Mathematics self-concept and university dropout

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Abstract: The phenomenon of university dropouts before completion of studies is a widespread and worrisome problem internationally and is increasingly becoming an issue of policy, institutional and research interest. Our study is within the strand of research aimed at investigating its causes, with the aim of providing valuable information for the design of effective interventions to counter them. The focus is on mathematics and, in particular, on the role of one of the affective factors that is increasingly being linked to the processes of learning and teaching mathematics, the mathematics self-concept. In this paper, we will report the results of a study conducted with students in the first year of a mathematics course, investigating the factors that relate to self-concept and its change during the secondary-tertiary transition and how self-concept is related to willingness to drop out of the course of study.

Keywords: mathematics self-concept, university dropout, secondary-tertiary transition

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1 Rationale

The university dropout issue is particularly relevant nowadays, as confirmed by Eurostat data, which show that in 2016, more than 3 million young people abandoned their university studies (Work beats study for 25% of university dropouts - Products Eurostat News - Eurostat). In Italy, the situation is increasingly discouraging. As highlighted by Aina and colleagues (2018), Italy stands out among OECD (Organisation for Economic Co-operation and Development) nations for its alarming dropout rates. More specifically, according to the National Agency for the Evaluation of the University System and Research (ANVUR - National Agency for the Evaluation of the University and Research Systems, 2018), the dropout rate for the cohort of students for whom complete data are available is about 28.2 percent, with nearly two-thirds of them (20 percent) dropping out in the first two years (ANVUR, 2018). Internationally, contrasting the phenomenon of university dropouts remains an open challenge, and the topic has been the subject of much research in various fields (Geisler, 2020). The first step in addressing the problem of university dropout rates involves defining the concept itself. Indeed, as outlined by Tinto as early as 1982, the definition of dropout varies depending on the perspective taken. From a “policy” perspective, dropout is defined as the phenomenon in which students leave the

university system without obtaining a degree. From an “institutional” perspective, dropout occurs when a student leaves his or her institution, regardless of whether he or she enrols elsewhere or exits the system completely. This second perspective has some limitations because universities have a view of only a fraction of a student's academic journey, limited to their own institution. Despite the distinctions in these perspectives, there is a shared goal between the policy and institutional viewpoints: the goal of reducing dropout rates. And it is in this direction that most educational research has focused. Several foundational studies (e.g. Tinto 1975; St John et al. 1996; Pascarella, 1980) propose models to show the processes of interaction among students, their characteristics, and the institutions that lead to dropout. Currently, various research is conducted on university careers, with the aim of studying predictive elements and changes between socio-demographic variables and education level (Del Bonifro et al., 2020, Mayra & Mauricio, 2018; Nagy & Molontay, 2018) and some of them are focused specifically on the predictive role of mathematics (e.g. Gambini et al., 2022). And it is in the mathematical area that our research focuses.

As for mathematics and in general, the STEM (Science, Technology, Engineering, and Mathematics) field, the Italian situation is particularly alarming: research conducted immediately after the pandemic identifies 34.8 percent of STEM university students as willing to drop out ("Ask me how I am": the answer of 30,000 students – ed-work.it). As with other areas, most dropouts in the field of mathematics occur at the beginning of the academic journey. Among those enrolled in the course of study in Mathematics, there is a high dropout rate as early as the first year. Between 2009 and 2012, for instance, almost one in four mathematics freshmen1 in Italy dropped out before enrolling in the second year (Di Martino & Gregorio, 2019). As we will see in detail below, our research investigates the causes of undergraduate dropouts during the first year of a degree course in Mathematics.

1.1 Main causes of the Mathematics University dropout

The transition from secondary to tertiary mathematics education often presents widespread difficulties that are experienced regardless of whether the students being considered are mathematics majors or are enrolled in a programme for which mathematics is a service subject (Casalvieri et al., 2024). Over the years, various research methods have been employed to explore this topic in greater depth, leading to the

[1] We will be using the term “freshman” to refer to students enrolled in their first year of undergraduate education.

