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The transition from school to university mathematics in different contexts: affective and sociocultural issues in students' crisis

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Abstract
Understanding the secondary–tertiary transition is not only an educational matter, but also an inclusion and equality matter as mathematics qualifications lead to better employment and better earning for students. Research on what causes the crisis associated to this transition has so far focused on the impact of cognitive and epistemological changes in university mathematics. Recently, attention has been given to sociocultural and affective issues, which indicate the impact of diverse contexts on such event in the students' life. Here we present a study investigating the experiences of first-year mathematics students in three European countries. The study adopted the framework of transition as a rite of passage and to detect the changes in attitudes towards the mathematics which originated the crisis, the three-dimensional model for attitude towards mathematics (TMA) was used. Data consist in one questionnaire translated into three languages and administered to students in the first year of study. Most of the questions were open-ended, and the data were analysed first qualitatively and then quantitised. Results show that while the transition experiences of the students may seem on the surface uniform, some significant differences emerge for motivation to join mathematics degrees, motives for changes in perceived competence, and impact of university mathematics formalism. We hypothesise a link between these changes and the differences in educational environments in the three countries. We conclude with highlighting the need for more research of this kind to understand the secondary–tertiary transition in the educational context in which it happens.

Keywords Secondary–tertiary transition (STT) · University mathematics · Comparative context · Rites of passage

1 Introduction

The transition from school to university mathematics (secondary–tertiary transition, STT) has attracted much attention in recent years both from researchers in mathematics education and from mathematicians (Koichu & Pinto, 2019) worried by the high drop out of

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mathematics students (Rach & Heinze, 2017). Governments are also interested in increasing retention of mathematics students, as having a workforce with advanced mathematics skills is deemed to be paramount for the development of strong economies (Adkins & Noyes, 2016). Moreover, students with a university degree in mathematics are advantaged both in terms of social mobility and in terms of future earnings (for the UK context, see the report by Higher Education Statistics Agency, 2018). Therefore, understanding the difficulties of the STT is not only an education or economy matter, but also a matter of equality and inclusion for the students. Studies that investigate this transition further will eventually contribute with their findings to alleviate these issues.

A recent review of the literature on transitions in mathematics education (Gueudet et al., 2016) points out that although many studies have addressed the cognitive and epistemological factors that make transitions difficult for students, there are still many questions to be answered regarding the sociocultural and affective aspects. This appears particularly true in the case of the STT. On the other hand, the crucial role of affective and sociocultural factors in the students' experience with mathematics has long been recognised in mathematics education (Lerman, 1998; Zan et al., 2006). Therefore, to consider affective and sociocultural issues in the study of transitions, it is crucial to collect students' voices for understanding how they experience this event, which emotions they feel, and how these experiences are affected by the context in which they occur. Moreover, the consideration of contextual and sociocultural issues in the STT is necessary to compare experiences between different countries or between different institutions in the same country to ascertain how much the results found are dependent on the context in which the research happens. Therefore, the development of studies that compare students' experiences in different institutions and countries appears to be particularly relevant.

In this paper, we report one such study between three universities in three European countries aimed at investigating similarities and differences in first-year mathematics students' experience.

2 Literature Review

An extensive literature review on the STT is included in this special issue (Di Martino et al., 2022). We will focus here on some points of relevance to the present study.

Gueudet (2008) reported the status quo of the research on STT at that time. It pointed out that the STT had been studied from a variety of theoretical viewpoints and indicated that studies of the cognitive aspect of this transition dominate the literature, although the importance of studying the change in the didactical contract during the STT and the impact of institutional approaches (from an Anthropological Theory of the Didactic viewpoint) are also mentioned. Only a few years before this review, Lerman (2000) detected a change in perspectives in mathematics educational research, which he called 'the social turn'. This change, according to Lerman (2000), emphasised that sociocultural and affective issues in learning mathematics are integral to the learning experience as much as cognitive and epistemological issues are. Therefore, since the review of Gueudet (2008), the emphasis of research on STT has shifted to also include studies on sociocultural (Hernandez-Martinez & Williams, 2013) and affective (Di Martino & Gregorio, 2019) perspectives, as the review in this special issue (Di Martino et al., 2022) shows. Of relevance to the present study is the realisation that the variety of theoretical approaches to the STT has increased since 2008, including now also an emphasis on institutional cultures. Gueudet et al. (2016) include the Anthropological Theory of the Didactic (Chevallard, 2006), the commognitive approach (Sfard, 2007), and the community of practice perspective (Wenger, 1998) amongst new theories that have been adopted to investigate the STT. We note that common to these theories is the potential to understand sociocultural and affective issues linked to the STT in a way that perspectives based only on cognitive approaches (such as APOS Theory, Dubinsky & McDonald, 2001) could not. In the study reported here, we start from the realisation (as seen in Di Martino et al., 2022) that there is very little research that addresses differences between experiences of transition caused, amongst other factors, by the differences in institutional cultures. In their entry on STT in the *Encyclopaedia of Mathematics Education*, Gueudet and Thomas (2020) notice that there is ongoing research on transition that accounts for the differences in institutional cultures, mostly from the perspective of the Anthropological Theory of the Didactic, and that there may be many contextual differences between institutions and countries that play a role in the way in which students experience this transition, but they do not discuss these roles indicating again that research around this topic is still in its infancy. Therefore, our study focuses precisely on detecting these differences amongst three cohorts of first-year students in mathematics in three countries, mapping the change in students' attitudes towards mathematics during the STT.

Below we discuss the frameworks adopted for the study, explaining why this choice is appropriate for the goals of the study.

3 Theoretical Framework and Research Questions

At the beginning of the twentieth century, the ethnographer Arnold van Gennep (1909) realised that the moments in an individual's life characterised by the transition from one group to a new one share common features and called them '*rites de passage*'. Since this seminal work, the construct of rites of passage has been well established in ethnography and anthropology and is used to describe life events such as childbirth, bereavement, marriage, and coming of age.

van Gennep (1909) identified three stages in the rites of passage (see Fig. 1): the separation stage (separation from the old group), the liminal stage (during the passage, when the individual does not belong to the old group anymore but is not yet versed in the practices of the new group), and the incorporation stage (when the individual becomes a fully fledged member of the new group). The passage between these stages is characterised by a cognitive and affective crisis. Moreover, this crisis is necessary for the passage to happen, and without it, the individual will not be able to fully join the new group.

Tinto (1988) observed how the transition from school to university studies can be also considered a rite of passage:

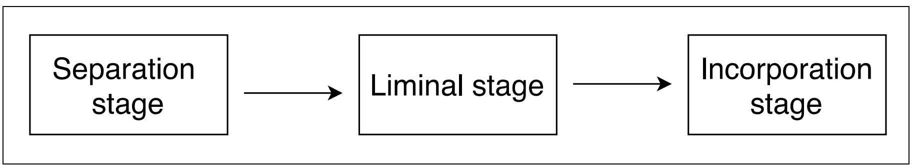

Fig. 1 The three stages of the rite of passage identified by van Gennep (1909)

> …the problem of becoming a new member of a community that concerned van Gennep is conceptually similar to that of becoming a student in college, it follows that we may also conceive of the process of institutional persistence as consisting of three major stages or passages – separation, transition, and incorporation – through which students typically must pass in order to complete their degree programs.
> (Tinto, 1988, p. 442)

Clark and Lovric (2008) applied this framework to the STT. In the separation stage, students leave behind the context in which they have been successful as mathematics learners to join a new context. In the liminal stage—which Clark and Lovric (2008) locate during the first year of university—students do not belong either to the old context of school nor to the new one of university as they are still relative novices in the mathematical practices of the new context.

In the incorporation stage, students become fully integrated in the new university mathematics community. Using this framework, Di Martino and Gregorio (2019) studied the students' crisis during this rite of passage, identifying several 'first time' events in first-year students' mathematical life: the first time that they were not the best student in mathematics, the first time that they understood little or nothing about what was taught during the lessons, and the first time that they experienced failure in mathematics.

