematics, and learning experiences in this discipline. In initial teacher education (ITE), this phenomenon is particularly relevant, as prospective teachers not only learn mathematical content but also construct dispositions, beliefs, and ways of relating to mathematics that may be projected into their future professional practice (Beilock et al., 2010; Gresham, 2018; Lavidas et al., 2023; Lu et al., 2025; Olson & Stoehr, 2019; Stoehr, 2017). Therefore, understanding how prospective teachers experience and attribute meaning to MA is a relevant issue for mathematics teacher education.

Prospective mathematics teachers occupy a distinctive dual position: they are current learners of disciplinary mathematics and future professionals learning to teach it (Olson & Stoehr, 2019; Stoehr, 2017). Their experiences of MA are intertwined with their mathematical histories, efficacy beliefs, professional identities, and experiences of learning to teach (Gresham, 2018; Olson & Stoehr, 2019; Stoehr, 2017). This position is educationally consequential because MA may persist into professional practice and affect how teachers approach mathematics instruction; in some contexts, teachers' MA has also been associated with students' beliefs and achievement (Beilock et al., 2010; Gresham, 2018). Because prospective teachers are still immersed in teacher education, their perceptions are particularly relevant for preventive interventions involving instruction, assessment, feedback, and academic support (Gresham, 2021; Stoehr & Olson, 2023).

Although MA has traditionally been studied as a psychological construct associated with emotional and cognitive responses to mathematical situations (González-Gómez et al., 2023), in the context of ITE it can also be understood as a pedagogically situated experience. MA among prospective teachers does not emerge in isolation, but rather in relation to formative experiences, beliefs about one's own ability, assessment practices, teaching methodologies, and forms of pedagogical interaction (Beisly et al., 2025; Bosica, 2022; McMinn & Aldridge, 2020; Stoehr, 2017; Uddin, 2022). In particular, within initial teacher education programs, the literature has associated MA with experiences of high assessment pressure, public exposure of error, accelerated teaching pace, lack of clarity in assessment criteria, and limited opportunities for feedback (O'Hara et al., 2022; Richland et al., 2020). In contrast, teacher support, formative feedback, peer collaboration, normalization of error, and the strengthening of self-efficacy

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have been identified as relevant conditions for mitigating MA in formative contexts (Bosica, 2022; McMinn & Aldridge, 2020; Tassell et al., 2020). In this sense, MA is not reduced solely to individual characteristics of students, but is configured in interaction with assessment practices, classroom dynamics, forms of feedback, and pedagogical relationships embedded in the formative experience. From this perspective, it is relevant to examine how prospective teachers interpret the pedagogical conditions they associate with the intensification or relief of MA (Basso, 2019).

Although these studies have advanced the understanding of MA in ITE, further evidence is still needed on how prospective teachers themselves interpret the pedagogical conditions they associate with their mathematics anxiety. Previous studies have shown that narratives and self-reported experiences of prospective teachers allow researchers to understand how MA is linked to school trajectories, beliefs about one's own ability, and expectations about teaching (Olson & Stoehr, 2019; Stoehr, 2017). Moreover, experiences of MA do not necessarily manifest homogeneously among prospective teachers. While some may associate their anxiety mainly with assessment conditions, others may attribute it to dynamics of pedagogical interaction, previous experiences of failure, or difficulties in self-regulation. This perspective is relevant because students' perceptions make it possible to identify dimensions of the formative experience that may remain less visible in studies focused exclusively on psychometric scales, particularly those related to classroom climate, pedagogical interaction, and learning conditions (McMinn & Aldridge, 2020; O'Hara et al., 2022). Therefore, exploring whether students' responses can be summarized through latent class patterns may help identify heterogeneous ways of interpreting formative conditions associated with mathematics anxiety, without assuming that these patterns necessarily represent stable or naturally occurring subpopulations.

Within this framework, the present study explores latent class patterns in prospective mathematics teachers' perceptions of formative experiences they associate with the intensification or relief of MA in disciplinary courses. It also examines, on an exploratory basis, whether students assigned to these classes differ in reported levels of mathematics anxiety, affect, and associated beliefs.

The research questions guiding this study are:

a) What exploratory latent class patterns characterize prospective mathematics teachers' perceptions of formative experiences associated with mathematics anxiety?

b) What descriptive differences in mathematics anxiety, affect, and associated beliefs are observed between the estimated classes?

Answering these questions contributes to research on mathematics teacher education by providing evidence on how prospective teachers interpret formative conditions associated with MA. In addition, the findings may inform the revision of assessment practices, teaching methodologies, academic support mechanisms, and strategies aimed at strengthening self-efficacy and self-regulation in mathematical learning.

THEORETICAL FRAMEWORK AND BACKGROUND

Although MA has traditionally been defined as an emotional and cognitive response to mathematical situations, evidence from initial teacher education shows that its development and manifestation also depend on pedagogical and formative experiences. In this section, we present MA as a psychological construct that is shaped during teacher education, where formative conditions such as assessment practices, classroom dynamics, forms of feedback, and previous school trajectories may foster, sustain, or mitigate the experience of mathematics anxiety.

Psychological Constructs Associated with MA

Mathematics anxiety

MA is a key variable in mathematical performance, defined as a feeling of tension or fear that interferes with academic achievement and with the manipulation of numbers and problem solving (Ashcraft, 2002; Richardson & Suinn, 1972). It manifests through symptoms such as nervousness, restlessness, confusion, and mental blocks (Tobias & Weissbrod, 1980). High levels of MA interfere with inhibitory processes, making it more difficult to suppress intrusive thoughts, affecting processes involved in mathematical learning and, potentially, the development of professional competencies related to mathematics teaching (Weyers et al., 2024). Hembree (1990) showed that reducing MA is associated with higher academic achievement, a finding supported by Zhang et al. (2019), who identified a significant negative correlation ($r = -.32$), and by Antón-Sancho (2023), who reported a negative correlation between anxiety and mathematics performance among prospective teachers ($r = -.30$). In addition, MA negatively affects mathematical attitudes (−.47 to −.82) and promotes avoidance of activities related to this discipline, generating negative self-perceptions and limited learning (Ashcraft & Ridley, 2005).

MA, self-efficacy, and self-concept are interconnected in ITE (Tassell et al., 2020). In this regard, Olson and Stoehr (2019) suggest that MA and mathematics teaching anxiety may be similar. That is, prospective teachers perceive a logical continuity and cumulative effect of their experiences of MA as students throughout their school trajectories, which may influence their practices as mathematics educators (Chandia et al., 2024). This relationship has led to the development of the concept of mathematics teaching anxiety (MTA). Although MTA is not addressed in the present study, evidence indicates that MA and MTA are positively related (Patkin & Greenstein, 2020).

