# Novice Mathematics Students at the University: Experiences, Orientations and Expectations

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*In this paper, we report on an on-going study of novice university students in mathematics and the secondary-tertiary transition. A total of 146 novice mathematics students from three Swedish universities were given a questionnaire in the beginning of the semester. The aim was to characterize them as learners of mathematics. The results were summarized with descriptive statistics and Principal Component Analysis (PCA) was used to look for correlations. The results show that the teacher and the textbook play a crucial role in their learning of mathematics. Further more, the students can be characterized as either individual or interactive learners, which relates to students' grades.*

## Introduction

This on-going study concerns novice mathematics students and their transition to university studies in mathematics. In this study, the novice students are first-semester university students. The notion of transition should be understood as students' learning of mathematics in a new setting in light of their previous experiences of studying mathematics. The comprehensive study is based on two questionnaires, one distributed at the beginning and the other at the end of the first semester. The aim of the first questionnaire is to give an account of their previous experiences of studying mathematics at the secondary level, their views of mathematics and learning mathematics, and their expectations regarding their forthcoming mathematics studies. The aim of the second questionnaire is to examine how these transition-related aspects are affected after the first semester of mathematics studies at the university. In this paper, we report on the results from the first questionnaire.

## Background and methodological considerations

Mathematics students' encounter with the secondary-tertiary transition seems to be associated with a variety of problems (Gueudet, 2008). In different studies, students' under-preparedness for mathematics studies at tertiary level has been paid attention to (Brandell, Hemmi & Thunberg, 2008; Kajander & Lovrick, 2005; Lawson, 2003; Selden, 2005; Thunberg & Filipsson, 2005), in particular students' lack of sufficient and suitable mathematical pre-knowledge and skills

(Jourdan, Cretchley & Passmore, 2007; Lindston & O'Donoghue, 2009), their difficulties with mathematics as a more scientific subject (Guzmán et al., 1998) and the challenge of adapting to a new learning environment (de Abreu, Bishop & Presmeg, 2002). These studies contribute to our understanding of some of the difficulties that can be associated with the transition, but without specific considerations of what is also a problem from a student perspective.

The transition is a multifaceted phenomenon that has been researched from different theoretical perspectives (Gueudet, 2008). However, choosing a theoretical perspective for a study of the transition in advance also entails deciding on the focus of research questions, methodological approaches and features of research results. The differences in definitions of the crucial aspects of the transition may result in incompatible research results and also complicate the accumulation of knowledge of the phenomenon over time.

For the current study, our main interest is to examine novice students' transition without simplifying the nature of this phenomenon. In order to accomplish that, we have based our quantitative study on a general conceptual model for describing students' learning of mathematics. This model consists of a categorization of the main features of learners of mathematics and was developed, using an inductive qualitative approach, as part of a qualitative study on the secondary-tertiary transition from a student perspective without any priori assumptions or pre-defined theoretical perspective (Stadler, 2009).

Choosing this model as a foundation for the questionnaire contributes to the on-going discussion about how mixed methods can result in a more comprehensive examination of a specific phenomenon (Winberg 2006). In the qualitative study, crucial aspects of learning mathematics and the transition were identified. The quantitative study provides an opportunity to find out how often these aspects occur, to what extent, and for whom.