To analyse students' trajectory during the rite of passage, Di Martino and Gregorio (2019) used the three-dimensional model for attitude towards mathematics (TMA—Di Martino & Zan, 2010, 2011). Through a narrative approach where students were asked to write about their relationship to mathematics, Di Martino and Zan developed a theoretical framework for attitudes toward mathematics grounded into students' practices. They identified three core themes used for describing the relationship with mathematics: emotional disposition towards mathematics, vision of mathematics, and perceived competence in mathematics. These three dimensions and their mutual relationship constitute the TMA model (Fig. 2).

The multidimensionality of the model permits to outline different profiles of attitude towards mathematics. However, Di Martino and Zan (2011) also stressed the need to limit the complexity of the profiles to render the framework operational for data analysis. For this reason, the complexity of each of the three dimensions was reduced to the following dichotomies: emotional disposition (positive/negative), vision of mathematics (following Skemp's (1976) classification, relational/instrumental), and perceived competence (high/low). Adopting this theoretical framework, Di Martino and Gregorio (2019) showed how the crisis during the STT involves all the three dimensions of the TMA model. Therefore,

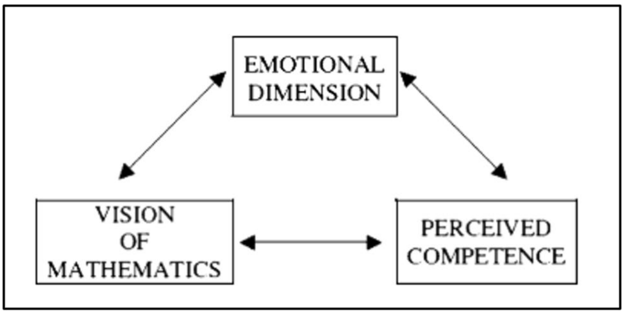

Fig. 2 the TMA model (Di Martino & Zan, 2011, p. 476)

considering affect and comparing students' attitude towards mathematics before and after the passage appears necessary to understand the crisis.

In the study reported in this paper, we also frame the STT as a rite of passage, focusing on the attitudes towards mathematics that the students hold in the liminal stage of this passage, i.e. the first year of study. Our study has two characteristics. Firstly, it involves students who are enrolled on a mathematics degree: there are few studies focused on this sample (see Di Martino et al., 2022) and this sample is particularly interesting for the presumed initial positive attitude towards mathematics. Secondly, we develop the data collection across three student bodies in three European countries. Comparisons between educational contexts are complex and such studies do not feature in the literature on STT, yet educational contexts vary widely between countries. Therefore, in the present study, we ask the following research questions:

RQ1: How do attitudes towards mathematics change in the STT, as reflected in the changes of each of the three dimensions of the TMA model?
RQ2: Are there differences in the STT between different educational contexts? Does the context in which the transition happens contribute to shape this transition?

4 Methods

Data were collected in three European universities: the University of Pisa (Italy), Loughborough University (UK) and the École Polytechnique Fédérale de Lausanne, (EPFL, Switzerland). As often is the case of qualitative studies, this is a purposeful sample (Patton, 1990) in that the universities are chosen to represent three very different higher education traditions (see Table 8 in Appendix 1). This is a key feature of the sample, and it allows an investigation of the impact of institutional differences on students' experiences of STT. The questionnaire used in Di Martino and Gregorio (2019) was translated into English and French (the English version is in Appendix 2) and administered to first-year students enrolled on a mathematics degree at the three universities. Complete data were collected from 26 students from Italy, 45 from the UK, and 58 from Switzerland.

A critical issue for the project, as in all comparative studies (Cao et al., 2008), was the translation of the questionnaire. Great attention was given to keep the meaning of the questions unaltered while at the same time adapting the questionnaire to the different contexts. The questionnaire comprised four parts:

1. Biographical information (e.g. type of secondary school).
2. Reasons for studying mathematics and university choice.
3. Students' perception of their experiences with mathematics (e.g. difficulties and the reasons for such difficulties, related emotions).
4. Students' comparison between secondary school and university mathematics (e.g. perceived differences between secondary and tertiary mathematics, evolution of self-perception in mathematics and of the relationship with the subject).

Most of the questions in parts two, three and four were open-ended to allow the emergence of the students' voice. In line with the operationalisation of the TMA model proposed in Di Martino and Zan (2011), some questions regarding self-perception and emotional disposition were given in closed form (on a 5-point Likert scale). Participation was voluntary and anonymous, and the study was approved by the Ethics Boards of each of the three institutions where it took place, according to the local requirements. The questionnaire was administered during the first year of the mathematics degrees, recognised as the liminal stage of the passage from school to university mathematics (Clark & Lovric, 2008).

5 Data Analysis

Data analysis consisted in three stages and followed the method of data reduction (Namey et al., 2008). Following this technique, the data were analysed first qualitatively with coding techniques that allowed the development of a unified set of codes and then quantitatively investigating frequencies distributions, when possible.

Stage 1: creation of a simultaneous and descriptive coding (Saldaña, 2015).

The qualitative answers to the questionnaires were coded independently by two researchers, and then a common list of agreed upon codes across the complete dataset was reached via an inductive process as follows:

1. Two researchers coded the data independently, developing a definition for each code introduced. When a new code was created, the researcher reviewed the previously coded data to ascertain whether the new code could be used in previous sections.
2. The researchers shared their list of codes and definitions, and each one re-coded the data using the other researcher's list of codes.
3. After step 2, a discussion about the codes and their explanatory power was held until a final list of codes—a mixed selection of the two independent lists—was shared. The final list of codes was simultaneous, meaning that the application of two or more codes to a single utterance was possible, and descriptive since the labels used for the coding were strictly related to the summarised content.
4. The two researchers compared and discussed the outcome of point two of the above process until agreement was reached. At the end of this stage, the three datasets shared the same code schemes (triangulation analysis, Mok & Clarke, 2015). An example of the process described in points 1–4 is reported in Table 1.

Stage 2: mapping of codes in the TMA model.

The codes obtained by the qualitative analysis of the three samples were mapped on the dimensions of the TMA model (Di Martino & Zan, 2010). Codes not included in this model and related to other aspects of the passage (e.g. teaching methods) were considered separately.

In this way, a qualitative analysis of the open-ended questions of the questionnaire was obtained.

Stage 3: quantitative analysis.

Table 1 An example of the coding process (Stage 1)

Utterance (answer to Q3.3)	Researcher #1 codes	Researcher #2 codes	Final code	Reason for the choice
The study of mathematics in high school was focused on solving routine exercises using trivial notions learned from lecturers and textbooks. Now, at university, the focus is on theory, concepts, theorems and much more…	1) Conceptual VS procedural 2) Rigour	1) Routine exercises 2) Theory	1) CP (Conceptual VS Procedural) 2) FO (Formalism)	Analysing the complete data, researchers wanted to: 1) Return a recurrent dichotomy 2) Use a broader code. The final code FO includes references to rigour, theory, symbolism, definition, technical language…

Starting from the coding described in the previous stages, qualitative data were 'quantitised' for statistical analysis, using the frequency of each code in each sample (Namey et al., 2008).

With the aim of evaluating the comparative significance of the responses of the three different populations, the frequencies of each of the codes were analysed, when possible, first with X^2 test across the three datasets and then with paired X^2 tests with Bonferroni adjustment between pairs of datasets. Because of the simultaneous coding, it was not possible to perform a unique X^2 test (which is made for exclusive answers) for each question. Instead, we coded 'Yes' for students who had the code under consideration in their answer and 'No' for those who did not. However not all questions could be analysed statistically because of the small size of the Italian sample.

6 Findings

The first part of the questionnaire highlights a first difference: the educational backgrounds needed to access a degree in mathematics are very different in the three countries and this contextual issue is reflected on the three cohorts. While in England the educational background of the students is uniform with more than 95% of the students arriving through the A-level[1] route, in Switzerland and Italy this is not the case. In Italy, there are no entrance requirements for the degree in mathematics beyond having completed five years of high school[2] (lyceum, technological or professional institute) and the data show two of the three access routes (lyceum and technological school) in our sample. It is also interesting to note that in the Swiss sample, almost half of the students (48.2%) have a French Baccalaureate[3]

1 Advanced level qualifications (known as A-levels) are subject-based qualifications in the UK that may lead to university study. Students take this qualification at the age of 17 for two years. It is compulsory to have mathematics as one of the A-levels subjects taken by a student to access mathematics degrees.