Self-efficacy and mathematical beliefs

The literature reports a significant negative relationship between self-efficacy, understood as a belief, and MA, implying that high levels of MA are usually associated with a low perception of personal capability (Danan & Ashkenazi, 2022; Jameson et al., 2024; Morán-Soto & González-Peña, 2022). This link is particularly relevant in ITE, where high levels of MA are associated with lower performance in professional tasks such as the design of mathematical tasks (Gonzalez-DeHass et al., 2017; Russo et al., 2025; Stoehr, 2017). In addition, low beliefs in one's own capability increase anxiety and reduce performance (Thiel & Jenssen, 2018).

Among prospective teachers, greater cognitive flexibility and a stronger disposition toward critical thinking are negatively associated with MA (correlations ranging approximately from $r = -.49$ to $-.56$) and positively associated with achievement. Moreover, MA shows a direct negative effect on performance (Göçer & Özeren, 2025). Structural equation models confirm these patterns and indicate that these dispositions partially mediate the relationship between cognitive resources and achievement, attenuating MA in the process (Gökçe & Güner, 2024).

MTA is negatively correlated with teaching self-efficacy: feeling greater anxiety about teaching is associated with a lower belief in one's own ability to influence students' learning (Göçer & Özeren, 2025; Patkin & Greenstein, 2020).

Pedagogical and Formative Conditions Associated with MA

Factors that foster mathematics anxiety

From a theoretical perspective, MA has a multifactorial origin that combines personal, cognitive, affective, and contextual dimensions. Numerous studies have shown that negative school experiences—particularly those marked by rigid methodologies, punitive assessment practices, and public exposure of errors—constitute a critical antecedent in the development of MA among prospective teachers (Beilock et al., 2010; Finlayson, 2014; Uddin, 2022). These early experiences generate an emotional threat response toward mathematics, which tends to be reactivated during teacher education, affecting both dispositions toward learning and expectations about teaching (Gresham, 2021; Olson & Stoehr, 2019; Szczygieł, 2022a).

A second set of factors that may exacerbate MA is related to negative beliefs and attitudes toward mathematics (Szczygieł, 2022b). These beliefs include low mathematical self-concept, understood as an unfavorable perception of one's own mathematical competencies. This situation is reinforced through previous negative experiences, generating a sense of anticipated failure when facing the discipline (Beisly et al., 2025; Işıksal et al., 2009). In addition, low mathematical self-efficacy—that is, limited confidence in one's own ability to learn—has been observed to play a key role in deepening this anxiety (Bosica, 2022; Gresham, 2018; Tassell et al., 2020). Complementarily, the presence of a fixed mindset, which conceives mathematical ability as innate and unchangeable, intensifies frustration in the face of difficulties and perpetuates feelings of insecurity (Tassell et al., 2020).

At the pedagogical level, MA tends to intensify in instructional environments characterized by high assessment pressure, accelerated pacing, and low coherence between teaching and assessment (Bosica, 2022; O'Hara et al., 2022; Uddin, 2022). Practices centered on individual exposure, peer comparison, and public correction increase negative emotional activation and reduce students' sense of control (Maloney et al., 2015). Conversely, environments that promote emotional support, formative feedback, and a safe classroom climate mitigate anxiety and improve academic engagement (O'Hara et al., 2022; Richland et al., 2020).

Finally, insufficient didactic preparation in ITE also contributes to MA, both in its learning and teaching dimensions. Research reports that theoretical training without practical experiences or reflective support may maintain or even increase mathematics teaching anxiety (Antón-Sancho, 2023; Gresham, 2018; McMinn & Aldridge, 2020; Stoehr, 2017). These findings point to the need for more situated teacher education programs, where prospective teachers can reconstruct their beliefs and emotions toward mathematics through successful experiences and communities of practice.

Factors that mitigate mathematics anxiety

From a positive perspective, several studies have identified instructional and formative levers that reduce MA among prospective teachers. First, active methodologies—such as the systematic use of manipulatives, collaborative problem solving, explicit teacher modeling, and guided discussion—are associated with lower MA and higher self-efficacy, especially when tasks are transparent and error is normalized as part of learning (Bosica, 2022; O'Hara et al., 2022; Tassell et al., 2020). Timely formative feedback, anchored in clear criteria and understandable rubrics, decreases assessment-related threat and promotes participation, with observable effects on prospective teachers' confidence (Sears et al., 2022; Stoehr, 2017). Complementarily, alignment between teaching and assessment, as well as an instructional pace adjusted to students' actual progress, reduces uncertainty and overload, thereby mitigating MA (Beisly et al., 2025).

Second, socioemotional development and classroom climate play a central role. Safe, collaborative, and dialogic environments, together with explicit high expectations and sensitive teacher support, are associated with lower levels of MA and better performance among prospective teachers (O'Hara et al., 2022). In ITE, this effect operates through sociocognitive pathways: teacher educators' expectations shape the type of feedback provided, the structuring of tasks—gradual, based on clear criteria, and aligned with assessment—and the emotional framing of error as a learning resource. These conditions may buffer the threat response, increase self-efficacy, and reduce both MA and MTA among prospective teachers (Gresham, 2018; McMinn & Aldridge, 2020; O'Hara et al., 2022; Patkin & Greenstein, 2020).

Third, interventions that strengthen adaptive beliefs are also relevant. Mathematical self-efficacy emerges as a key mediator in the relationship between MA and performance. Programs that combine mastery experiences, expert modeling, and effort-based attributions can increase self-efficacy and thereby reduce MA (Bosica, 2022; Patkin & Greenstein, 2020). Promoting a growth mindset helps students reinterpret difficulties as challenges that can be overcome, supporting persistence and adaptive coping

(Tassell et al., 2020). In ITE, evidence suggests that situated practice experiences may reduce MA more consistently than purely theoretical courses; however, their sustainability at the beginning of professional practice is heterogeneous, which highlights the need to articulate ongoing support (Boyd et al., 2014; Gresham, 2018; Uddin, 2022).

Finally, the scope of very brief interventions should be treated with caution. For example, expressive writing before demanding tests has not shown robust effects in recent trials in higher education and has even been associated with punctual increases in state anxiety. This suggests that sustained reductions in MA require more extensive designs, integrated into the curriculum and the assessment ecosystem (Brunyé et al., 2013; O'Hara et al., 2022). Thus, sustained reduction of MA requires broader strategies embedded in the curriculum and in assessment practices within teacher education.