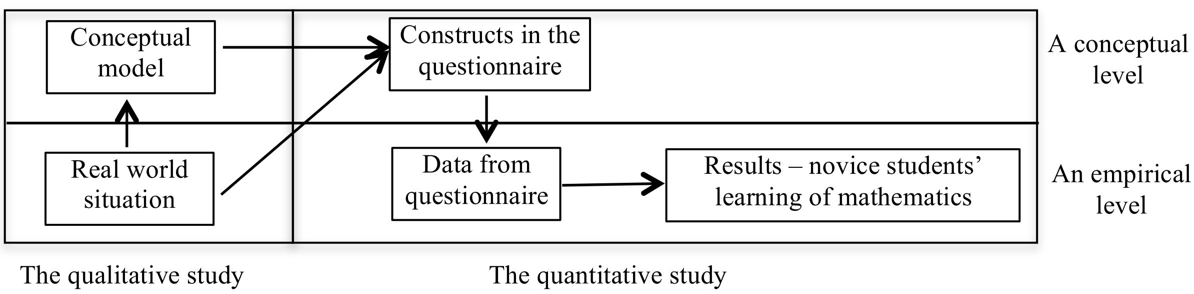


Figure 1. Our methodological approach

A conceptual model (Fig. 1) was generated as a theoretical description of the crucial aspects of students' learning of mathematics in a new setting in light of their previous experiences. To make use of these concepts for the quantitative study, they must be made operational (Bryman, 2002). In this case, the conceptual model is the result of a systematization of empirical data. Thus, we have returned to the empirical data it was based on in the first place to construct questions within themes related to the conceptual model. These constructs were put into the questionnaire to generate quantitative data from this new sample.

## The conceptual model – three categories

The conceptual model consists of three relational categories that constitute significant aspects of learning and understanding mathematics from a student perspective (Stadler, 2009). These three categories are mathematical learning objects, mathematical resources and students' actions as learners.

The *mathematical learning objects* category refers to the students' view of the overall purpose of learning mathematics. It captures students' interpretation of what mathematics is and what learning mathematics is all about. For students in secondary school, an essential part of mathematics studies is working with textbook exercises and problem solving exercises can be a mathematical learning object in itself. Mathematical learning objects can consist of actions or knowledge. For example, students may focus on verbal explanations to other peers as a mathematical learning object, which not only involves the knowledge of how to explain something to someone else but also requires mathematical knowledge of what should be explained.

The *mathematical resources* category concerns those objects and phenomena that students need in order to learn mathematics. Textbooks, teachers, peers, mathematical pre-knowledge and logical thinking are some examples of potential mathematical resources that can constitute mathematical resources when the students use them as such. In discussions of students' learning of mathematics, mathematical resources can be labelled in accordance with how they can be used. As a mathematical resource, an explanation from the teacher can be regarded as dynamic since the teacher interacts with the students and can adjust or change the explanation based on how it is received by the students. On the other hand, the textbook can be regarded as a static mathematical resource because it does not change its content, whether the student understands it or not. The textbook is also a constantly available potential mathematical resource.

The *students' actions as learners* category captures students' actions, intentions and conceptions in relation to their learning of mathematics. It is a category that comprises both mathematical learning objects and mathematical resources in a mutual relationship. The students use mathematical resources they believe can be helpful with respect to a specific mathematical learning object. On the other hand, the availability of potential mathematical resources determines which mathematical learning objects students focus on.

**The design of the questionnaire**

As mentioned earlier, our study is based on two questionnaires. The first, which is reported on in this paper, aims at accounting for novice mathematics students' previous experiences of studying mathematics at upper secondary school, their orientations (i.e. beliefs, dispositions, values, tastes and preferences about mathematics studies) and their expectations concerning their forthcoming mathematics studies. According to Hartas (2010), survey questions can be sorted into four main categories: knowledge, attitudes, behaviour and attributes. Students' preferences about mathematical resources can be captured by questions both about their attitudes and behaviour to determine how they have considered different mathematical resources and how they have been using them. To operationalize mathematical learning objects, i.e. what students regard as the main aim of studying mathematics, we have to focus on students' attitudes. Questions about what they regard as important aspects of mathematics and learning mathematics can capture their mathematical learning objects. On the other hand, the "students' actions as learners" category concerns their behaviour rather than their attitudes. Thus, what the students think they actually did when learning mathematics at secondary level will illustrate this category.

Based on these considerations, we designed a questionnaire with 15 themes:

1. Entry requirements (attributes)
2. Lesson activities in upper secondary school (behaviour)
3. Valuation of lesson activities in upper secondary school (attitudes)
4. Help-seeking behaviour during mathematics lessons in upper secondary school (behaviour)
5. Valuation of homework activities outside school (attitudes)
6. Help-seeking behaviour during homework in upper secondary school (behaviour)
7. Valuation of resources for the learning of mathematics (attitudes)
8. Valuation of the mathematics teacher's actions (attitudes)
9. Valuation of working with peers (attitudes)
10. Valuation of the textbook (attitudes)
11. Orientations towards mathematics and the learning of mathematics (attitudes)
12. Expectations concerning forthcoming studies of mathematics at university
13. Orientations about mathematics studies at university
14. Estimation of time required for self-studies
15. Other comments