2 However, the largest number of students comes from the sciences high school as this is the one that contains the most advanced mathematics curriculum.

3 The French Baccalaureate is the national qualification that students take at the end of high school in France and may lead to university entrance.

Table 2 Summary of the educational routes through which students in the sample accessed the mathematics degree

	Sample size	Qualifications
UK	44	42 A-levels 2 Other
CH	58	18 Sciences high school 28 French Baccalaureate 7 High School (other than Science) 1 Professional School plus Foundation Year 2 Foundation Year 2 Other
IT	26	1 Arts high school 1 Technical high school 2 Classics high school 22 Sciences high school

while there are five more access routes recorded that account for the rest of the sample (see Table 2).

7 Motivation to study mathematics at the tertiary level

The motivation for the choice of mathematics is a relevant issue in the liminal stage of the rite of passage since it signifies the reasons to join the new stage. Thematic analysis of the utterances reveals differences across the samples, showing how the choice for the Italian sample is strongly and almost exclusively related to passion for the discipline, while the motivation linked to career prospects is very influential for the UK students:

Because it is the subject that fascinated me the most at school, and even though I knew it was going to be difficult [at university] I believe that it is worth trying. (IT19)[4]
Maths is useful in all sectors of work - I didn't know what I wanted to do as a career, so maths keeps a lot of career doors open for me. (UK27)

Moreover, 80% of the Italian students' quotes referring to work opportunities are about the passion for becoming a teacher, as the one below shows:

Because I like mathematics and it is my dream to become a mathematics teacher. (IT15)

Swiss students seem to be located somewhere in the middle, with both motivations, passion, and work prospects, mentioned with similar frequencies:

Because I love mathematics. (CH18)
Studying mathematics opens many career choices. (CH41)

[4] Each student was assigned an alphanumeric code: IT, UK and CH for the country and a number starting from two. From IT2 to IT27 for Italy, from UK2 to UK46 for UK, from CH2 to CH59 for Switzerland. The Italian and Swiss extracts of qualitative data have been translated by the authors.

Table 3 Distribution of codes across the questions regarding the motivation for joining mathematics. The second level of coding allowed several codes to be associated to the same utterance therefore the percentages in the table may exceed 100%. The percentages in this table, and in those which follow, are the frequencies of the occurrence of the code (tagged with Yes in the sample—see Stage 4 of data analysis) in the given sample

	Passion	To be good at it	Work opportunities	Characteristics of mathematics	Other
UK	55.56%	22.22%	46.67%	2.22%	8.89%
IT	84.62%	23.08%	19.23%	15.38%	0%
CH	56.9%	10.34%	31.03%	13.79%	1.72%

Indeed, examination of the codes' distribution, reported in Table 3, shows this difference to have also statistical significance.

A X^2 tests for the distribution of the code 'passion' over the three populations returned significance ($p \cong 0.029$) which indicated significance of the occurrence of the code in one of the samples. Paired X^2 tests with Bonferroni adjustment returned significance of occurrence of the code in the Italian sample with respect to the UK sample ($p \cong 0.013$) and the Italian sample with respect to the Swiss sample ($p \cong 0.014$). As frequencies in Table 3 suggest, indeed passion as a motivation for choosing university mathematics characterises the Italian sample. The same investigation for the code 'work opportunities' returned borderline significance ($p \cong 0.0507$) when performed across the three sites. The paired X^2 tests again with Bonferroni adjustment failed to return significance, but only just, between the UK and Italian samples ($p \cong 0.02$) indicating likely significant difference in the distribution of this code between the two datasets.

In summary, UK and Italian students appear to report different motivations for joining a mathematics degree: the UK students are significantly more driven by extrinsic motivation (employability opportunities) than the Italian students are to join mathematics degrees, while Italian students report mostly intrinsic motivation (passion for the subject). Swiss students seem placed in the middle with the frequencies for 'work opportunities' in the middle of the frequencies of the other two samples.

8 Thinking back to School Mathematics

The questionnaire asked the students to think back to their mathematics experience at school, also in comparison with their current experience. We analysed the data coding the students' answers along the three dimensions of the TMA model.

Table 4 reports the codes with their percentages across the three dimensions of the TMA framework referring to the school experience. The fields in the view of mathematics dimension are the codes that emerged from the data and are relative to this dimension. The codes associated to the vision of mathematics have been elaborated further from the dichotomy procedural/conceptual adopted originally from Skemp (1976).

Although the percentage of references to emotional disposition are not uniform in the three samples[5] (in the Swiss data only about half of the questionnaires refer to

[5] Depending on the country considered, a certain dimension of the TMA model may be given as "Not stated" in varying percentages (e.g., 53.4% of the Swiss sample is classified as "Not stated" for the emotional disposition towards school mathematics). This depends on the fact that all questions in the questionnaire were optional. Moreover, the questions were open-ended, so students could answer what they wanted and sometimes the answers could not be framed in the TMA model.

Table 4 Comparison between samples of the percentage of codes matched to the dimensions of the TMA framework referring to school experience. The code 'Not formal language' is used when it is stated that the language was not formal

Dimension of TMA	Code	UK	IT	CH
Emotional disposition towards school math	Positive	97.8%	80.8%	46.6%
	Negative	0%	0%	0%
	Not stated	2.2%	19.2%	53.4%
View of mathematics at school	Process/calculation	40%	30.7%	34.5%
	Problem solving	2.2%	0%	0%
	Not formal language	17.7%	3.8%	0%
	Superficial	0%	23%	27.5%
	Easier/quicker to understand	8.9%	0%	1.7%
	Not stated	31.1%	42.%	36.2%
Perceived competences in mathematics at school	High	95.6%	100%	89.7%
	Low	4.4%	0%	0%
	Not stated	0%	0%	10.3%

emotional disposition), the students' profiles—as for attitudes towards mathematics—are similar across the three sites. When a reference to emotional disposition towards mathematics at school is present, it is positive: no one declares a negative emotional disposition.

Most of the students perceived their competence to be high or very high, and they describe mathematics at school as mainly characterised by application of procedures and algorithms.

> *Mathematics at school focuses on solving exercises using basic notions learned from the teacher during the lesson and from textbooks.* (IT3)

However, in this algorithmic understanding of mathematics, there are some small differences. UK students are the only ones who detect the difficulty of acquiring a technical language which they were not prepared for at school:

> *The different notations used at university is far more complicated as well as how work is set out.* (UK37)

Both Italian and Swiss students reflect on how mathematics at school seems now superficial, when compared to university mathematics, and they recognise strong differences in the demands they face in the two stages:

> *[University mathematics is] more detailed, and more rigorous, not just a surface approach. Demands real work of understanding the concepts.* (CH6)
> *At school you are presented with special cases relative to various branches of mathematics in a way much more superficial than at university where everything has a proof that uses rigorous formalism.* (IT19*)*

Summarising, despite the different routes that students had taken to access a mathematics degree, their reflections on the school experience of mathematics are similar. They all enjoyed the subject, which they believed is mainly characterised by applications and calculations, and they have a high mathematics self-concept. Of course, the positive attitudes of the students when they enter university are not surprising: the choice of mathematics for further study alone suggests some level of motivation, confidence in competence, and enjoyment for the subject.

9 The university mathematics experience

Table 5 reports the codes that emerged from the qualitative analysis of the data related to the questions about the university mathematics experience and their distributions in the three samples. Also in this case, there is a common thread in the evolution of attitude towards mathematics across samples.

The change in emotional disposition towards mathematics at university is very noticeable: whereas nearly only positive emotions were associated to school mathematics, now the students across the three samples experience also negative—such as stress and anxiety—or ambivalent emotions. The code ‘ambivalent’ refers to utterances where students have expressed both positive and negative emotional responses to university mathematics. The ambivalence is mainly associated to the negative aspect of being (unpleasantly) challenged and the positive experience of being able to overcome the challenge.

