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An Exploratory Study on the Emotions of Undergraduate Mathematics Students during the Secondary-Tertiary Transition

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Abstract

This descriptive, qualitative research explores the evolution of emotions in students of the bachelor's degree in mathematics and applied mathematics during the secondary-tertiary transition. It uses the Theory of the Cognitive Structure of Emotions (better known as the Ortony, Clore, and Collins's [OCC] theory) as a theoretical framework. The study was carried out at the Faculty of Physical and Mathematical Sciences of the Meritorious Autonomous University of Puebla, Mexico, with the participation of seventeen first-year students, selected by convenience sampling. Three emotions were identified, of which four were positive and nine were negative. The findings indicate that emotional experiences have a considerable effect on the ability of students to acquire advanced mathematical language. The research is based on a descriptive empirical design, focusing on the experiences of the participants. The data collection instruments include an incomplete sentence questionnaire, a questionnaire, and a semi-structured interview. The research highlights the importance of considering emotions in the secondary-tertiary transition, stating that experiences are crucial in the transition and it is essential to address these aspects to improve support for students in their mathematical learning.

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INTRODUCTION

The transition from secondary to tertiary education in mathematics represents a notable difficulty for many students today and has attracted the interest of mathematics education researchers (Bardelle & Di Martino, 2012; Di Martino et al., 2022a; Di Martino et al., 2022b; Gueudet, 2008; Gueudet, 2023). This process, which begins at the end of secondary school and culminates at the beginning of university, involves a fundamental change in the way of thinking and approaching mathematics, moving from a school context to a university context, where a more formal and rigorous approach is required, including proofs and demonstrations (Gueudet, 2008). Despite advances in research on the cognitive aspects of

university mathematics, the impact of affective factors during the secondary-tertiary transition has been neglected (Di Martino & Gregorio, 2019; Di Martino et al., 2022b; Gueudet et al., 2016). Recently, the need to consider emotions in the study of the secondary-tertiary transition has been highlighted, suggesting that it is crucial to collect students' voices to understand how they experience this process, what emotions they feel and how these experiences are influenced by their educational context (Di Martino et al., 2022b).

Concern about the high dropout rate among mathematics students in various universities in Western countries emphasizes the complexity of this problem, both at the individual level and in terms of the psychological pressure faced by students (Rach & Heinze 2017; Geisler et al., 2023). From a psychological perspective of learning, the question arises as to whether all students present similar patterns in their emotional development, or whether those at risk of dropping out show unfavorable progress (Geisler et al., 2023).

Based on the above, this study proposes to address the following research questions: How have the emotions of Bachelor of Mathematics and Applied Mathematics students evolved during the secondary-tertiary transition? And what are the differences in the type of emotions of Bachelor of Mathematics and Applied Mathematics students during the secondary-tertiary transition?

The objectives of this research are to describe the evolution of the emotions of Bachelor of Mathematics and Applied Mathematics students during the secondary-tertiary transition and to compare the differences in the type of emotions of Bachelor of Mathematics and Applied Mathematics students during the secondary-tertiary transition.

The justification for this study lies in the need to explore the area of affective factors in the secondary-tertiary transition, an aspect that has been neglected and under-explored. Understanding how emotional experiences impact this stage is fundamental, especially considering that mathematics represents a considerable challenge for first-year students and that performance in this area considerably impacts university dropout rates (Bardelle & Di Martino, 2012).

A literature review on the secondary-tertiary transition in mathematics education points out that, although there are many studies that have addressed the cognitive and epistemological aspects that hinder the transition in students, there are still many questions to be answered regarding affective and sociocultural factors (Gueudet et al., 2016).

In addition, it is important to consider affective issues during the secondary-tertiary transition in order to compare students' experiences between different countries or between different educational institutions in the same country. This could help determine whether there are differences between educational contexts and investigate the impact this could have on students' transition experiences (Di Martino et al., 2022b).

Literature Review

When researchers realized that there was a change in students as they transitioned from high school to college mathematics, they discovered the secondary-tertiary transition (De Guzman et al., 1998; Moore, 1994; Robert, 1998; Tall, 1991).