development of specific theoretical models. Numerous studies have since examined how the transition from school mathematics to university-level mathematics influences this issue, which remains highly relevant within both academic institutions and modern society. From the literature review of Di Martino et al. (2023), an evolution of perspectives has emerged over the last fifteen years where the focus of the research has moved from a cognitive approach to a more holistic one, which includes sociocultural and affective issues. Retracing the historical evolution of the main research results, foundational studies date back to the late 1990s and were carried out by Tall (1991), in which epistemic differences and cognitive processes in this transition to advanced mathematical thinking were studied. This transition corresponds to a significant change in the type of mathematics that students must master. Mathematics is different not only because some of the topics are different, but more precisely because of a greater depth, both with respect to the technical skills needed to manipulate the new objects and to the conceptual understanding behind them (Casalvieri et al., 2024). This change has sometimes been described as corresponding to the shift from elementary to advanced mathematical thinking (see Tall, 1991) in that secondary school students often succeed in mathematics by relying on their ability to perform algorithms and despite a lack of real understanding of the mathematical concepts with which they are working. Students may experience considerable difficulty when they move to the tertiary level in being able to participate on their own in mathematical thinking processes and not simply learning to reproduce mathematical information. From these early findings, several studies have followed, and at the end of the last century, De Guzmán and colleagues (1998) summarised the main results of this field of research, identifying three categories related to the difficulties of students in the secondary-tertiary transition: epistemological-cognitive *(I)*, sociological-cultural *(II)*, and didactic (III). This categorization has guided several studies in this field, and the survey instrument at the heart of our study is also designed on these three categories, which we now explain in detail.

(I) The introduction to the *cognitive and epistemological aspects* of mathematical education research dates back to 1970, when Perry defined the correlation between "personal epistemologies" (Hofer & Pintrich, 2002) and academic achievements, thus opening studies to the conceptions of student learning and knowledge. Taking into consideration the mathematical domain alone, it emerges how this has aroused a lot of interest in research by triggering the birth of several studies in this regard. The epistemological and cognitive difficulties that, in a way, are "intrinsic" to

mathematics, as they relate to the change in the type of mathematics that students must master when they move on to tertiary education. Then there are extrinsic causes, as they do not stem directly from the student's abilities, but rather from the educational system, instructional methods, and the structure of mathematical knowledge at the university level (Koch, 1992).

(II) A second type of difficulty involves *sociological and cultural factors*. Especially when viewed from an institutional perspective, there is a great diversity of such difficulties, and local differences can be quite important. These factors may depend, in some cases, on the large class sizes at the university level that deviate from the small size of school realities, in other cases, on the democratization of school and university systems that has resulted in the increase of students enrolling in college, leading to the enrolment even of students who have low skills in the subject. As highlighted by Harel and Trgalová (1996), one cultural difficulty certainly concerns the general conception of the task of teachers at the university level. Some teachers' lack of pedagogical awareness may stem from the fact that in some countries, especially in Italy, most university teachers are predominantly research-focused, and thus their motivation and commitment to teaching may not be as strong as those of secondary school teachers, whose primary responsibility is teaching.

(III) The focus of the latter aspect is to investigate how and in what ways teachers' teaching at the university level might be the cause of the difficulties experienced by students. The research of De Guzmán and colleagues (1998) relates to teaching methods, classroom organisation, and available resources. Often, there's a mismatch between how mathematics is taught in school and at university, leading to a lack of continuity and support for students.

More recent studies have framed the educational factors behind this transition to one of Brousseau's (1997) *didactic contract*. In 2007, Artigue states that when a subproject enters the university, the didactic contract is no longer the same. The presence of the didactic contract—with specific characteristics tied to the educational level—is also evident at the university level, particularly at the beginning of students' academic journeys. This phenomenon has been acknowledged by several scholars as a key factor in analysing the difficulties students initially encounter (Grønbñk et al., 2009).

Across all aspects, the role and significance of affective factors have emerged in several studies. As highlighted in the literature review by Gaudet and colleagues (2016), although the central role of affective aspects in transitions within

mathematics teaching and learning is now widely acknowledged, research in this specific area remains limited. And this is also confirmed regarding specifically the transition between secondary school and university by the reviews carried out by Di Martino and colleagues (2023). Our study fits into the strand of thought that delves into the role of affective factors in this transition and, in particular, with regard to self-concept in mathematics.