Frustration and confusion! Then satisfaction once I have got it right. (UK21)

Across the three samples, the positive emotions are mostly associated to the satisfaction (sometimes pride) of having tackled successfully something perceived to be very difficult.

Pride when I finally solve a complex problem. (UK38)

The negative emotions are connected to frustration for repeated failures and uncertainty about the causes of these failures and what can be done to overcome them. The following metaphor by an Italian student describes this common feeling of helplessness:

Table 5 Comparison between samples of the percentage (over the sample) of codes matched to the dimensions of the TMA framework when students were asked to think about their experience of university mathematics

Dimension of TMA	Code	UK	IT	CH
Emotional disposition towards university math	**Positive**	40%	38.5%	25.9%
	Negative	11.1%	11.5%	25.9%
	Ambivalent	48.9%	46.2%	36.2%
	Not stated	0%	3.8%	12.1%
View of mathematics at university	**Conceptual vs Procedural**	26.67%	34.62%	22.22%
	Abstraction	8.89%	19.23%	18.97%
	Formalism	22.22%	42.31%	34.48%
	Proof	33.3%	23.08%	48.28%
	Not stated	24.4%	26.9%	19%
Perceived competences in mathematics at university	**High**	24.4%	15.4%	10.3%
	Scaled back	28.9%	11.5%	34.5%
	Low	42.2%	50%	39.7%
	Not stated	4.4%	23.1%	15.5%

[I feel] Like in quicksand. (IT20)

These emotional states are present in the three samples indicating that the process of adjustment to the new context, therefore the crisis inherent to the rite of passage, has started for these students.

Recall that the vision of mathematics dimension of the TMA model accounts for utterances linked to what the students perceive mathematics to be (e.g. 'mathematics is…' see Di Martino & Zan, 2010, p.476), therefore codes for the vision of mathematics are those that link mathematics to some of its features. With respect to the university experience, those codes reflect the newly found formalism and abstraction of mathematics. These codes are: CP (for the tension between conceptual and procedural understanding in mathematics, as it is perceived by the students), AB (where the utterance refers explicitly to abstraction in mathematics), FO (for formalism—which includes mentions of rigour, definitions, notation), and PR (for proof).

The codes found investigating the nature of mathematics at university are now different from those found when students reflected on the nature of mathematics at school. They all reflect the new demand of the subject for rigour and abstraction, although in different ways across the three samples, and the new emphasis on proof. We focus on the code PR, to investigate differences across the three samples qualitatively. All the three cohorts recognise proof as one of the features of university mathematics, but they have different reactions to this realisation.

Swiss students seem more preoccupied with the requirement for proof than their counterparts. For them the jump between mathematics dominated by algorithmic thinking to mathematics characterised by proof appears to be very noticeable.

There is an exploration of more general and abstract structures, and of different subdivisions of mathematics. The main difference, in my opinion, is the need to have a certain rigor and mathematical thinking, visible for example in the emphasis on proof. (CH50)

These students find the new requirement for proof also somewhat unexpected:

At the EPFL there are a lot of proofs and completely new things that I had never seen before (e.g., group theory). (CH39)

UK students also mention the new requirement for proof as one of the features of university mathematics, but they juxtapose this requirement to their view of school mathematics as calculations and applications.

Maths at uni is much more proof based and understanding why we carry out the calculations we do, whereas school maths was just learning a bunch of processes and definitions and applying them. (UK27)

The new requirement for proof does not appear as unexpected to Italian students as it was for Swiss and UK students, and it is also linked to an increased requirement for creativity and independent thinking:

The increased importance of proof (as it was to be expected) and the higher creativity needed to solve the exercises given. (IT26)

The frequencies of the codes related to the nature of mathematics are reported in Table 6.

Table 6 Frequencies of codes related to the nature of mathematics from the analysis of the answers to the question '*Could you describe at least one of the things you have found which are different between mathematics at school and mathematics at university?*'

	CP	AB	FO	PR
UK	26.67%	8.89%	22.22%	33.33%
IT	34.62%	19.23%	42.31%	23.08%
CH	43.10%	18.97%	34.48%	48.28%

Quantitative analysis returned no significance for the frequency of the code PR between pairs, with only the Italian and the Swiss sample (paired X^2 tests with Bonferroni adjustment, $p \cong 0.029$) nearing the cut-off point of $\alpha = 0.017$ needed, perhaps suggesting that the preoccupation for the sudden requirement for proof is most common amongst Swiss students, as illustrated previously.

Table 5 also shows a change in students' self-perception during the transition. In particular, the awareness of a change is explicit in the case of the code 'scaled back': this code was used when students stated they do not think they are as good at mathematics as they were at school. To better capture the change in self-perception the analysis that follows is restricted to the students who have reported a change. Those are 32 students in the UK sample (71.11%), 21 in the Italian sample (80.77%) and 41 in the Swiss sample (70.7%). Students explained this change using two different reasons: an internal reason, related to a change in their own ability in mathematics and an external reason, related to the change of the mathematics itself. To capture this dichotomy, we introduced two distinct codes: DIF and MAT. The code DIF was used when the focus of the change was internal, when the students themselves described an unexpected change in the perception of their own ability, as in the following excerpt:

> *Many things are changed, now I think my ability in mathematics has definitely decreased, since the poor results obtained during the first semester. Mathematics at university tests you, you must prepare yourself to many defeats and to get results with a lot of effort.* (IT9)

The code MAT was used when the focus of the change was external, when the nature of mathematics had changed, as in the utterance below:

> *I only think I have a slight fluency in math. The change is only due to the "change" of the subject itself.* (CH50)

The distinction between these two reasons for the change in perceived competence is important to understand the experiences of transition of the students. The Italian students attribute the change in their self-perceptions mainly to external reason: the mathematics being difficult to handle, while the UK students tend to attribute the cause more to internal reason:

> *No, I feel I lack confidence due to the irregular feedback from lecturers. Similarly, I am finding the concepts harder than school, therefore feel my ability is not as good.* (UK42)

Once more, Swiss students seem to occupy a middle ground, with some students ascribing their difficulties to themselves:

Table 7 Frequencies of the codes DIF and MAT across the three samples calculated only over the number of students who reported a change in self-perception

	UK	IT	CH
DIF	46.88%	9.52%	31.71%
MAT	15.63%	28.57%	19.51%

> *I don't think I find it easy anymore. Indeed, there has been a change: I see that my level relative to other students is much lower than before. In addition, it is more difficult for me to assimilate and understand the concepts correctly, and my results are poorer.* (CH14)

And others to the changed nature of the subject:

> *Ease seems less present to me, especially in analysis where the concepts are more abstract, and I have always preferred more "real" maths.* (CH43)

Table 7 reports the frequency distribution of the two codes across the restricted sample of students who reported a change.

A X^2 test on the three populations regarding the distribution of the code DIF returned significance ($p \cong 0.017$). The results of the X^2 test with Bonferroni adjustment between the Italian and UK samples for the code DIF returned significance ($p \cong 0.004$) supporting the qualitative analysis regarding a predominance of this code in the UK sample. It was not possible to carry out the same statistical analysis for the code MAT due to the very small size of the sample of Italian students who indicated a change in the nature of mathematics.

Lastly, regarding the evolution of the perceived competence, the data showed the effects of the constant comparison with peers: students who were at the top end of achievement in their school are now experiencing the 'big-fish-little-pond' effect (Marsh, 1987). This effect is based on the observation that the individual's self-concept is strictly related to the comparison with one's peers: in our case, first year students begin to compare themselves to many other very good students in mathematics. Manifestations of this effect emerge clearly from the questionnaire in all three samples:

> *Not really, was in a class with people who were better. (UK30)*
> *Something has changed since I have to confront myself with people more prepared than me. (IT20)*
> *.. yes there have been changes, being surrounded by mathematicians means that the level goes up, so we find ourselves in the average.* (CH12)

In summary—analysis of the data showed changes in the three dimensions of the TMA framework in the three samples, but those changes have distinct characteristics for each cohort of students indicating that their experiences are not uniform.