Tall (1991), for example, conducted important studies to describe different cognitive discontinuities in the transition from secondary to tertiary mathematics.

In this manner, he described the cognitive discontinuity between the two education levels in terms of the use of symbolism and generalizations, the role of definitions, formal reasoning, and proof, and finally, the level of abstraction, and emphasized that this change "implies a significant transition" (p. 20) He was also one of the pioneers in the study of advanced mathematical thinking.

In the same decade, Moore (1994) conducted a study in which he observed seven types of sources for the difficulties of beginning students when making a demonstration. The students did not know the definitions, did not know how to use the definitions, and did not even know how to start a demonstration, among others. This study indicated that there is a significant dilemma with formalism in mathematics and that students when faced with a mathematical exercise in college, had many difficulties due to lacking several concepts (Gueudet, 2008).

Robert (1998) used a more general analysis of the mathematical content taught at the end of high school and the beginning of college. He showed that some topics addressed at that level are complicated for students because they involve formalizing, proving, generalizing, unifying, and simplifying.

In the same year, De Guzman et al. (1998) summarized the main findings of this field of research and identified three categories related to students' difficulties in the secondary-tertiary transition: epistemological-cognitive, sociological-cultural, and didactic. They found evidence of specific difficulties faced by students in advanced mathematics, for what they consider a "major obstacle in the teaching of mathematics" (p. 756).

Lerman (2000) gave a change of perspective in mathematics education research, which he called the "social turn," where he highlighted that affective and sociocultural issues in mathematics learning are integral to students' learning experiences.

Di Martino et al. (2022a) report on the PME conferences held each year, where they include various types of contributions and activities. In the 2015–2021 period, 17 research reports on secondary-tertiary transition were found, and there was greater consideration for affective and sociocultural constructs.

In the same way, Di Martino et al. (2022b) looked at how students' attitudes toward mathematics changed as they moved from secondary education to tertiary education. They found that while students' transition experiences may seem similar at first glance, some important differences show up when it comes to entering mathematics majors, how competent students think they are at this stage of the transition, and how mathematical formalism affects students in college.

Geisler et al. (2023) researched the development of affective aspects in a mathematics program where they indicated how in the first semester of college they predict attrition in students, in which they measured their interest and self-concept.

Emotion: Theoretical Framework

Emotion is one of the central and pervasive aspects of human experience, as people experience a wide range of emotions. Moreover, emotions give color, depth, and richness to human experience and can cause dramatic breaks in judgment and action (Ortony et al., 1988).

The theory of cognitive structure of emotions defines emotions as "balanced reactions to events, agents, or objects, the particular nature of which is determined by the way the triggering situation is interpreted" (Ortony et al., 1988, p. 16).

The Theory of Cognitive Structure of Emotions

For this research, we used the theory of the cognitive structure of emotions (Ortony et al., 1988), commonly called OCC theory after the initials of the authors' last names, to analyze the emotional experiences of students during the secondary-tertiary transition.

According to García-González and Martínez-Sierra (2018), this theory is based on the idea that students' cognitive assessments of a situation, whether conscious or not, are what cause emotions to arise. The way in which those who experience emotions evaluate the circumstances that give rise to them is what causes them. The authors refer to the valuations given to three types of triggering situations: events, agents, and objects. The three types that trigger emotions are listed: (1) Being happy vs. being upset gives rise to reactions to events, (2) Approval vs. disapproval gives rise to reactions to agents, (3) Disliking vs. disliking gives rise to reactions to objects.

According to the Theory of the Cognitive Structure of Emotions, this contains twenty-two types of emotions that are grouped into four classes and six groups (Table 1). The different types of emotion-provoking situations are classified according to a word or phrase that corresponds to a relatively neutral example that fits the type of emotion. It is independent of emotions since it is a theory about things that concern people, to words denotative of emotions, and not a theory of words per se (Ortony et al., 1996).