Besides some initial questions in Theme 1 about the students' attributes and questions in Theme 2 about activities during an ordinary mathematics lesson, a majority of the questions concerned behaviour and attitudes, which corresponds to empirical instances of the three categories (Stadler, 2009). The 117 questions in Theme 3-13 were formulated as Likert scale questions with a five-step rating scale. For example, the initial questions about their orientations were formulated as follows:

11. Here are some questions about your views of mathematics and learning of mathematics.

| | Strongly Disagree | | | | Strongly Agree |
|---|---|---|---|---|---|
| a) It´s easy for me to learn mathematics. | 1 | 2 | 3 | 4 | 5 |
| b) I can solve most exercises by myself. | 1 | 2 | 3 | 4 | 5 |
| ⁞ | | | | | |
| w) I learn new concepts by solving exercises. | 1 | 2 | 3 | 4 | 5 |

Before the questionnaire was distributed to the students, it was tried out on 20 mathematics students. The aim with this pilot study was to find out if the questions were formulated in an understandable way, how long it would take for the students to answer it and if the questionnaire could yield usable data.

### Data collection and analysis methods

The questionnaire was distributed during the first two weeks at the beginning of the first semester of the study program. It took approximately 15-25 minutes to answer. The participating novice students came from one university and two technical universities. The specific groups of students at each university were chosen according to availability. The majority of the university students (U) were studying in a 3-year programme. However, some were also studying in a 5-year programme. All the students at the technical universities (TU1 and TU2) were in a 5-year programme. In total, 146 students answered the questionnaire, 110 of whom were men and 35 were women. A total of 83% of the students were between 18 and 22 years old.

The quantitative data have been analysed using two methods. Firstly, we have used descriptive statistics to summarize data in order to describe the main features of the participating students. Secondly, Principal Component Analysis (PCA) was used to find the co-variation pattern between categories as well as the relative importance of categories for discrimination between groups.

## Results

### Background attributes of participating students

The participating students had similar backgrounds, as can be seen from Table 1. 80% of the students had conducted their secondary level studies within a national programme (natural science or technology) at the secondary school. For TU1 and TU2, the mathematics entrance requirement is Mathematics E from upper secondary school, while for U Mathematics D suffices.

| | University | Technical university 1 | Technical university 2 |
|---|---|---|---|
| Number of students | 59 | 44 | 43 |
| Access programme | | | |
| Upper secondary school | 46 | 35 | 36 |
| Adult education | 10 | 2 | 7 |
| Natural science/technology foundation year programme | 3 | 6 | 0 |

| | | | |
|---|---|---|---|
| Grades – Math D | | | |
| Pass | 33 | 11 | 7 |
| Pass with credit | 20 | 12 | 8 |
| Pass with special distinction | 6 | 19 | 27 |

Table 1: Backgrounds of the participating students.

**The students' previous experiences of mathematics studies**

A clear majority of the students have hade the same experiences of mathematics lessons at upper secondary school. A mathematics lesson begins with the teacher giving a lecture, which lasts 10-15 minutes of a 60-minute lesson. The rest of the lesson is spent on the students' work with textbook exercises. This work can be handled either individually or in interaction with others, depending on if they typically used to work by themselves with textbook exercises, or if they worked in cooperation with their peers. Teacher initiated discussions within the whole class, group work organized by the teacher and activities involving use of computers are all very rare.

The student's valuation of the importance of different lesson activities for their learning of mathematics in upper secondary school can be seen in Diagram 1. The teacher's lectures at the board, individual work with textbook exercises and individual help from the teacher, which were considered to be the three most valuable activities, were also the most frequent during the lessons. Organized group work and discussions within the whole class, and computer activities is considered to be of less importance. This is partially due to the fact that many students never experienced these activities in upper secondary school.