Based on this framework, the present study distinguishes between conceptual constructs and operational dimensions. Conceptually, MA is understood as an affective-cognitive experience linked to learning, assessment, public exposure, and everyday uses of mathematics. Operationally, these manifestations are examined through specific subscales of anxiety toward learning mathematics, anxiety toward mathematics assessment, anxiety toward public evaluation, anxiety toward observing mathematics, and everyday/social mathematics anxiety. Complementarily, beliefs and dispositions toward mathematics are operationalized through indicators of positive affect, negative affect, and self-concept/self-efficacy beliefs in mathematics.

Consequently, this study does not seek to establish causal relationships between formative practices and mathematics anxiety. Rather, it aims to identify students' perception patterns regarding experiences they associate with the intensification or relief of anxiety.

METHODOLOGY

This study adopts a quantitative design that incorporates inductive coding of open-ended responses for the construction of categorical variables. The textual responses were coded into emergent thematic categories and subsequently transformed into dichotomous presence/absence indicators, which were used as inputs for latent class analysis (Chandía & Saadati, 2026).

Sample

The population consisted of students enrolled in a Secondary Mathematics Teacher Education program at a higher education institution in Chile. The sample was selected through intentional non-probabilistic sampling. The initial sample comprised 216 students, of whom 204 provided informed consent. During the data identification stage, 152 students completed the information required to construct the database. Of the total number of respondents, 100 students fully completed the questionnaire and constituted the final analytical sample. These students were in the third and fourth years of a five-year program, and the sample included 52 women and 48 men, corresponding to 46.3% of the total 216 students enrolled in the program. Incomplete responses were removed from the analyses. All participants signed the informed consent form before completing the instrument. All documents and procedures were reviewed and approved by the Ethics Committee of the University of Concepción.

Instrument

The instrument consisted of two sections: (A) three open-ended questions aimed at exploring perceptions of MA in disciplinary courses within initial teacher education, and (B) two specific scales on MA.

The three OQs were developed by the research team for this study to elicit qualitative perceptions and were not treated as a validated psychometric scale. Participants responded with reference to disciplinary mathematics courses taken across the program rather than to a single designated course, and they were not asked to identify a specific course. The three open-ended questions (OQs) sought to explore prospective teachers' perceptions of their teacher educators' practices and of the characteristics of mathematics courses that influence their level of anxiety. The questions were as follows: OQ1: "What characteristics of the courses do you think cause you anxiety?"; OQ2: "What practices or actions carried out by your professors in these courses do you think have increased your anxiety toward the courses?"; and OQ3: "What actions or practices in the courses do you think have relieved your anxiety?"

The two MA scales were Likert-type instruments whose psychometric validity had been previously evaluated. The MA Scale (MAS) comprises 22 items associated with experiences that may cause tension or apprehension in mathematics courses taken during teacher education, as well as in everyday situations. It includes five dimensions: anxiety toward learning mathematics (ALM), related to study and learning activities in mathematics and statistics in educational contexts (Plake & Parker, 1982); anxiety toward mathematics assessment (AMA), associated with fear of taking or receiving the results of mathematics exams (Núñez-Peña et al., 2013); anxiety toward public evaluation (APE), referring to the evaluation of mathematical ability, including performing calculations in front of others (Hunt et al., 2011); anxiety toward observing mathematics (AOM), associated with observing mathematics without direct calculation (Hunt et al., 2011); and everyday/social MA (ESMA), referring to calculations that occur in everyday situations (Hunt et al., 2011).

The Mathematics Anxiety and Beliefs Scale (MABS) is a 12-item Likert-type scale. It comprises three dimensions: positive affect (PA) and negative affect (NA), whose statements describe feelings of anxiety, fear, nervousness, and bodily symptoms associated with mathematical activity (Fennema & Sherman, 1976); and self-concept and mathematical self-efficacy beliefs (BEL), which describe perceptions related to mathematical self-concept and self-efficacy. In this study, these are considered beliefs associated with the experience of mathematics anxiety. Their items are consistently associated with negative attitudes and mathematical performance, while also reducing the overlap between MA and other domains of anxiety (Pizzie & Kraemer, 2019). In particular, the PA and BEL scores were reverse-coded for measurement and model fit estimation purposes. The scale dimensions are not

assumed to be exhaustive theoretical subconstructs of mathematics anxiety, but rather operational indicators that make it possible to observe different manifestations of the construct and associated beliefs.

A three-phase psychometric process was carried out to establish the validity and reliability of the two Likert-type scales: (a) exploratory factor analysis to examine latent dimensionality, (b) confirmatory factor analysis (CFA) to test the theoretical structure, and (c) internal consistency estimates using Cronbach's alpha (α) and Guttman's (1945) lower bounds. Model fit was assessed using χ^2, the Tucker–Lewis Index (TLI), the Comparative Fit Index (CFI), the Root Mean Square Error of Approximation (RMSEA), and the Bayesian Information Criterion (BIC), assuming TLI/CFI ≥ .90 as acceptable criteria (optimal ≥ .95; Hu & Bentler, 1999) and RMSEA < .08 as acceptable (optimal < .05; Schermelleh-Engel et al., 2003).

For the MAS, the CFA showed adequate fit, $\chi^2(199) = 284.74$, $p < .001$; TLI = .907; CFI = .920; RMSEA = .066, and high total reliability (α = .91). By subscale, the Guttman lower bounds and Cronbach's alpha were as follows: ALM, $.47 - .70$; $\alpha = .70$, AMA, .78–.93; α = .90, while APE and AOM showed intermediate-to-high values (.65–.89 and .62–.88, with α = .87 and α = .82 respectively), and ESMA showed intermediate values (.53–.79; α = .79). For the MABS, model fit was also satisfactory, $\chi^2(51) = 75.35$, $p = .015$; TLI = .913; CFI = .933; RMSEA = .069, with acceptable total reliability (α = .85) and moderate-to-adequate values by subscale: NA (.51–.77; α = .77), PA (.61–.75; α = .77), and BEL (.56–.79; α = .75). Overall, these findings support the factorial validity and internal consistency of both scales, consistent with psychometric standards reported in the literature (Hu & Bentler, 1999; Schermelleh-Engel et al., 2003).

Procedure

Between June and August 2025, the instrument was administered through an online survey platform. The invitation was sent to each student's institutional email address and included a unique access link. The questionnaire could be completed using computers or mobile devices. Before beginning the survey, participants were informed about the purpose of the research and the relevance of the study; participation was voluntary, and informed consent was obtained electronically. The average response time was 17 minutes. The database used for the analyses included only questionnaires that had been fully submitted at the end of the application.