10 Teaching and the environment

Codes relative to the changes in teaching and educational environment were less frequent than expected, although more frequent in the UK sample (24.44%) compared to the Italian sample (7.7%) and the Swiss sample (15.52%). However, some of the themes across the three samples are similar. For example, reference to the fast pace of the lectures can be found in the three datasets:

> *The largest difference is the times – at school (obviously) the pace is slower, both because the teacher writes more slowly so that students have the time to write too and because the students do not understand and ask for clarification repeatedly (and even this does not guarantee that all is clear).* (IT20)
> *Yes, huge change, I have a lot of trouble understanding the concepts and knowing how to apply them. The course goes by very quickly and I don't have time to assimilate and make the connections.* (CH44)
> *The pace is going very fast and we don't do as many exercises during the lecture (if we do any).* (UK14)

Although the very low incidence of this code in the Italian sample did not warrant statistical analysis, qualitative analysis suggests that the change in teaching style preoccupies UK students more than students in the other two sites. One additional issue raised by the UK students is the lack of interaction during lectures and the abstract nature of mathematics reflected in the lack of learning through exercises.

> *The way it is taught. At uni the lecturers just talk at you, whereas school was much more interactive.* (UK21)
> *In school there was a lot of sitting down during lessons and doing exercise after exercise. In University there is more concept teaching and theory in the lectures.* (UK34)

In summary, what was a uniform picture of the students' perceived attitudes towards mathematics at school becomes a very varied experience during their first year. Changes in each of the three dimensions of the TMA model are evident in the three cohorts, but they present distinct nuances. Below we discuss the data analysis in relation to the research questions and the plausible links to the characteristics of the contexts in the three countries.

11 Discussion

The aim of this study was to map the changes in attitudes towards mathematics experienced by students in the STT in three European countries (RQ1), to investigate whether there are differences in these experiences and whether the educational context may impact on such differences (RQ2).

Attitudes towards mathematics at the end of school (separation stage) appear to be similar in the three contexts: students left school having a positive emotional disposition towards mathematics and being confident in their mathematical ability. Despite this uniformity, it is possible to detect some differences in the view of mathematics: a dimension strongly affected by how mathematics is presented in school (Kloosterman, 2002) and, therefore, potentially affected also by the national curriculums. The absence of formal language in school mathematics appears predominantly in the reflections of the UK students, while the realisation that mathematics at school was somewhat 'superficial' occurs predominantly in the Swiss and Italian students' narratives. The latter realisation highlights a comparative approach when answering the questionnaire: students are in the liminal stage, and they describe their previous experience with mathematics in the light of the new one.

The clear result is that a procedural view of mathematics is strongly associated to school mathematics by all the three cohorts.

The data analysis shows that the attitudes towards mathematics change for the three samples during the liminal stage of the rite of passage in each dimension of the TMA framework (RQ1). The appearance of the adjective 'difficult' in the students' narratives is the most evident difference between the school memories and the present-day experience. The success or failure in overcoming these (often unexpected) difficulties is crucial in the determination of the emotional disposition and in the evolution of the students' perceived competence. The comparison with peers in a very competitive context adds elements for students' self-perception crisis, as some of the utterances reported earlier show, resembling the so-called 'big-fish-little-pond' effect (Marsh, 1987).

The third dimension of TMA—the view of mathematics—also changes in the liminal stage: all students recognise that the subject they knew as mathematics at school is very different from the subject they encounter at university. The requirements to be good in mathematics also change, affecting the students' theories of success in mathematics and, therefore—as underlined by Di Martino and Zan (2010)—their view of mathematics. The picture which emerges is rather uniform amongst the three samples: university mathematics is characterised by more formalism and abstract thinking, an unexpected attention to the requirement of proof and the lack of emphasis on computations.

While the new students' view of mathematics incorporates some of the epistemological elements recognised as the main causes of the cognitive difficulties in the STT (Gueudet et al., 2016; Tall, 1991), our data confirm that the rite of passage of the STT produces a crisis in nearly all of the first-year students which is also affective—at least in our sample.

Within this apparent homogeneous situation, however, it is possible to note some differences between the three samples. In what follows, we will discuss such differences as they emerge from the analysis of the data (RQ2).

The first difference is that of motivation to join mathematics degrees between Italian and UK students. While Italian students were intrinsically motivated to join mathematics degrees, reporting passion for the subject as main motivation, UK students reported motivation linked to employability (extrinsic motivation) for the same choice. Indeed, Chadha and Toner (2017) show that the employability discourse in UK universities is prominent, with prospectuses of UK universities reporting employability figures for their recent graduates to show to prospective students that their degree courses are 'value for money' and indicate how this prominence is due to the process of marketisation of universities started in the UK with the introduction of tuition fees in 1998. Therefore, it is not surprising that prospective students in this country access this information and are influenced by it when choosing a degree course. In Italy, the employability discourse is not prominent at institutional level, and students seem to choose mathematics mostly motivated by their passion for the subject. This difference in motivation can have long-term effects on the transition to university and on study outcomes. Dyrberg and Holmegaard (2019) discuss the impact of extrinsic and intrinsic motivation on achievement of STEM students at a Danish university and notice that, in line with the findings of Self-Determination Theory, motivation is time and context depended. This observation supports the need to investigate motivation to join mathematics at a contextual level (also intending the education and cultural context) and at one significant point in time (the liminal stage of the transition from school to university mathematics).

Moreover, although intrinsic motivation leads to better quality learning, extrinsic motivation can have many facets and may lead to improved or impoverished learning (Ryan & Deci, 2000). Therefore, this difference in motivation found in our study warrants further investigation if the characteristics of the passage to university are to be understood for these cohorts of students.

The change in emotional disposition seems similar across the three samples, with students experiencing also negative and ambivalent emotions towards mathematics: the unexpected difficulties encountered in the first year of study often result in frustration and anxiety. Amongst the negative emotions, the stress induced by the very fast pace of the lessons is common to the three samples, reflecting how the change in teaching may also impact on the emotional disposition of the students. On the other hand, the 'big-fish-little-pond' effect is stronger in relation to the specific local context, and this may be amongst the factors that amplify the effect. The references to the perceived high ability of the other students are particularly frequent in the answers of the Italian students: our hypothesis is that this result depends on the specific Italian context chosen for the study. The University of Pisa is particularly renowned for its quality and the famous Scuola Normale[6] is also located in Pisa.

The findings related to the changes in vision of mathematics are more nuanced. The vision of mathematics is strongly related to students' experiences: for this reason, students' answers about mathematics tell us also about the teachers' and lecturers' choices.

As seen in the previous section, the main codes which described attributes that students ascribe to mathematics are related to the newly found need for rigour and formalism and to the need for proof. In our data, however, there appear to be differences across the three cohorts in how the students experience cognitive difficulties. We focus here on the analysis of the data concerning the need for proof. The Swiss students, and to some extent the UK students, seem to be more preoccupied for the new requirement for proof than their Italian counterparts and seem to find this requirement surprising, to some extent. We may hypothesise that this difference originates from the difference in high school curriculum in the three countries. Without wanting to attempt a curriculum comparison study, we notice that in the Swiss curriculum[7] mathematics is mostly described as an instrument to study other sciences and although abstraction and technical language are mentioned in the curriculum documents, together with proof, in practice the proofs seen at high school (at the advanced level) are not many and mostly in linear algebra (DFJC & DGEP, 2020). In the UK, mathematics at high school (A-levels) is mainly driven by applications and proof. However, although proof is mentioned in curriculum documents (DfE, 2016), in practice it does not play a prominent role in teaching. Indeed Darlington (2015) reports that, following an analysis of examination questions in A-levels papers using the MATH taxonomy (Smith et al., 1996), most of the marks awarded for A-level examination papers (over 85%) were for routine calculations and procedures. In the light of these findings, it is not surprising that proof does not occupy a large part of the teaching of A-levels in the UK. Lastly, in

[6] The *Scuola Normale* of Pisa is one of the most prestigious universities in Italy. In 2020 it ranked 197 in the world university ranking, first of the Italian universities to appear in this league table together with *La Sapienza* in Rome – see also https://bit.ly/3EiaLG7.