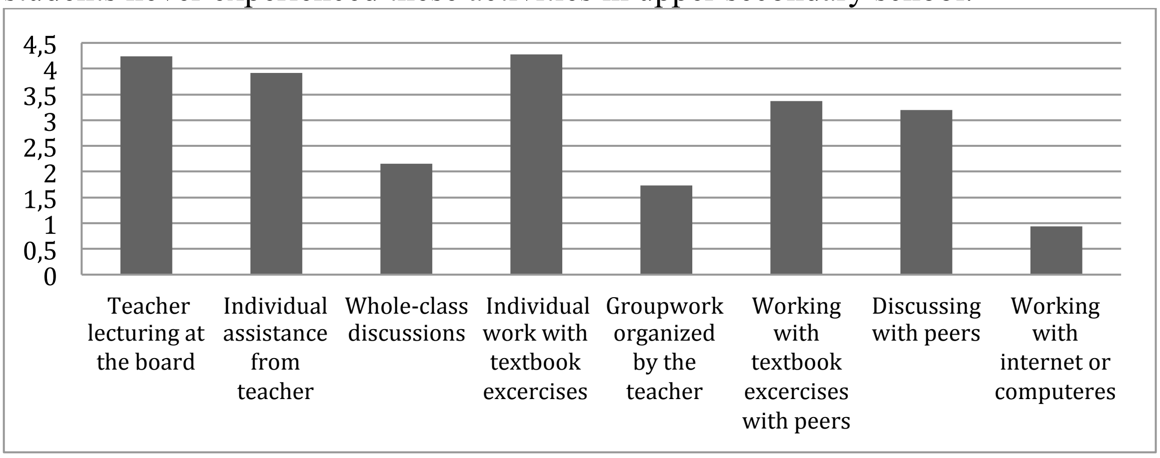


Diagram 1: Students' evaluation of lesson activities (averages).

Students were also asked to evaluate the importance of different potential mathematical resources for learning mathematics in upper secondary school. As illustrated in Diagram 2, the two most important resources are the teacher and the textbook. Other important resources are their peers, the pocket calculator and the book of formulae. Working with tests and exams from previous years was of less importance, and computer or Internet based resources received a very low score.

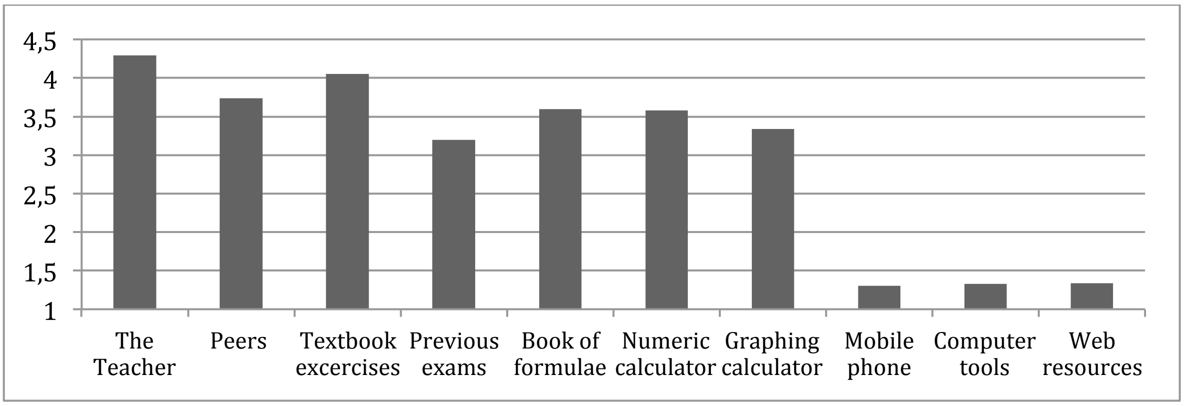


Diagram 2: The importance of potential mathematical resources (averages)

The students have a clear opinion that the most important contribution from the teacher is to provide whole class lectures. As can be seen in Diagram 3, the students also regard the teacher's ability to motivate the students, and to provide help with textbook exercises on an individual basis, as very important.