Data Analysis

Data analysis was conducted in four stages: (a) inductive coding of the open-ended responses; (b) transformation of the emergent categories into dichotomous student–category matrices; (c) estimation of latent class models; and (d) comparison of the profiles according to the subscales of mathematics anxiety, affect, and associated beliefs.

(a) Inductive coding of open-ended responses. The open-ended responses were inductively coded by two research assistants. The first 10% of responses served as a diagnostic calibration phase, during which both coders independently applied the initial set of emergent categories and obtained 69% raw agreement. Because this value was below the commonly accepted 80% benchmark (Bradley et al., 2007), disagreements were reviewed to clarify category definitions, coding boundaries, and decision rules before continuing. Independent coding of the following 20% produced 83% agreement, and agreement reached 93% for the remaining responses after the coding scheme had stabilized. Disagreements were resolved through discussion between the coders and, when necessary, review by the research team. These percentages represent raw agreement and do not account for agreement expected by chance; therefore, they should be interpreted as evidence of progressive coder calibration rather than as a chance-corrected reliability coefficient.

(b) Transformation of emergent categories into matrices. Once the category system had been stabilized, an incidence matrix was constructed for each open-ended question. In these matrices, each row corresponded to a student and each column to an emergent thematic category. A value of 1 was assigned when the student's response included sufficient textual evidence of the category, and a value of 0 was assigned when the category was not present. This procedure made it possible to transform open-ended responses into dichotomous categorical indicators suitable for latent class analysis.

(c) Latent class analysis. Separate Bernoulli latent class models were estimated for the dichotomous indicator matrices derived from OQ1, OQ2, and OQ3. For each question, solutions ranging from one to four classes were examined. Models with more than one class were estimated using 1,000 random initializations to reduce the risk of retaining a local maximum. Model comparison considered the log-likelihood, AIC, BIC, sample-size-adjusted BIC, CAIC, normalized entropy, class sizes, replication of the maximum log-likelihood, and the presence of boundary parameters. The one- and two-class solutions were additionally compared using a parametric bootstrap likelihood-ratio test based on 199 bootstrap samples and 50 initializations per bootstrap fit. Local independence was examined using bivariate Pearson residuals, and classification stability was evaluated through 300 nonparametric bootstrap samples. Because the model-selection criteria did not identify a single preferred solution, the two-class models were retained as the lowest-complexity multiclass representations yielding substantively interpretable contrasts. They were treated as exploratory descriptive summaries rather than as evidence of confirmed latent subpopulations.

All 100 participants were retained in the primary analysis for each open-ended question. An all-zero indicator vector was treated as a valid observed response pattern indicating that none of the retained categories had been identified, rather than as missing information. Before model estimation, responses producing all-zero vectors were checked against the original text. This audit resulted in coding one OQ2 response for course pace and another OQ2 response for professional coherence and academic overload. Analyses excluding all-zero response patterns were treated as sensitivity analyses.

(d) Comparison between profiles. Once students had been assigned to the latent class with the highest posterior probability of membership, scores on the subscales ALM, AMA, APE, AOM, ESMA, PA, NA, and BEL were compared between the profiles derived from each open-ended question. Class comparisons derived from OQ1 were conducted using Mann–Whitney–Wilcoxon tests. Comparisons derived from OQ2 and OQ3 were conducted using pooled-variance independent-samples *t* tests. Holm-adjusted

Table 1. Fit and classification indices for the one- and two-class solutions

OQ	n	K	AIC	BIC	SABIC	CAIC	Entropy	Boundary parameters	Replicated maximum
OQ1	100	1	1028.531	1067.608	1020.234	1082.608	—	0	—
OQ1	100	2	1027.416	1108.177	1010.271	1139.177	.695	6	59.1%
OQ2	100	1	771.353	797.404	765.822	807.404	—	0	—
OQ2	100	2	771.623	826.332	760.009	847.332	1.000	4	30.1%
OQ3	100	1	706.100	729.547	701.123	738.547	—	0	—
OQ3	100	2	701.948	751.446	691.439	770.446	1.000	5	16.2%

Note: SABIC = sample-size-adjusted Bayesian information criterion; CAIC = consistent Akaike information criterion. Boundary parameters were defined as conditional probabilities ≤ .001 or ≥ .999. Replication indicates the percentage of 1,000 random initializations that reproduced the maximum log-likelihood within 10^{-6}. BLRT results for K1 versus K2 were $p = .120$, $p = .190$, and $p = .045$ for OQ1, OQ2, and OQ3, respectively.

values (Holm, 1979) were calculated from the unrounded values across all 24 comparisons. Because these analyses relied on modal class assignment and did not adjust for classification uncertainty, they were interpreted as descriptive.

Psychometric analyses, latent class models, bootstrap diagnostics, and group comparisons were conducted in R version 4.5.0 (R Core Team, 2025). Bernoulli latent class models were estimated using a custom expectation–maximization routine. All random procedures used seed 20260814.

RESULTS

The results are presented in two stages, aligned with the research questions. First, the exploratory latent classes derived from the open-ended responses to OQ1, OQ2, and OQ3 are reported. These profiles characterize how students perceive formative experiences associated with the intensification or relief of mathematics anxiety. Second, levels of mathematics anxiety, affect, and associated beliefs are compared across the identified profiles to estimate the magnitude and direction of differences between classes.

Exploratory Latent Classes of Perceptions Associated with MA

Table 1 presents the fit and classification indices for the one- and two-class solutions retained for detailed comparison. The complete results for solutions ranging from one to four classes are reported in **Supplementary Table S1**.

Model-selection criteria provided mixed evidence. BIC and CAIC favored the one-class solution for all three questions. For OQ1, AIC slightly favored K2 over K1 (1027.416 vs. 1028.531), whereas the BLRT did not support the addition of a second class ($p = .120$). For OQ2, AIC slightly favored K1 over K2 (771.353 vs. 771.623), whereas SABIC favored K2; the BLRT was not statistically significant ($p = .190$). For OQ3, K2 improved AIC and SABIC relative to K1, and the BLRT nominally favored K2 at the conventional .05 threshold ($p = .045$). However, across the complete K1–K4 comparison, AIC was marginally lower for K3 than for K2 (701.840 vs. 701.948), SABIC continued to decrease through K4, and BIC and CAIC favored K1. Accordingly, the two-class solutions were retained as parsimonious and substantively interpretable exploratory representations rather than as confirmed population structures.