Table 1. OCC typology

Class	Group	Types (Name example)
Reactions to events	Vicissitudes of others	- Happy for an event desirable for someone else (happy for). - Happy for an undesirable event for someone else (happy for the misfortune of others). - Unhappy about an event desirable to someone else (resentful of). - Unhappy about an undesirable event for someone else (complaining about).
	Based on forecasts	- Pleased by the anticipation of a desirable event (hope). - Pleased by the confirmation of the forecast of a desirable event (satisfaction). - Delighted by the refutation of the forecast of an undesirable event (relief). - Dissatisfaction with the refutation of the forecast of a desirable event (disappointment). - Unhappiness due to the anticipation of an undesirable event (fear).
		- Dissatisfaction with the confirmation of the forecast of an undesirable event (confirmed fears).
	Welfare	- Glad for a desirable event (jubilation). - Unhappiness over an undesirable event (distress).

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Table 1. (*continued*)

Class	Group	Types (name example)
Reactions to agents	Attribution	- Approval of a plausible action of oneself (pride). - Approval of a plausible action of another (appreciation). - Disapproval of a reprehensible action of oneself (self-reproach). - Disapproval of a reprehensible action of another (reproach).
Reactions to objects	Attraction	- Liking of an attractive object (liking). - Dislike for a repulsive object (dislike).
Simultaneous reactions to the event and the agent	Welfare/ attribution	- Approval of another person's plausible action and contentment for the related desirable event (gratitude). - Disapproval of another person's objectionable action and dissatisfaction with the related desirable event (anger). - Approval of another person's objectionable action and dissatisfaction with the related desirable event (complacency). - Disapproval of an objectionable action of oneself and dissatisfaction with the related undesirable event (remorse).

RESEARCH METHODS

This research is considered empirical because it is based on the collection and analysis of data obtained directly from the experience of undergraduate students in Mathematics and Applied Mathematics. Adopting a qualitative approach, in which we seek to capture the real emotions and experiences of students during the secondary-tertiary transition, which allows obtaining direct and contextualized information. In addition, it is descriptive since it not only allows us to identify emotions, but also to understand how these manifest and affect their academic experience.

Participants

The research was carried out at the Faculty of Physical and Mathematical Sciences of the Meritorious Autonomous University of Puebla, Mexico, with 17 students in the second semester of the programs for bachelor's degrees in mathematics and applied mathematics. The participants were selected through a convenience sample and have an age range of 18 to 21 years, covering both men and women. These undergraduate students regularly take three subjects in the area of mathematics, differential calculus, analytical geometry of space and theory of equations, corresponding to the current curriculum of 2016.

Data Gathering Procedure

Three data-gathering instruments were used for the present study. The first was a questionnaire of incomplete sentences, which was created as a methodological tool

for students to narrate their emotional experiences individually. Eleven incomplete sentences were designed based on the three academic degrees they took in mathematics during the secondary-tertiary transition.

For the second instrument, it was decided to consider two instruments proposed in previous research for data collection, the Di Martino and Gregorio (2019) questionnaire, which consists of four parts: (1) Biographical information (school), (2) Reasons for studying mathematics and university choice, (3) Students' perceptions of their emotional experiences with mathematics, and (4) Comparison of students between high school and college mathematics

In this instrument, items three and four were modified, where the proposals of two research studies by Martínez-Sierra and García-González (2014; 2017) were used, in which five open questions based on the OCC Theory were considered and, as a result, reformulated in the open questions adapted to that study.

Finally, the semi-structured interview was based on a study by Pals (2016). In this work, the concept of causal connections was used as a methodological tool to examine patterns of self-creation within the life story narrative, as derived from McAdams' (1993) Life Story Interview. Life story construction is an interpretive process of self-creation that operates to produce coherence through the formation of meaningful connections between experiences and the self (Pals, 2016).