1.2. Self-concept in mathematics and university dropouts

Self-concept is defined as one's perception of the self that is continually evaluated and reinforced by personal inferences about oneself (Bong & Clark, 1999). Often, it is defined as self-perception of one's abilities and skills that influence the probability of success in a wide range of activities (Byrne & Shavelson, 1986), including the educational field. Due to its link to achievement in schooling, self-concept is a highly studied construct in educational research. In 1998, Stipek's study highlighted that people who have a positive self-concept show more motivated behaviours and greater perseverance in challenging tasks and recent research supports the belief that self-concept is a strong facilitator of academic success and that a positive or negative change in self-concept tends to produce a change in academic success or performance (Valentine et al., 2004; Yara, 2010). This also seems to apply to mathematical learning processes, the topic of some research in mathematics education, from which a close link to De Guzmán 's third category also appears (Nicchiotti & Spagnolo, 2024). In 1997, Marsh and Craven hypothesized that a student's self-concept was not only a desirable goal, but it was also likely to be linked to improved student mathematics performance. Subsequent studies (Ireson & Hallam, 2009; Trautwein et al., 2006) have confirmed the early underlying hypotheses and show that mathematics self-concept captures beliefs about one's competence with regard to mathematical skills and is positively correlated with mathematics achievement in a variety of school contexts and countries. Specifically at the university level, Wheat et al. (1991) found that students' self-concept in Mathematics significantly relates to high grades in a college algebra course.

Although there is a good degree of agreement in the literature regarding its measurement, and the Wilkins' item, "I usually do well in math" (Wilkins, 2004) from TIMSS (Trends in International Mathematics and Science Study) to refer to self-concept is considered a statement that represents a substantially valid measure for self-concept, there are still several open questions regarding the factors

determining self-concept in mathematics. In line with social cognitive theories, self-concept consists of beliefs about oneself that are formed through interaction with the environment. Following Bong and Skaalvik (2003), self-concept is a multidimensional and hierarchical construct that is influenced by social comparison, causal attribution, evaluations of significant others, and mastery experiences. One of the issues that has always characterized self-concept in the field of education is the external or internal factors that determine it. Taking the classic definition of self-as-doer and self-as-object as interconnected aspects (originated from the studies of James (1890) and also taken into consideration in the most current TIMSS surveys), Marsh (1990) proposed a framework of self-concept consisting of two components, an internal and an external one. The internal component consists of intra-individual comparisons in which students compare their performance in one subject with their performance in another subject whereas the external component consists of social comparisons in which students link their achievements to those of their classmates. As highlighted by Pajares and Cheong (2003), students' self-concept may also decline - rather than from an objective decline in actual ability or performance - because of uncertainties resulting from school transitions, less personalized instruction, and perceived increased academic pressures.

It is in the light of these studies that we have defined our research problem, aimed at investigating the presence of self-confident change in the secondary-tertiary transition, its role in university dropouts, and to investigate its causes by delving into its internal and external factors. In our research, we extend Marsh's definitions and, within the external factors, we consider not only the social comparisons in which students link their achievements to those of their classmates, but also all those factors that come from “outside”, such as the evaluation and judgments provided by professors. The research questions that guided our study are: *What are the features that characterize the link between self-concept and dropouts? What are the characteristics of self-concept in relation to De Guzmán ’s categories?*

2 Methodology

To investigate our research problem, we designed, administered and analysed data from two questionnaires which were administered to freshman in the Mathematics course at the University of Ferrara at the beginning of the academic years 2021-22, 2022-2023 and 2023-2024. This research took place within the tutoring activities of the course of study and within the National *Piano Lauree Scientifiche* (PLS) project

carried out at the University of Ferrara as part of the action aimed at contrasting university dropouts. The questionnaires originate from the questionnaire used by the Department of Mathematics at the University of Pisa, whose data analyses have already led to numerous reflections in different directions, shared in the national and international research community (see, for example, Di Martino & Gregorio, 2017, 2019, and Gregorio, 2023).

To the questionnaires containing the questions under investigation, 36 freshmen in the 2021/22 academic year, 17 freshmen in the 2022/23 academic year and 15 freshmen in the 2023/24 academic year responded. Questionnaires were anonymous, and students were asked to voluntarily leave an email address if they were willing to be contacted to pursue the investigation. In this study, we will focus only on analysing the answers given to questions that were common to both questionnaires (the questionnaires administered in the three academic years differ in three questions that are not the subject of this study).