Solutions with three or four classes were not retained because their additional complexity generated numerous boundary probabilities and, in some cases, small classes without sufficiently clear substantive gains. Considering the exploratory purpose of the study, the interpretability of the conditional-response patterns, and the greater parsimony of K2 relative to K3 and K4, two-class solutions were retained for descriptive examination. This decision should not be interpreted as confirmation that the underlying populations are composed of two discrete and stable subgroups.

Bootstrap analyses indicated limited stability of the specific class partitions. Median adjusted Rand indices were .119 for OQ1, .202 for OQ2, and .033 for OQ3. One of the 300 OQ2 bootstrap replications did not converge; no nonconvergence was observed for OQ1 or OQ3. These results indicate that the specific class partitions were not consistently recovered and should be interpreted as sample-dependent descriptive summaries.

The response matrices were sparse. OQ1 contained 53 distinct response patterns among 100 participants, including 39 patterns observed only once. OQ2 contained 35 patterns among 100 participants, including 21 singleton patterns, whereas OQ3 contained 28 patterns among 100 participants, including 15 singleton patterns. Bivariate Pearson residuals greater than 3.84 were observed for four indicator pairs in OQ1, one pair in OQ2, and one pair in OQ3. Detailed pattern frequencies and bivariate residuals are provided in **Supplementary Tables S2** and **S3**.

Sensitivity analyses excluding all-zero response patterns retained 98 participants for OQ1, 90 for OQ2, and 96 for OQ3. Modal classifications agreed with the primary all-case solution for 91.8% of the common cases in OQ1 and for 100% of the common cases in OQ2 and OQ3. For OQ3, the BLRT changed only marginally, from $p = .045$ in the primary analysis to $p = .050$ after excluding the four all-zero patterns, while modal classifications were identical for the common cases. Thus, excluding the all-zero patterns did not materially alter the profile solution, although statistical support for K2 remained borderline.

Table 2 presents the emergent thematic categories, their operational descriptions, and the conditional probabilities of the presence of each category within the latent classes estimated for OQ1 and OQ2. Higher values indicate categories with greater relative weight in the substantive characterization of each profile.

Table 2. Thematic categories and conditional probabilities by latent class (OQ1 and OQ2)

Category	Description	Class OQ 1		Class OQ 2	
		C_1 $n = 57$	C_2 $n = 43$	C_3 $n = 73$	C_4 $n = 27$
Teaching strategies	Perceptions regarding the orientation of teaching processes.	.080	.278	—	—
Course approach	References to the perceived difficulty of the course or to an approach focused excessively on mathematical content, with limited pedagogical connection.	.087	.049	—	—
Course reputation	References to the general perception of a course, either because of its high failure rates or because of the professor who teaches it.	.000	.154	—	—
Self-efficacy	Students' perceptions of their own ability to face and overcome academic challenges.	.032	.203	—	—
Contextual factors of the course	Factors external to the course itself, linked to academic organization, teaching modality, and the student's social environment.	.113	.150	—	—
Student-perceived content overload	Perception that the amount of content covered in the course is excessive in relation to the time available or the number of weekly class hours.	.331	.000	—	—
Administrative conditions of assessment	References to the institutional planning of assessments, including the number of exams, their weighting, and their temporal distribution.	.274	.200	—	—
Assessment methodology	Perceptions of the forms of assessment used by the professor, highlighting a lack of transparency or clarity in assessment criteria.	.044	.167	—	—
Assessment structure	References to the length, coverage, format, or perceived complexity of assessments, as well as their weighting in the final grade.	.459	.000	.110	.000
Teaching methodology	Evaluations of the didactic model implemented by the professor and its impact on understanding, confidence, or the dynamics of the learning environment.	.000	.154	.000	1.000
Professional coherence	Perceptions of the professor's professional competence, both in organizational and attitudinal terms, including responsibility, consistency, and preparation.	.047	.054	.164	.222
Awareness of students' needs	Evaluations of the professor's ability to incorporate students' trajectories, prior knowledge, and needs into the teaching process.	.051	.092	.096	.333
Academic overload	Perception of an excessive load of assignments, tasks, or materials, which makes time management and self-regulation of learning more difficult.	.000	.132	.123	.074
Course pace	Judgments about the speed at which content is covered in class, either perceived as too fast or poorly adjusted to the pace of the group.	.000	.132	.151	.074
Feedback	Perception of the absence or scarcity of effective feedback on academic performance, such as delays in the return of grades or lack of opportunities for review.	.034	.091	.110	.037
Assessment models	Evaluations of the coherence and adequacy of the assessment models used, including possible methodological shortcomings or lack of alignment with the content addressed.	—	—	.123	.111
Teacher expectations of students	Perceptions of the expectations expressed by the professor toward students when these generate insecurity or pressure in the learning process.	—	—	.110	.000
Quality of course materials	Judgments about the quality of the study materials provided in the course, such as illegible notes, outdated materials, or insufficient pedagogical resources.	—	—	.096	.074

Perception profiles regarding course characteristics that elicit anxiety

Regarding OQ1, "What characteristics of the courses do you think cause you anxiety?", profile C1 was labeled "Assessment-Centered Anxiety." This profile groups students (n = 57) whose responses show a higher probability of referring to assessment-centered aspects of mathematics courses. The most prominent conditional probabilities corresponded to assessment structure, $P(Y_j = 1 \mid C = 1) = .459$, student-perceived content overload, $P(Y_j = 1 \mid C = 1) = .331$, and administrative conditions of assessment, $P(Y_j = 1 \mid C = 1) = .274$.

For example, students referred to the "*very large amount of content taught in a single course*" (E38, E56, E61, E67, E82), dependence on *"only two assessments to pass the course"* (E56, E60, E67), and assessments in which *"exercises usually seen in class or in practice sessions are included; however, more complex exercises have also been assessed"* (E62). These aspects generate uncertainty about what will be assessed and how. Such conditions are perceived by students as associated with overload, uncertainty, and academic pressure, configuring an assessment-centered anxiety profile. This profile is not characterized by self-perception of learning or internal beliefs about one's own abilities, which are more distinctive of Profile C2.

The second profile, C2, labeled "Anxiety Centered on Self-Perception of Learning," includes students (n = 43) whose responses refer mainly to their personal perceptions of learning mathematics. This pattern was reflected in teaching strategies, $P(Y_j = 1 \mid C = 2) = .278$, self-efficacy, $P(Y_j = 1 \mid C = 2) = .203$, and administrative conditions of assessment, $P(Y_j = 1 \mid C = 2) = .200$. Unlike Profile C1, the latter refers mainly to the frequency of assessments within short time periods rather than to their weighting.