[7] As a representative of the Swiss curriculum, we took the one for *École de maturité* from the canton of Vaud, where the EPFL is based.

Italy, the mathematical goals in the curriculum are different in the three types of high schools (grades 9–13): lyceum, technical institute, and professional institute. However, the word proof and the reference to mathematical formalism are included in each of the relative curriculum documents. At the end of the lyceum, students should have acquired deductive mathematical reasoning and should be familiar with definitions, proof, generalizations, formalisations, and, at the end of the technical or professional studies, students should master the formal language and some proof techniques in mathematics (MIUR, 2010). Already from these three very brief observations regarding the relevant curriculum documents, it is possible to detect a different place that proof and abstract mathematics has in the three countries—which is in turn reflected in the differences of emphasis that the students ascribe to the new need for proof in the three samples.

Another noticeable difference is found in the reasons that students give for explaining the crisis in their self-perception as mathematics learners. Two main reasons emerged: a sudden decrease in their mathematical ability or a significant change in the nature of the subject 'mathematics' (and therefore in its requirements). Within our sample, UK students tend to ascribe changes in their self-perception more often to a change in the perception of their mathematical abilities than Italian students, who ascribe this change more often to the change in the nature of the subject. This can appear strange in the light of the discussion about national mathematical curriculum, since the Italian curriculum includes some ideas of the mathematical formalisation typical of the university approach. However, the continuity between school and university mathematics in Italy is often not fully realised in the classroom (Accascina et al., 1998) and several studies show how the idea of mathematics developed in secondary school is very different from the mathematics proposed at university level also when a formal approach is proposed (Deeken et al., 2020). This difference is particularly evident in prestigious universities such as the University of Pisa. For the UK students, who spent the A-level years in classes that are typically small when compared to other core subjects such as English (DfE, 2017), we may hypothesise that the change in self-perception is motivated by the impact of finding themselves in very large classes with students who are also very good at mathematics, in short by the predominance, for this cohort, of the 'big-fish-little-pond' (Marsh, 1987) effect this time made more evident by a much increased cohort size.

Lastly, we detect a difference in the impact that teaching has on the university experience, beyond the impact on the emotional predisposition mentioned earlier. We have already seen that the UK students seem to be much affected by the changes in teaching and, as well as the Swiss students, they mention the fast pace of the lectures and the lack of interaction during lectures as difficulties compared to the teaching style they experienced at school. On the other hand, despite the apparent continuity between the requirements of the school curriculum and that of formalism in university mathematics in Italy, the Italian sample reports that differences between assessment at university and at school, and the competences which are assessed, constitute one of the main reasons to explain the increased difficulty in being successful in mathematics.

Studies that highlight differences between different cohorts of students in the STT, focusing on the discussion of the possible relation to the educational context, are new to this research area. Indeed, to the best of our knowledge, no review of the literature on STT has found research aimed at highlighting the differences of the transitions across contexts, although some studies have addressed the sociocultural aspect of such transition (e.g. Hernandez-Martinez & Williams, 2013). The analysis reported above shows that the instrument we adopted is both suitable to detect changes in attitudes towards mathematics across the three populations and in highlighting some of the differences in the students' experiences.

12 Concluding Remarks and future research directions

Our study was motivated by the need for developing cross-cultural studies on STT and in doing so it also highlighted the difficulties of developing this kind of research.

A first observation is related to the different length of the narratives of the three samples. We observed that the answers to the open-ended questions given by Swiss students used on average 25% fewer words than the answers given by the Italian students, and the ones given by the UK students used on average half the number of words used by the Italian students. This may depend on several factors, such as the nature of the language (we notice that French and Italian are Romance languages while English is not), cultural factors, and students' survey fatigue that may be experienced in some countries. However, these marked differences in the length of responses may represent an issue when analysing narratives.

Secondly, we experienced translation issues: both for the questionnaire and for the replies. In our study, the original questionnaire was initially written in Italian and administered to Italian students (Di Martino & Gregorio, 2019). It was then translated into two more languages for Swiss and UK students. The translation process was developed with the help of mother tongue and bilingual colleagues, but the translation was neither immediate nor unambiguously determined and several choices were made during the translation phase. It is outside the scope of this paper to discuss all such choices, but they are nonetheless important. Together with language differences, we also had to account for local differences between universities. For example, in the biographical part of the questionnaire we asked UK students whether one of the reasons for choosing Loughborough University was that this is a campus university, while the idea of campus university is not applicable to Italian Universities. We introduced this option as the campus experience is a factor for UK students' choices, even if this was irrelevant or near irrelevant in the other two contexts. Therefore, in the translation we had to be careful both to preserve the meaning of the questions and for the question to be meaningful in the given context. We were not always successful: for example, during data analysis we realised that one question (Question 4.2 of the questionnaire in Appendix 2) was interpreted differently across the three cohorts. This problem with the translation led us to discard the data related to this question for the comparative analysis reported in this study. It would be therefore highly recommended to involve linguistic specialists to fully understand the language related difficulties and work to overcome them when designing comparative studies that involve translation of research tools in several languages.

The study reported in this paper is an investigation into whether differences across educational contexts in the STT could be found and whether those differences were likely to have an impact on the transition experiences of the students. The study did not aim at finding general statements on the experiences of all Swiss, UK, or Italian students at the start of mathematics degrees. There are other crucial contextual aspects that have not been considered and that would be an interesting issue for further research, such as the reputation and type of university within the national context. Indeed, the data suggest that the influence of the context is on at least two levels: a general and cultural level, and a more specific and local level, determined by the kind of institution within the national context. Selecting three other universities in Italy, Switzerland and the UK may therefore have led to the emergence of other differences between the cohorts' experiences.

However, we believe that this study contributes to our knowledge on the experiences of students in the secondary–tertiary transition in two ways: one methodological and one substantive. For the methodological contribution, we notice that the study design can be replicated in other contexts to give rich descriptions of students' transitions experiences and highlight their main contextual characteristics. For the substantive contribution, the results show how the individual rite of passage is strongly affected by cultural differences: it cannot be reduced to the change in the culture of mathematics or in the capacity of the individual. It is an outcome of these and other changes in cognitive and social demands embedded in a sociocultural context that, in turn, makes the crisis inevitable and necessary for the transition to happen. The latter observation is particularly significant: future research on secondary–tertiary transition will have to encompass the sociocultural and affective dimensions of the phenomenon, as well as the cognitive/epistemological one, to offer a clear picture of STT. Therefore, one of the foci of this research should be to investigate how these three components (cognitive/epistemological, sociocultural and affective) interact and shape students' experiences of this transition.

For this reason, we believe further comparative studies are needed to better understand the reach and the strength of contextual issues that affect the STT. A better understanding of these influences is crucial to design actions to promote a successful transition. Although a crisis is needed to achieve a successful transition, this crisis can surely be better supported by all those involved (i.e. schools, universities, researchers) .