Pals (2016) uses three causal connection cases, where they reveal quite different strategies in narrating the low points of their lives, particularly concerning the goal of building a positive sense of growth within oneself. In the data revealed in the present study, the following causal connection cases were considered, where an interview was designed for each case: (1) From positive to negative: the narrowing of the self, (2) Positive to positive, and (3) Negative to positive: the trampoline effect and the transformation of the self

Emotion Coding

According to the Theory of the Cognitive Structure of Emotions (OCC), when analyzing the three stages of this research, it focuses on two important elements: the triggering situation, in this case we identified in the answers those phrases that accounted for events that triggered an emotion in the student. On the other hand, the emotional word, in which phrases or words that showed us some name of emotion stood out, since this accounts for the students' assessment. For this reason, García-González and Martínez-Sierra (2018) established the following coding: (1) A precise phrase that expresses all the triggering situations of the students' emotional experiences; (2) The emotional words that express the emotional experience; (3) To locate the students' responses, keys were used to make known the students' responses according to the two elements mentioned above, M for female, M for male followed by the consecutive number in which they answered the questionnaire.

RESEARCH RESULTS

According to the Theory of the Cognitive Structure of Emotions (OCC), when analyzing the three stages of which this research consists, we considered two important elements: the triggering situation; in this case, we identified in the

responses those phrases that gave an account of events that triggered an emotion in the student and the emotional word.

For this reason, García-González and Martínez-Sierra (2018) establish the following coding: (1) A precise phrase that expresses all the triggering situations of the students' emotional experiences (in bold), (2) The emotional words that express the emotional experience (in italics).

Following the consecutive number in which they responded to the questionnaire, we identified the students as W for women and M for men.

For incomplete sentences, 12 types of emotions and their triggering situations were identified in both stages: eight emotions in the secondary stage, of which four are positive and four are negative, and ten emotions in the tertiary stage, where they reflected four positive and six negative emotions (Table 2). The positive emotions are pleasure, joy, satisfaction, and pride; the negative emotions are disappointment, complaining, self-reproach, fear, grief, confirmed fears, anger, and displeasure.

Table 2. Emotions identified from incomplete sentences

Emotion	Triggering situation	
	Secondary stage	Tertiary stage
Pleasure	- Mathematics - Solving exercises - Continuing studies - Easy exercises	- Mathematics courses - Learn more topics - Continue your career
Joy	- Understanding mathematics - Mathematics made easy - Explanation from teachers - Ability to solve problems - Understanding topics	- Learn new topics - Solving exercises - Understanding exercises and topics
Satisfaction	- Being able to solve problems - Obtaining good grades - Obtaining correct results	- Solving exercises - Doing demonstrations
Dislike	- Mathematics - Mathematics topics	- Mathematics
Pride	- Concluding studies - Ability to solve	- Entering the degree program - Being able to make demonstrations - Concluding exercises
Disappoint-ment	- Failure to complete the entire syllabus - Having classes during the pandemic - Repetitive topics	- Mathematics courses - Understanding mathematics - Being able to solve problems
Anger	- No permanent teacher	
Complain-ing	- Repetitive topics - Not learning more - Boring topics	
Self-reproach		Not being able to understand the problems and classes

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Tabel 2. (*continued*)

Emotion	Triggering situation	
	Secondary stage	Tertiary stage
Fear		- Failure to complete studies - Not understanding the class - New topics - Not understanding the teacher's explanation - Doubt that the exercises are solved correctly
Affliction		- Not understanding the topics - Not knowing mathematics topics - Difficult topics - Not being able to solve the exercises
Fears confirmed		- Mathematics different from previous academic grades

For the questionnaire, 12 types of emotions and their triggering situations were identified in both stages: four emotions in the secondary stage, of which three are positive and one is negative, and eleven emotions in the tertiary stage, where they reflected four positive and seven negative emotions (Table 3). The four positive emotions are pleasure, joy, satisfaction, and pride; the seven negative emotions are disappointment, reproach, self-reproach, fear, sorrow, confirmed fears, anger, and displeasure.