These students mentioned that the *"too abstract"* nature of the content (E1), *"excessive lecture-based classes"* (E1, E12), and the *"lack of practical classes*" (E9, E50) generate concern about not adequately understanding the topics. They also stated that one factor that causes anxiety is *"lack of confidence regarding knowledge or mastery of content before assessments"* (E27), as well as *"uncertainty about whether what I do is right or wrong […] due to the limited office hours and time available from professors"* (E59). This can be interpreted as a perception of lower confidence in one's own mathematical performance. In addition, students highlighted that *"having a large number of assessments in the same week"* (E27) exacerbates their anxiety. Overall, in this group,

Table 3. Thematic categories and conditional probabilities by latent class (OQ3)

Category	Description	Class OQ 3	
		C_5 $n = 84$	C_6 $n = 16$
Self-regulation of learning	Students' behaviors related to managing individual or group study and autonomously planning their learning processes.	.000	1.000
Teaching assistantship	Valuation of academic support opportunities, such as tutoring or exercise sessions, provided by professors or senior students.	.155	.063
Feedback	Recognition of teaching practices that include constructive feedback on student performance, contributing to learning improvement.	.119	.063
High teacher expectations of students	Positive valuation of expectations expressed by the professor, which generate motivation, confidence, or closeness with students.	.143	.188
Course organization	Perceptions of the structure and planning of the course, including the sequencing of content and clarity of learning objectives.	.095	.000
Assessment organization	Valuations of the planning and scheduling of assessments, both formative and summative.	.083	.000
Coherence between assessment and course methodology	Judgments about the alignment between the content addressed in class, the methodology used, and the assessment instruments applied.	.048	.063
Flexibility regarding assessment	Perceptions of the professor's willingness to provide flexibility in assessment schedules or assignment deadlines according to students' needs.	.179	.000
Awareness of students' needs	Teacher attitudes that reflect genuine concern for students' educational needs, such as availability to answer questions or adapt to diverse realities.	.464	.063

anxiety appears to arise mainly from self-evaluation in relation to learning and from certain teaching practices that may restrict the development of self-regulation, in contrast to Profile C1, where assessment load constitutes the central factor.

Perception profiles regarding teacher educators' practices that elicit anxiety

Regarding OQ2, "What practices or actions carried out by your professors in these courses do you think have increased your anxiety toward the courses?", the first class, C3, was labeled "Anxiety Related to Interaction and Course Pace." Prospective teachers assigned to this class ($n = 73$) reported anxiety mainly associated with teaching and assessment dynamics. The highest conditional probabilities corresponded to professional coherence, $P(Y_j = 1 \mid C = 3) = .164$, course pace, $P(Y_j = 1 \mid C = 3) = .151$, and both assessment models and academic overload, $P(Y_j = 1 \mid C = 3) = .123$.

In particular, students mentioned the "*professors' lack of concern for their course*" (E45), comments such as "*we are behind in the content*" (E10, E61), and the "*speed at which content is taught*" (E33, E96) as practices that increase their anxiety by generating uncertainty and tension. They also perceived misalignment between teaching and assessment, for example, when assessment questions "*did not resemble those seen in class or in the exercise guides provided*" (E45). Overall, this profile suggests that anxiety is centered more on interaction with the professor, planning, and classroom dynamics.

The second profile, C4, labeled "Anxiety Centered on Methodology and Closeness to Students," includes prospective teachers (n = 27) whose responses concentrate on references to teaching methodology ($P(Y_j = 1 \mid C = 4)$= 1.000). This defining probability was accompanied by comparatively higher conditional probabilities for professional coherence ($P(Y_j = 1 \mid C = 4)$ = .222) and awareness of students' needs ($P(Y_j = 1 \mid C = 4)$= .333). This pattern indicates that the perceived sources underlying anxiety during the academic experience include structural and dynamic features of classes, perceptions of the professor's preparation, responsibility, and attitude, and the professor's ability to consider students' needs.

Teaching practices characterized by a lack of "*clarity when presenting content*" (E98), a didactic model in which students perceive "*little explanation of certain knowledge*" (E41), or a "*disorganized presentation of content*" (E58) generate uncertainty about what will be assessed and affect understanding and the learning environment. In contrast to Profile C3, these students connect experiences of professional coherence with methodology, directly linking the way teaching is carried out with professor–student interaction, for example: "*The way they communicate with students. Poor teaching […]*" (E27), and "*Explaining too quickly […]. Not addressing questions as they should"* (E59). Likewise, students mentioned interactions that reflect a lack of empathy and attention, such as: *"[…] questions are not listened to with the aim of helping us learn, but rather to humiliate the student"* (E26); *"[…] when professors begin to criticize actions or mistakes one makes in front of the whole class*" (E44); and "*Not answering a question and saying that we should have studied that before*" (E83).

Perception profiles regarding teacher educators' practices that mitigate anxiety

Regarding OQ3, "What actions or practices in the courses do you think have relieved your anxiety?", a two-class exploratory solution was retained based on the conditional probabilities of the presence of each category within each latent class. **Table 3** presents the emergent thematic categories, their operational descriptions, and the conditional probabilities of the presence of each category within each latent class for OQ3. These values make it possible to identify the most representative categories of the profiles constructed from practices that students perceive as mitigating mathematics anxiety.

In profile C5, labeled "Anxiety Relief Centered on Awareness of Students' Needs, Flexibility, and Academic Support," students ($n = 84$) most frequently referred to awareness of students' needs, $P(Y_j = 1 \mid C = 5) = .464$, followed by flexibility regarding assessment, $P(Y_j = 1 \mid C = 5) = .179$, and teaching assistantship opportunities, $P(Y_j = 1 \mid C = 5) = .155$.

Awareness of students' needs was expressed mainly through the teacher educator's closeness and willingness to support students. Participants valued attitudes that fostered a respectful, friendly, and trusting environment, for example, *"closeness or trust shown when students ask questions*" (E27), and *"not seeing them as distant subjects"* (E57). They also valued concrete actions that facilitated understanding and reduced perceived anxiety, such as answering questions, explaining again, offering office hours, reviewing content, or showing flexibility when students faced difficulties. For example, one student stated: *"When professors show empathy toward students, both academically and personally, they give the impression that one can explain problems or doubts to them […]"* (E44).

In addition, students reported that anxiety decreased when they perceived flexibility and judgment from professors regarding assignment deadlines or assessment scheduling. For example, one student referred to *"the flexibility of some professors regarding deadlines, or in general when the professor really shows a supportive attitude toward the student"* (E72).