2.1 The questionnaire

The main lines of investigation explored through the questionnaires can be theoretically framed using the model proposed by De Guzmán et al. (1998), particularly with regard to the factors investigated—epistemological-cognitive (I), sociocultural (II), and didactic (III). Additionally, the different stages of the high school–university transition were considered following the approach suggested by Clark and Lovric (2008). These authors propose a rite-of-passage model applied to mathematics, emphasizing that the transition between educational levels is a complex and prolonged process involving three distinct phases. Therefore, in order to gain a comprehensive understanding of the phenomenon, it is essential to study the dynamics that occur within each of these three stages:

- separation (from secondary school); this stage takes place while students are still in secondary school, and includes anticipation of forthcoming university life;
- liminal phase (from secondary school to university) includes the end of secondary school, the time between secondary school and university, and the start of the first year at a university;
- incorporation (into university) includes, roughly, the first year at a university. (Clark & Lovric, 2008, p. 35)

In line with the theoretical lenses already introduced, the questionnaires investigate the three factors (I, II, III) transversally in the three stages of the transition. Here we outline the four main sections:

1. Questions related to the decision to enrol in mathematics and the participants' secondary school background.
2. Questions about the differences between secondary school and university
3. Questions regarding the experience in the university, focusing on emotions and difficulties encountered.
4. Questions pertaining to dropout considerations.

In this study, we focus on investigating the role of self-concept, how it has changed during the transition, and what the main factors are that impact it. In the first phase of analysis, we analysed the answers obtained to the following questions by outlining some interpretative categories and connecting the answers provided to the questions.

The questions – common to both questionnaires - are the following:

> 1a. During secondary school, did you think you were good at mathematics?
> 1b. Why?
> 2. Has your perception of how good you are at mathematics changed during this first year?

Questions 1a and 2 are closed questions with two answer options: Yes and No. Question 1b is an open question. In line with Wilkins (2004) definition, we argue that the above questions investigate self-concept in mathematics.

In the second phase of analysis, we connected the answers provided in the first phase of analysis with the answers provided to the following question:

> 3. Have you ever thought about dropping out of this course of study?

Question 3 is multiple choice with possible options: “never”, “sometimes”, and “often”. As the questionnaires were administered during the first year of the university to students still attending, no one among the respondents had already dropped out.

3 Data Analysis

The data collected from these questionnaires allowed us to outline profiles and study the role that self-concept plays in the transition and, so, in the decision to drop out of university. Since the focus questions of this survey are the same in both questionnaires and since, for the purposes of the research problem, it is not necessary to distinguish the students of the two different academic years investigated, we will consider the data in aggregate form, therefore considering a total of 68 respondents. Indeed, the responses reflect each student's personal experience, rather than being tied to a specific academic year.

62 students answered "Yes" and 6 answered "No" to question 1a: During secondary school, did you think you were good at math? So, 91% of the students considered themselves good at math in secondary school.

The following table presents the main categories of responses provided by these 62 students to question 1b, along with two example excerpts of responses for each category. In line with the framework, we classified the responses by considering the internal and external components of mathematical self-concept.

Table 1. Answers to Question 1b – Categories

External component	Reference to (high-school)classmates	S9_22 I was always able to help my classmates who had difficulties in the subject matter
		S4_24 I had a different reasoning ability than my classmates and therefore understood arguments faster than they did
	Reference to (high-school)evaluation	S3_23 I always got high grades
		S2_22 For the five years I averaged a 9 in math
	Reference to (high-school)professors	S4_23 Due to the considerations of the professors
		S2_22 Sometimes professors would ask me to explain concepts to classmates
Internal component	Reference to ease of comprehension	S14_23 I have always been able to understand everything without too much difficulty
		S2_22 Because I understood everything
	Reference to ease of doing math	S1_22 I could do the exercises with ease
		S7_24 I found it simple and consequently I could do everything with ease
	Reference to the personal enjoyment	S3_24 And I liked to do the exercises assigned
		S9_22 I related to the subject matter with great pleasure