Appendix 1

Table 8 Sample universities' characteristics

	Loughborough University https://www.lboro.ac.uk/departments/maths/	EPFL https://www.epfl.ch/education/bachelor/programs/mathematics/	Università di Pisa http://www.dm.unipi.it/webnew/
Entrance requirements	Three As (A and A* are the top marks) or a A*, A, B (A* in mathematics) at A-levels including mathematics. Score of 78–88 in the International Baccalaureate with Mathematics at high level, equivalent qualifications for oversea students	*École de maturité* certificate (or Swiss equivalent, which offers the highest level of knowledge and general culture of Swiss secondary schools. This school has different subject options). Equivalent qualifications for members of EU or EFTA plus the final grade average 80% or more of the maximum grade. Students without these qualifications or from outside EU or EFTA may be admitted to a year of study prior to the Bachelor's degree	Any 5-year high school certificate in any high school type. However, in the last 5 years, at least 85% of the first-year students in Mathematics had graduated from a science or classics lyceum
Number students in Year 1 (over the past 3 years)	About 100 students in Year 1	About 190 students in Year 1	About 170 students in Year 1
University reputation	Loughborough University is consistently amongst the top 10 universities in the national league tables, and it is very popular with its students	EPFL is one of the top universities in Switzerland – and ranks amongst the first Swiss universities in every world university ranking	The University of Pisa is one of the best and oldest universities in Italy. It attracts both home and international students

Table 8 (continued)

	Loughborough University https://www.lboro.ac.uk/departments/maths/	EPFL https://www.epfl.ch/education/bachelor/programs/mathematics/	Università di Pisa http://www.dm.unipi.it/webnew/
Modules taught in the first year	Computing and Numerical Methods Analysis 1 and 2 Linear algebra 1 and 2 Mathematical methods 1 and 2 Mathematical Thinking Introductory probability and Statistics Mechanics Geometry and groups (Modules are either one or two semesters long)	Advanced analysis 1 and 2 Advanced linear algebra 1 and 2 General Physics: Mechanic General Physics: Fluids and Electromagnetism Information, Computation and Communication Geometry 1 and 2 Object-oriented programming Global issues (Modules are one semester long)	Analysis 1 Arithmetic Physics 1 Programming Geometry 1 Computing and Numerical Methods (Modules are two semesters long)
Differences in progression from first to second year	Students can take each examination once at the end of the semester when it is taught. Exams are marked out of 100 and the pass mark is 40. If they fail, students can re-take the same examination in the retake period (September) before the new academic year, but their pass mark will be capped at 40% (which is the minimum pass mark). If they fail for a second time the student will fail their degree. There are some caveats to this rule related to the nature of the module (whether they are compulsory or not, or whether the fail is a mark between 30 and 39). A student is expected to take no more than 3 years to finish their degree. Mitigating circumstances may be applied to individual students	Students can take each examination once per year. To enter the second semester, it is necessary to have an average of 3.50 out of 6 at the end of the first semester. If the average is lower than 3.50, students must take a course in the second semester (MAN), success in this course (4/6 at the end of the second semester) allows students to start the first year again. A student who does not pass the MAN fails the first year. To be admitted to the second year, students are required to reach an average of 4 out of 6. A student can take the first year a maximum of two times but cannot take MAN twice	Students can take exams at any point in the four examination sessions after the year in which the module was taught. Exams are marked out of 30, the pass mark is 18. Students can re-take exams any number of times and can refuse to take the mark given, opting to re-take the examination instead. There is no limit to how long a student can be registered at university

Table 8 (continued)

	Loughborough University https://www.lboro.ac.uk/departments/maths/	EPFL https://www.epfl.ch/education/bachelor/programs/mathematics/	Università di Pisa http://www.dm.unipi.it/webnew/
High school syllabi re: abstraction and proof in mathematics	In the UK, mathematics at high school (A-levels) is mainly driven by applications. Proof, although mentioned in curriculum documents (DfE, 2016), in practice does not play a prominent role in teaching	Abstraction and technical language are mentioned in the curriculum documents for *École de maturité*, together with proof. In practice the proofs seen at high school (at the advanced level) are not many and mostly in linear algebra (DFJC & DGEP, 2020)	The mathematical goals in the curriculum are different in the three types of high schools (grades 9–13): lyceum, technical institute, and professional institute. However, the word proof and the reference to mathematical formalism are included in each of the relative curriculum documents. At the end of the lyceum, students should have acquired deductive mathematical reasoning and should be familiar with definitions, proof, generalizations, formalisations, and, at the end of the technical or professional studies, students should master the formal language and proof techniques in mathematics (MIUR, 2010)

DfE—Department for Education (2016). *Mathematics AS and A level content.* https://www.gov.uk/government/publications/gce-as-and-a-level-mathematics

Département de la formation, de la jeunesse et de la culture (DFJC), Direction Générale de l'enseignement postobligatoire (DGEP). (2020). *École de maturité. Plan d'études et liste des examens*. Site official État de Vaud. https://www.vd.ch/themes/formation/formations-gymnasiales/ecole-de-maturite/

MIUR—Ministero dell'istruzione, dell'università e della ricerca (2010). *Indicazioni nazionali per i licei*. https://www.indire.it/lucabas/lkmw_file/licei2010/indicazioni_nuovo_impaginato/_decreto_indicazioni_nazionali.pdf

Appendix 2

This appendix includes the questionnaire in English which was administered to the UK students. The Swiss and Italia students received the same questionnaire in translation.

Section 1: About you

Q1.1 Please indicate your age	I am ------ years old
Q1.2 Please indicate your gender by clicking the appropriate box	☐M ☐F ☐Other ☐Prefer not to say
Q1.3 Please tell us what qualification you had when you joined the university	☐A levels ☐International baccalaureate ☐Other
Q1.4 Please tell us what course you are enrolled in	----------

Section 2: The University

Q2.1 Why did you choose to study mathematics at university?

Q2.2 What was the main reason you choose to come to Loughborough?

☐ Location of the university
☐ I was attracted to the course
☐ Other ----------------

If you selected 'Other' please specify

Section 3: Studying mathematics at university

Q3.1 Do you think that the mathematics you study at university is different from the mathematics you studied at school?

☐Very different	☐Different	☐Not so different	☐The same

Q3.2 Did you enjoy doing mathematics at school?

☐Very much	☐Much	☐Indifferent	☐Not so much	☐Not at all

Q3.3

Could you describe below at least one of the things you have found which are different between mathematics at school and mathematics at university?

Q3.4 Do you enjoy studying mathematics at university?

☐Yes	☐Indifferent	☐No

Q3.5 Did you feel you were good at mathematics when you were in school? Why?

Q3.6 Do you feel the same about your mathematics ability at university? Why?

Section 4: Comparing school and university

Q4.1 Compare university mathematics to school mathematics. Do you think that university mathematics is more difficult compared to university mathematics?

☐ Much more difficult	☐More difficult	☐About the same	☐Easier	☐Much easier

Q4.2 Can you tell us why you think mathematics at university is easier or more difficult?

(Note this question has been excluded by the analysis in the 3 samples as the meaning was interpreted differently by the students in the translation into Italian and into French)

Q4.3 Do you like mathematics as much as when you were in school? Can you explain why you do (Or you don't)?

Q4.4 Can you describe one emotion/feeling that you link to studying mathematics at university?

Q4.5 Can you describe a key moment since coming to university that has played an important role in how you feel about studying mathematics at university now?

Thank you!

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Data availability The datasets generated during and/or analysed during the current study are not publicly available due to its nature: the data is mostly qualitative, and it is not made publicly available to protect the anonymity of the participants under the European General Data Protection Regulation and the conditions of the ethics agreements signed with the participants.

Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

References

Accascina, G., Berneschi, P., Bornoroni, S., De Vita, M., Della Rocca, G., Olivieri, G., Parodi, G. P., & Rohr, F. (1998). *La strage degli innocenti. Problemi di raccordo in matematica tra scuola e università*. Giovanni Battagin Editore.

Adkins, M., & Noyes, A. (2016). Reassessing the economic value of advanced level mathematics. *British Educational Research Journal, 42*(1), 93–116. https://doi.org/10.1002/berj.3219

Cao, Z., Forgasz, H., & Bishop, A. (2008). Doing surveys in different cultures: Difficulties and differences–A case from China and Australia. In B. Atweh, A. Calabrese Barton, M. C. Borba, N. Gough, C. Keitel, C. Vistro-Yu, & R. Vithal (Eds.), *Internationalisation and globalisation in mathematics and science education* (pp. 303–320). Springer. https://doi.org/10.1007/978-1-4020-5908-7_17

Chadha, D., & Toner, J. (2017). Focusing in on employability: Using content analysis to explore the employability discourse in UK and USA universities. *International Journal of Educational Technology in Higher Education, 14*(1), 1–26. https://doi.org/10.1186/s41239-017-0071-0

Chevallard, Y. (2006). Steps towards a new epistemology in mathematics education. In M. Bosch (Ed.), *Proceedings of the 4th Conference of the European Society for Research in Mathematics Education* (pp. 21–30). Fundemi IQS.