Finally, teaching assistantships, whether provided by peers or by teacher educators themselves, were also relevant because they expanded opportunities for practice, reinforced difficult content, and conveyed direct academic support. For example, students stated that *"teaching assistantships help a lot to understand concepts that could not be understood in class"* (E51), and called for "*more practice, more concern from professors regarding students' needs"* (E83).

By contrast, profile C6, labeled "Anxiety Relief Through Self-Regulation" (n = 16), groups responses in which anxiety relief is mainly associated with learning self-regulation strategies ($P(Y_j = 1 \mid C = 6)$ = 1.000), reinforced to a lesser extent by teacher expectations ($P(Y_j = 1 \mid C = 6)$ = .188).

Students in this profile mainly perceived planning and organizing their study as key factors for mitigating anxiety, as they helped them recognize their progress and difficulties. For example, one student stated: "*Devoting the necessary time and doing things calmly and within the appropriate time frame, as well as asking questions during class […]"* (E64). They also valued collaborative learning with peers as a strategy for reinforcing knowledge and building confidence, as reflected in the statement: *"Being part of a course with my friends comforts me and gives me strength to continue with the course"* (E65).

Likewise, some students used high teacher expectations as a source of motivation and self-regulation, strengthening their autonomous learning. For example, student E26 stated:

> "[…] In the courses in which professors are indeed capable of guiding students' learning, although the demands remain high, they never caused me anxiety. Quite the opposite: they motivated me to be more demanding with myself and to focus on learning and learning how to learn, instead of merely copying the professor's procedures."

Comparison of Estimated Classes According to Levels of Mathematics Anxiety

Comparison between profiles C1 and C2 on mathematics anxiety, affect, and belief scores

Scores on the eight outcome scales were compared between profiles C1 ($n = 57$) and C2 ($n = 43$) using Mann–Whitney–Wilcoxon tests. Most differences were small. BEL scores were nominally higher in C1 ($Mdn = 3.257, IQR = 2.771 - 3.771$) than in C2 ($Mdn = 3.000, IQR = 2.542 - 3.400$), $U = 1511$, $p = .046, r_{rb} = .233$. However, this difference did not remain statistically significant after Holm correction (adjusted $p = 1.000$). No other unadjusted comparison reached $p < .05$.

Comparison between profiles C3 and C4 on the MA subscales

Scores were similar between C3 ($n = 73$) and C4 ($n = 27$), and none of the eight comparisons was statistically significant. The largest descriptive differences were observed for BEL, with slightly higher scores in C3 ($M = 3.174, SD = .587$) than in C4 ($M = 2.960, SD = .598$), $t(98) = 1.610, p = .111, r = .161$, and for ALM, with C3 ($M = 2.273, SD = .616$) scoring slightly higher than C4 ($M = 2.095, SD = .681$), $t(98) = 1.245, p = .216, r = .125$.

Comparison between profiles C5 and C6 on the MA subscales

Overall, mathematics anxiety, affect, and belief scores were similar between C5 ($n = 84$) and C6 ($n = 16$). The unadjusted comparison for ALM suggested lower scores in C6 ($M = 1.904, SD = .571$) than in C5 ($M = 2.286, SD = .632$), $t(98) = 2.248, p = .027, r = .221$. However, this difference did not remain statistically significant after Holm correction across the 24 comparisons (adjusted $p = .643$) and should therefore be interpreted as a small descriptive tendency.

DISCUSSION

Assessment-Centered Anxiety and Self-Perception

The findings reflect the multifactorial nature of MA among prospective teachers. While Profile C1 is characterized by anxiety associated with external factors, such as the structure and weight of assessment, Profile C2 is linked to internal factors, particularly self-perception and confidence in one's own abilities. The pressure generated by high-stakes assessments and heavy content loads has been identified as a source of anxiety among prospective teachers (Brady & Bowd, 2005; Ersozlu et al., 2022). In this context, the importance of promoting self-efficacy and teaching methodologies that may help mitigate anxiety is emphasized (Gresham & Burleigh, 2019; Stoehr & Olson, 2023; Vinson, 2001; Çatlıoğlu et al., 2009). The course characteristics reported by students, such as excessive lecture-based classes or classes lacking practical components, reinforce the need for more active teaching strategies centered on conceptual understanding. These strategies may support students' self-efficacy and, consequently, reduce MA (Gonzalez-DeHass et al., 2017; Işıksal et al., 2009).

Although the unadjusted BEL comparison was nominally significant, it did not remain significant after Holm correction; all other differences were small and nonsignificant. The distinction between both profiles highlights the relevance of differentiated approaches to addressing MA, including attention to conditions in the assessment environment while also strengthening self-efficacy and learning strategies.

Anxiety Linked to Teaching Practices and Classroom Dynamics

Profiles C3 and C4 reflect two related but differentiated manifestations of how pedagogical practices and classroom dynamics are perceived by students as conditions associated with MA. Profile C3 is characterized by anxiety linked to interaction with the professor and an accelerated pace of content coverage. Students in this profile perceived professional "lack of concern" and misalignment between teaching and assessment, which generated uncertainty and tension. These conditions are related to low levels of teacher expectations and support, which have been associated with higher anxiety and lower performance (Hollenstein et al., 2024; Göçer & Özeren, 2025). In addition, rigid structural practices that prioritize quantity and coverage over understanding contribute to stress and demotivation (Brady & Bowd, 2005).

In contrast, Profile C4 focuses anxiety on teaching methodology and professor–student closeness, highlighting lack of clarity, dynamism, and empathy, as well as public criticism that may amplify anxiety. The literature supports the importance of active, varied methodologies centered on conceptual understanding, including the use of manipulatives and the promotion of collaborative reflection, as ways to reduce anxiety (Gresham & Burleigh, 2019; Vinson, 2001; Stoehr & Olson, 2023). The affective quality of the learning environment and social interaction, reflected in negative experiences and lack of empathy, play a crucial role in these experiences (McMinn & Aldridge, 2020; Uddin, 2022).

Profile C3 showed slightly higher mean ALM and APE scores than C4. However, the corresponding effects were small and the differences were not statistically significant. Therefore, these results do not provide evidence of reliable differences in anxiety between the profiles and should be interpreted only as descriptive tendencies.