Table 3. Identified emotions from the questionnaire

Emotion	Triggering situation	
	Secondary stage	Tertiary stage
Pleasure	- Mathematics - Mathematics class	- Mathematics - Mathematics homework - Mathematics topics
Joy	- Understanding mathematics - Easy mathematics	- Learning new topics - Easy mathematics
Satisfaction	- Being able to solve problems - Understanding the topics - Solving problems from formulas	- Passing exams - Performing tasks correctly
Dislike	- Repeating topics - Boring topics	- Failing exams
Pride		- Passing exams
Reproach		- Not having a good teacher
Self-reproach		- Not understanding mathematics - Not studying more

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Tabel 3. (*continued*)

Emotion	Triggering situation	
	Secondary stage	Tertiary stage
Fear		- Failure to complete studies - Level of abstraction of the topics - Demonstrations - Teachers' comments
Affliction		- Problem-solving - Studying mathematics
Fears confirmed		- To be exposed by the teacher
Anger		- Grading of exams

Three interviews were conducted to delve into the answers found in the questionnaire and the incomplete sentences. Considering that three student profiles were found during the secondary-tertiary transition: positive-positive, positive-negative, negative-positive, and negative-positive, students M2, W2, and W1 were selected. The interviews were conducted face-to-face with voice recording and lasted between 5 and 10 minutes each.

Interview with M2: Positive-positive Emotions

In the questionnaire and incomplete sentences, student M2 responded to feeling the emotion of liking mathematics in the secondary and tertiary stages. It includes emotional words such as “liked and enjoyed.”

R : Why did you like mathematics when you were in junior high school and high school?
M2 : Because they were so easy for me, the topics explained by the teacher were very understandable—nothing out of the ordinary. I really liked solving the exercises that were left in class, as well as the homework that was left for me because I enjoyed doing it so much.
R : How do you feel about your mathematics courses in college?
M2 : Very excited about new topics; I like learning things that I had no idea existed, and I find it very interesting how we can prove anything, even if it seems so absurd.

Interview with W2: Positive-negative Emotions

In the answers to the questionnaire and the incomplete sentences, W2 expressed feeling the positive emotions of joy, pride, pleasure, and satisfaction in the tertiary stage, and the negative emotions of self-reproach, disappointment, confirmed fears, sorrow, and fear.

R : Why did you like mathematics when you were in your last year of junior high school and high school?
W2 : Because we had the advantage that when we did the procedures, they already had a method and that method never changed, the procedure

was not justified, … it didn't matter what happened in the process, but only the result and no one could question that.

R : How did you feel in your first year of college for your bachelor's degree in Mathematics?

W2 : It was very difficult because of the way the professors wanted to change the idea of mathematics from how it was in high school or middle school because we had a method that was all repetitive, and here it is not like that, the professors … they made you feel bad, in addition to creating insecurities.

Interview with W1: Negative-positive Emotions

In the answers to the questionnaire and the incomplete sentences, W1 stated that they felt the negative emotions of anger, disappointment, and reproach in the tertiary stage, and the positive emotions of joy and pleasure.

R : Do you remember having a negative experience related to mathematics in junior high school or during high school? Which one?

W1 : Not a specific experience as such, but it was very constant that due to my lack of interest in researching or deducing information, it was common for me to have difficulty with some problem or exercise because I could not find the solution since the solution was possibly derived from some theorem or formula that I did not know, and that made me sad, disappointed, and I struggled a lot to try to understand the topics.

R : What was it that helped you to like mathematics?

W1 : I would say that I adapted to the environment and kept a positive attitude; you automatically get used to it, and it makes sense to you whether you get good at it or you just like it.

DISCUSSION

The results obtained from the questionnaire applied in the present investigation allowed for the identification of three positive emotions in the secondary stage: pleasure, joy, and satisfaction, as well as one negative emotion, which was displeasure. In the tertiary stage, four positive emotions were identified: pleasure, joy, satisfaction, and pride, and seven negative emotions: disappointment, displeasure, self-reproach, fear, sorrow, confirmed fears, and anger. The results found in the incomplete sentences of this research allowed for the identification of four positive emotions in the secondary stage: pleasure, joy, satisfaction, and pride, and four negative emotions: displeasure, complaining, disappointment, and anger. While in the tertiary stage, four positive emotions were identified: pleasure, joy, satisfaction, and pride, and six negative emotions: disappointment, reproach, self-reproach, fear, sorrow, and confirmed fears.