Clark, M., & Lovric, M. (2008). Suggestion for a theoretical model for secondary-tertiary transition in mathematics. *Mathematics Education Research Journal, 20*(2), 25–37. https://doi.org/10.1007/BF03217475

Darlington, E. (2015). Post-16 mathematics qualifications: Differences between GCE A level, International A level, Cambridge Pre-U and Scottish examination questions. *Research Matters: A Cambridge Assessment Publication, 20*, 6–12.

Deeken, C., Neumann, I., & Heinze, A. (2020). Mathematical prerequisites for STEM programs: What do university instructors expect from new STEM undergraduates? *International Journal of Research in Undergraduate Mathematics Education, 6*(1), 23–41. https://doi.org/10.1007/s40753-019-00098-1

Département de la formation, de la jeunesse et de la culture (DFJC), Direction générale de l'enseignement postobligatoire (DGEP). (2020). *École de maturité. Plan d'études et liste des examens.* Site official État de Vaud. https://www.vd.ch/themes/formation/formations-gymnasiales/ecole-de-maturite/. Accessed 16 August 2021.

Department for Education. (2016). *Mathematics AS and A level content*. https://www.gov.uk/government/publications/gce-as-and-a-level-mathematics. Accessed 24 August 2022.

Department for Education. (2017). *Understanding costs of A level provision via the decision-making process behind class sizes*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/603546/DfE_Cost_of_A_levels_Class_sizes_report.pdf. Accessed 24 August 2022.

Di Martino, P., & Gregorio, F. (2019). The mathematical crisis in secondary-tertiary transition. *International Journal of Science and Mathematics Education, 17*(4), 825–843. https://doi.org/10.1007/s10763-018-9894-y

Di Martino, P., & Zan, R. (2010). 'Me and maths': Towards a definition of attitude grounded on students' narratives. *Journal of Mathematics Teacher Education, 13*(1), 27–48. https://doi.org/10.1007/s10857-009-9134-z

Di Martino, P., & Zan, R. (2011). Attitude towards mathematics: A bridge between beliefs and emotions. *ZDM-Mathematics Education, 43*(4), 471–482. https://doi.org/10.1007/s11858-011-0309-6

Di Martino, P., Gregorio, F., & Iannone, P. (2022). The transition from school to university in mathematics education research: New trends and ideas from a systematic literature review. *Educational Studies in Mathematics*, this issue.

Dubinsky, E., & McDonald, M. A. (2001). APOS: A constructivist theory of learning in undergraduate mathematics education research. In D. Holton, M. Artigue, U. Kirchgräber, J. Hillel, M. Niss, & A. Schoenfeld (Eds.), *The teaching and learning of mathematics at university level. New ICMI Study Series* (pp. 275–282). Springer. https://doi.org/10.1007/0-306-47231-7_25

Dyrberg, N. R., & Holmegaard, H. T. (2019). Motivational patterns in STEM education: A self-determination perspective on first year courses. *Research in Science & Technological Education, 37*(1), 90–109. https://doi.org/10.1080/02635143.2017.1421529

Gueudet, G. (2008). Investigating the secondary-tertiary transition. *Educational Studies in Mathematics, 67*(3), 237–254. https://doi.org/10.1007/s10649-007-9100-6

Gueudet, G., Bosch, M., DiSessa, A. A., Nam Kwon, O., & Verschaffel, L. (2016). *Transitions in mathematics education*. Springer. https://doi.org/10.1007/978-3-319-31622-2

Gueudet, G., & Thomas, M. O. J. (2020). Secondary-tertiary transition in mathematics education. In S. Lerman (Ed.), *Encyclopedia of mathematics education* (pp. 762–766). Springer. https://doi.org/10.1007/978-3-030-15789-0_100026

Hernandez-Martinez, P., & Williams, J. (2013). Against the odds: Resilience in mathematics students in transition. *British Educational Research Journal, 39*(1), 45–59. https://doi.org/10.1080/01411926.2011.623153

Higher Education Statistics Agency. (2018). https://www.hesa.ac.uk/news/18-06-2020/sb257-higher-education-graduate-outcomes-statistics/study. Accessed 24 August 2022.

Kloosterman, P. (2002). Beliefs about mathematics and mathematics learning in the secondary school: Measurement and implications for motivation. In C. Deeken, I. Neumann, & A. Heinze (Eds.), *Beliefs: A hidden variable in mathematics education?* (pp. 247–269). Springer. https://doi.org/10.1007/0-306-47958-3_15

Koichu, B., & Pinto, A. (2019). The secondary-tertiary transition in mathematics: What are our current challenges and what can we do about them? *Newsletter of the European Mathematical Society, 112*, 34–35. https://doi.org/10.4171/news/112/8

Lerman, S. (1998). Research on socio-cultural perspectives of mathematics teaching and learning. In J. Kilpatrick & A. Sierpinska (Eds.), *Mathematics education as a research domain: A search for identity* (pp. 333–350). Kluwer Academic Publisher. https://doi.org/10.1007/978-94-011-5196-2_6

Lerman, S. (2000). The social turn in mathematics education research. *Multiple Perspectives on Mathematics Teaching and Learning, 1*, 19–44.

Marsh, H. W. (1987). The big-fish-little-pond effect on academic self-concept. *Journal of Educational Psychology, 79*(3), 280–295. https://doi.org/10.1037/0022-0663.79.3.280

Ministero dell'Istruzione, dell'Università e della Ricerca (2010). *Indicazioni nazionali per i licei*. https://www.indire.it/lucabas/lkmw_file/licei2010/indicazioni_nuovo_impaginato/_decreto_indicazioni_nazionali.pdf. Accessed 24 August 2022.

Mok, I. A. C., & Clarke, D. J. (2015). The Contemporary Importance of triangulation in a post-positivist world: Examples from the learner's perspective study. In A. Bikner-Ahsbahs, C. Knipping, & N. Presmeg (Eds.), *Approaches to Qualitative Research in Mathematics Education. Advances in Mathematics Education.* Springer. https://doi.org/10.1007/978-94-017-9181-6_15

Namey, E., Guest, G., Thairu, L., & Johnson, L. (2008). Data reduction techniques for large qualitative data sets. *Handbook for Team-Based Qualitative Research, 2*(1), 137–161.

Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Sage. https://doi.org/10.1002/nur.4770140111

Rach, S., & Heinze, A. (2017). The transition from school to university in mathematics: Which influence do school-related variables have? *International Journal of Science and Mathematics Education, 15*(7), 1343–1363. https://doi.org/10.1007/s10763-016-9744-8

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25*(1), 54–67. https://doi.org/10.1006/ceps.1999.1020

Saldaña, J. (2015). *The coding manual for qualitative researchers*. Sage.
Sfard, A. (2007). When the rules of discourse change, but nobody tells you: Making sense of mathematics learning from a commognitive standpoint. *The Journal of the Learning Sciences, 16*(4), 565–613. https://doi.org/10.1080/10508400701525253
Skemp, R. R. (1976). Relational understanding and instrumental understanding. *Mathematics Teaching, 77*(1), 20–26.
Smith, G., Wood, L., Coupland, M., Stephenson, B., Crawford, K., & Ball, G. (1996). Constructing mathematical examinations to assess a range of knowledge and skills. *International Journal of Mathematical Education in Science & Technology, 27*(1), 65–77. https://doi.org/10.1080/0020739960270109
Tall, D. (Ed.). (1991). *Advanced mathematical thinking*. Springer Science & Business Media. https://doi.org/10.1007/0-306-47203-1
Tinto, V. (1988). Stages of student departure: Reflections on the longitudinal character of student leaving. *The Journal of Higher Education, 59*(4), 438–455. https://doi.org/10.2307/1981920
van Gennep, A. (1909). *Les rites de passage. Étude systématique des rites.* Picard.
Wenger, E. (1998). *Communities of practice: Learning, meaning and identity*. Cambridge University Press. https://doi.org/10.1017/cbo9780511803932
Zan, R. S., Brown, L., Evans, J., & Hannula, M. (2006). Affect in mathematics education: An introduction. *Educational Studies in Mathematics, 63*(2), 113–121. https://doi.org/10.1007/s10649-006-9028-2

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