Anxiety Relief Through External Support and Self-Regulation

Two differentiated patterns of perception regarding the relief of MA were identified. Profile C5 centers on external factors related to professors' awareness of students' needs, flexibility in assessment, and academic support sessions. Students particularly valued professors' closeness, willingness, and supportive attitudes, together with concrete opportunities to reinforce content and flexibility in deadlines, which generated a perception of a trusting environment that reduced tension. This profile is broadly supported by the literature, which highlights the importance of a positive environment and varied instructor strategies for managing anxiety and fostering self-efficacy (Gresham & Burleigh, 2019; Stoehr & Olson, 2023). In addition, support and closeness among peers and professors contribute to reducing anxiety (Karunakaran, 2020; McMinn & Aldridge, 2020). Flexibility in assessment and academic support also act as complementary factors for reducing pressure (Gonzalez-DeHass et al., 2017; Gresham & Burleigh, 2019).

In contrast, Profile C6 emphasizes the role of student self-regulation in anxiety relief, through planning, organization, and recognition of progress and difficulties. In this profile, high teacher expectations may be positively internalized (Hollenstein et al., 2024), functioning as a stimulus for effort and autonomous learning. This orientation aligns with research that highlights students' capacity to manage anxiety through proactive strategies and the importance of personal reflection (Stoehr & Olson, 2023; Tassell et al., 2020; Pahmi et al., 2025). Likewise, promoting conceptual understanding strengthens self-regulation and reduces anxiety (Ersozlu et al., 2022), while conceptual mastery is linked to the reduction of acquired anxiety (Vinson, 2001).

From a quantitative perspective, the unadjusted comparison suggested lower ALM scores in C6. However, this difference did not remain statistically significant after correction for multiple comparisons and should therefore be interpreted as a descriptive tendency. The pattern is substantively consistent with the characterization of C6 as oriented toward self-regulation, but the current evidence does not demonstrate that membership in this exploratory class is reliably associated with lower mathematics anxiety.

The descriptive differentiation between the estimated classes was clearer at the level of the coded perceptions than at the level of the psychometric measures. This suggests that students with similar levels of anxiety may attribute their experience to different formative conditions. Therefore, the profiles should not be interpreted as different levels of anxiety, but rather as differentiated patterns of attribution and perception regarding the conditions that intensify or relieve this experience.

Limitations

This study has some limitations that should be considered when interpreting the results. First, the sample was drawn from a single institution and selected through intentional sampling; therefore, the findings cannot be directly generalized to other teacher education programs. Second, the sample size limits the statistical power of comparisons between profiles, particularly for profiles with fewer participants. This limitation is especially relevant to C6, which included only 16 participants compared with 84 in C5, limiting the ability to detect differences and the precision of the estimates in the comparison. In addition, the information criteria provided partially discordant evidence, with the BIC favoring the one-class solution. Furthermore, bootstrap analyses showed that the specific two-class partitions were not consistently recovered across resampled datasets. Several conditional response probabilities were located at the boundary of the parameter space, and the response matrices contained a substantial number of low-frequency or unique patterns. These results indicate that high entropy within the selected solutions should not be interpreted as evidence of population-level class stability. The classes are better understood as exploratory summaries of the patterns observed in this sample and require replication in larger and independent samples.

Therefore, the comparison between C5 and C6 should be interpreted as exploratory, and the observed difference in anxiety toward learning mathematics should be considered preliminary rather than confirmatory evidence of a difference that can be generalized to the population. Third, the ALM subscale showed the lowest internal consistency among the MAS dimensions. Although the different reliability coefficients provide complementary evidence of internal consistency, the relatively lower values observed for this subscale warrant caution when interpreting findings derived from this measure. In particular, the unadjusted descriptive difference observed in ALM should be interpreted cautiously given the comparatively lower internal consistency of this subscale. These findings should be replicated using a measure with stronger evidence of internal consistency. Fourth, the data are based on self-reports, which may involve memory bias, social desirability, or subjective interpretations of formative experiences. In addition, although inductive coding made it possible to incorporate students' textual responses, the study did not develop an in-depth interpretive qualitative analysis; rather, the emergent categories were transformed into dichotomous indicators for latent class analysis. In addition, coder agreement was summarized using raw percentage agreement rather than a chance-corrected coefficient. The reported values should therefore be interpreted as evidence of progressive coder calibration rather than as a formal estimate of interrater reliability.

Finally, student assignment to profiles was based on posterior probabilities of class membership, and the cross-sectional design prevents the establishment of causal relationships between reported experiences and levels of mathematics anxiety. Future research could expand the sample, include multiple institutions, and complement this approach with longitudinal designs, interviews, or classroom observations.

Implications

The findings offer relevant implications for initial mathematics teacher education. First, the descriptive class patterns suggest the need for pedagogical strategies that address both external formative conditions, such as assessment structure, course pace, and content load, and internal dimensions, such as self-perception, self-efficacy, and self-regulation. Teacher education programs could strengthen academic and emotional support mechanisms, including tutoring, formative feedback, opportunities for revision, and spaces for reflecting on beliefs about mathematics.

Second, the results suggest that assessment practices should be reviewed not only in terms of their technical design, but also in relation to how students perceive their coherence, transparency, timing, and alignment with teaching. Assessment structures based on few high-stakes exams, unclear criteria, or excessive content coverage may be perceived as conditions that intensify anxiety. Therefore, more distributed, formative, and transparent assessment practices could contribute to reducing uncertainty and strengthening students' sense of control.

Third, the distinction between externally supported anxiety relief and self-regulation-based relief suggests that academic support should not be understood only as external assistance. Rather, tutoring, feedback, and teacher support can be designed as opportunities to progressively develop students' self-regulation strategies, including study planning, monitoring of understanding, error analysis, and preparation for assessments. In this sense, the role of teacher educators is not limited to reducing anxiety directly but also involves creating conditions that help prospective teachers develop confidence, autonomy, and adaptive strategies for learning mathematics.

CONCLUSIONS

The findings suggest that prospective mathematics teachers describe heterogeneous formative experiences associated with the intensification or relief of mathematics anxiety. Exploratory two-class solutions provided descriptively interpretable contrasts related to assessment conditions, self-perception of learning, pedagogical interaction, teaching methodology, academic support, and self-regulation. However, because BIC favored one-class models and the class partitions showed limited bootstrap stability, these patterns should not be interpreted as confirmed or naturally occurring student types.

Two nominally significant unadjusted comparisons were observed, involving BEL for OQ1 and ALM for OQ3, but neither remained statistically significant after Holm correction. The small descriptive tendency toward lower ALM scores in the self-regulation-oriented class requires independent replication. The main contribution of the study therefore lies in identifying potentially relevant patterns in how prospective teachers interpret formative conditions associated with mathematics anxiety, rather than in establishing a definitive taxonomy or demonstrating differences in anxiety between latent subpopulations.

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