In our results, we find three categories related to the difficulties of students in the secondary-tertiary transition highlighted in De Guzmán 's studies: as far as the external component is concerned, the references with respect to secondary-school (as opposed to university) relating to classmates can be placed in the sociological-cultural category (II), as each student is confronted with the environment around

them, that is their own class. On the other hand, the answers referring to evaluation allow an epistemological-cognitive reading (I), since they refer to one's mathematical abilities in relation to the grades awarded by their professors. The references to professors, on the other hand, recall the didactic context (III), highlighting the reciprocal expectations between students and professors On the other hand, as far as the internal component is concerned, the references relating to ease of comprehension are in the epistemological-cognitive sphere (I), focusing on one's mathematical abilities both in terms of skill and time. The answers relating to ease of doing mathematics are more related to the didactic category (III), in that the student is not confronted with problems commensurate with his or her preparation and finds satisfaction in the ease of doing mathematical exercises. Finally, the references relating to personal enjoyment are mainly in the sociological-cultural field (II), where satisfaction emerges from not experiencing difficulties and the positive feedback received from the school environment. In the responses, in total, we find more than twice as many excerpts referring to external components as those referring to internal components (not all students who answered question 1a answered question 1b; the number of extracts is so low that it would not make sense to report percentages).

To question 2, has your perception of how good you are at mathematics changed during this first year? 53 out of 67 students answered “Yes.” Thus, 79% of the students who participated in our survey changed their self-concept in mathematics. Going on to analyse these responses in relation to the answers given to question 1a and 1b, it appears that the vast majority of students (all but two) who stated that they had a good self-concept in secondary school (answering “Yes” to question 1a) and who in question 1b refer to at least one of the external components, state that they have changed their self-concept during the first year of university.

Relevant in relation to the above-mentioned categories are also the data relating to question 3, have you ever thought about dropping out of this course of study? Most students (35 – 51%) indicated that they had never thought about dropping out, 23 students (34%) indicated that they thought about it sometimes, and 10 students (15%) indicated that they thought about it often. Analysing the responses of students who often think about dropping out of university, we can observe that the majority of them (98%) changed their self-concept and that for most (78%), the determining factors for their self-concept in secondary school were external by nature.

4 Discussion and further directions

Despite broad international agreement regarding the importance of affective factors regarding difficulties in the secondary-tertiary transition in mathematics, the literature on the subject is still lacking (Di Martino et al., 2023), and, as highlighted by Archambault et al. (2009), the same situation applies to dropouts at the university level.

Our study shows evidence that seems to contribute to understanding the role of one of the affective factors currently much studied in mathematics education research, as it has been found to be highly related to the process of learning mathematics, such as self-concept in mathematics, the transition between secondary school and university, and the possible link to college dropouts. In particular, we found evidence regarding the link between self-concept in mathematics at the secondary school level, change in self-concept during the first year of attendance at a course of study in mathematics, and willingness to drop out of such course of study.

As early as 1986, Pascarella, Terenzini, and Wolfe found that pre-university self-concept generally has a positive, and direct influence on college academic performance, even when other factors such as academic achievement and degree aspiration are taken into account. In our study, we found which factors of pre-university mathematics self-concept are determinants of its own change and thoughts inherent in dropout willingness, in terms of the well-known and studied distinction of internal and external components (Marsh, 1990). The results obtained seem to show that when mathematics self-concept is determined by internal components, such as *reference to ease of comprehension*, and *reference to ease of doing maths* or *reference to personal enjoyment*, appears to be more stable, and not subject to changes during the first year of mathematics university course, nor to be linked to the desire to drop out from this course of study. Alternatively, when mathematics self-concept is determined by external factors such as *reference to secondary school classmate, professors* and/or *evaluation*, it seems that this is more susceptible to change and related to willingness to drop out of the course of study. These results provide new insights regarding how to counter university dropouts in mathematics, an issue that has been much discussed and explored in research, institutional and policy fields for several years but of which as yet no definitive solutions have been found. Investigating its causes and finding new characterizations can certainly contribute to insights on how to combat dropouts and help students cope with the difficult secondary-tertiary transition.

This study has some limitations, such as the influence of context factors on the results and the constraint due to the analysis of only a portion of the results of the questionnaires administered. Analysis of other questions from the questionnaires may provide insights into all the factors outlined by Guzman et al. (1998) and all stages of transition under investigation defined by Clark and Lovric (2008). Only a holistic view of the matter will be able to provide insights to be able to design and implement effective actions in different directions, and a comparison with data obtained in other university environments will be desirable to provide insight that is as untethered as possible from contextual factors.

Research ethics

Author contributions

The results analysed in this paper are the subject of reflection in the mathematics master's degree dissertation of one of the authors, Giulia Ciccanti.

All authors contributed equally to the paper. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest.

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