The results coincide with those obtained in Di Martino et al. (2022b), who conducted the study with three samples from three European countries where students experienced negative emotions towards mathematics: unexpected difficulties encountered in the first year of study in college often result in frustration

and anxiety. Among the emotional words identified, stress had an impact on students' emotional disposition.

The findings related to the change in negative emotions that students have in the tertiary stage provide evidence that there are no differences between educational contexts or the country where they are located. Negative emotions are more prevalent in students in the tertiary stage in both this research and the study by Di Martino et al. (2022b).

In the interview conducted with W2, where a change of emotions from positive to negative was identified, the student showed a strong adverse effect due to the change of advanced mathematical language. The emotions of fear, disappointment, grief, and self-reproach were the ones that stood out the most. Most of the students suffer from this radical change while in the bachelor's degree programs in mathematics and applied mathematics.

A strong similarity is found with Di Martino and Gregorio (2019), where they recognized a typical pattern that characterized the Bachelor of Mathematics experience: a high-achieving student enrolled in such a program, almost always unexpectedly and abruptly, faces difficulties, and these difficulties were linked to strong negative emotions.

Finally, we emphasized that one of the most frequent triggering situations for students was the change in teaching and attitudes taken by teachers when the bachelor's degree program was beginning; this makes emotions have a negative impact.

CONCLUSION

In this research, we found a considerable impact between the secondary and tertiary stages. The absence of formal language in school mathematics appears to be predominant in the experiences of students of Mathematics and Applied Mathematics bachelor's degrees.

We were able to identify 13 emotions, of which four are positive: liking, satisfaction, pride, and jubilation; nine are negative: disappointment, reproach, self-reproach, fear, distress, confirmed fears, anger, dislike, and complaining. Of the emotions that occurred most frequently, we observed fear, disappointment, sorrow, liking, and satisfaction. We also identified three student profiles during the secondary-tertiary transition: (a) Profile 1: positive-positive emotions: which represents 29.4% of the participants, (b) Profile 2: positive-negative emotions: which represents 64.7% of the participants, (c) Profile 3: negative-positive emotions which represents 5.8% of the participants

Students who experienced positive emotions in both stages of transition had triggering situations such as doing homework, having good mathematics teachers, learning new topics, seeing more difficult topics in class, learning to demonstrate, etc. The student who experienced negative emotions in the secondary stage and positive emotions in the tertiary stage had triggering situations such as: not having a good teacher, repetitive topics, boring topics, etc. In the secondary stage and the tertiary stage, there were: seeing new subjects, learning to demonstrate, classes, etc.

From the results obtained, it was observed that students frequently face emotional experiences with mathematics, since in the context of the study where it was conducted, students have classes in several mathematics courses. We can say

that the assumption is fulfilled and that a large part of the students of the bachelor's degree programs in mathematics and applied mathematics change their emotions from being positive to negative, since the change towards advanced mathematical language (tertiary stage) causes triggering situations that are more common in students, which are: exam grades, difficult topics, not being able to solve exercises, not understanding the teacher's explanation, and, above all, derogatory remarks from teachers that cause the students' academic performance to decline.

We would like to conclude by discussing some implications for educational practice from our research, in order to prevent or overcome negative emotions in mathematics during the secondary-tertiary transition. On the one hand, the university should consider the impact of the emotional aspects of students' difficulties, particularly in the case of first-year students of mathematics and applied mathematics.

According to our findings, it is important to include in teacher training components on emotional management in the classroom, fostering empathy and understanding of students' emotions. Likewise, creating an environment where students feel comfortable sharing their doubts and mistakes, minimizing the fear of failure. This may include promoting positive language and recognition of efforts. Promoting group activities that encourage interaction and mutual support, helping students to share experiences and overcome difficulties together. Using different theoretical frameworks to adapt to the different learning styles and emotions of students.

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