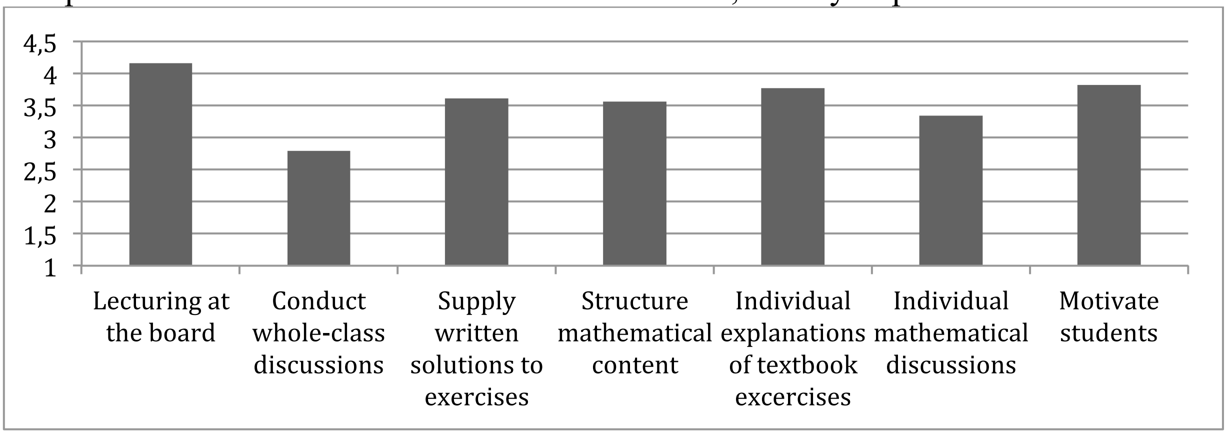


Diagram 3. The importance of the teacher's contribution (averages)

Tables with formulas and short summaries, worked examples, exercises and answers to the exercises are the most highly valued features in the textbook, while text describing concepts and theory is considered somewhat less important. Peers are seen as an important resource primarily during lesson while working with textbook exercises. It is interesting to note that many students felt that providing explanations to other students was a situation of potential learning.

**The students' expectations regarding their university studies in mathematics**
An important aspect of the novice students' expectations regarding their forthcoming university studies in mathematics concerns similarities and differences compared to secondary level. According to the novice students who participated in the study, the significant difference is that mathematics will be harder and more difficult. To succeed with their studies, the novice students believe it is important to do what the teacher tells them to do, participate in all

the teaching activities that are provided and spend a great deal of time on studying in addition to the scheduled teaching activities. In particular, over 90% of the students feel that they have to improve their time planning and take more responsibility for their studies at the university compared to what they are used to doing at upper secondary school. Thus, spending a great deal of time studying independently is what the students expect to be the most important difference between secondary and tertiary mathematic studies.

## Results from the PCA analysis

Data was subjected to PCA, using SIMCA P+ software (Umetrics, 2004), to examine the relations between different features of the novice mathematics students (Table 2).

| Themes | A | N | $R^2$ | Single theme $Q^2$ | Top model $Q^2$ ** |
|---|---|---|---|---|---|
| Student competence profile | 1 | 146 | 0,42 | 0,21 | |
| Valuation of learning activities | 2 | 135 | 0,54 | 0,05 | 0,61*/0,04* |
| Help seeking behavior during math lessons | 2 | 145 | 0,43 | -0,07 | 0,25*/0,12* |
| Valuation of math activity outside school | 2 | 145 | 0,53 | -0,14 | 0,07*/0,04* |
| Help seeking behavior during homework | 1 | 144 | 0,30 | 0,08 | 0,32* |
| Valuation of resources for learning math | 2 | 145 | 0,43 | 0,04 | 0,18*/0,00 |
| Valuation of math teacher actions | 1 | 145 | 0,46 | 0,24 | 0,47*/0,22* |
| Valuation of working with peers | 1 | 144 | 0,62 | 0,45 | 0,22* |
| Valuation of the textbook | 1 | 144 | 0,48 | 0,19 | 0,31* |
| Orientations towards math and math learning | 3 | 146 | 0,37 | 0,06 | 0,70*/0,36*/0,00 |
| Expectations of university math studies | 2 | 144 | 0,36 | 0,01 | 0,13*/0,00 |
| Orientations towards university math studies, including time requirements | 1 | 142 | 0,36 | 0,21 | 0,33* |
| Top model | 2 | 146 | 0,35 | | 0,07*/0,14* |

* Significant on the 95 % level

** For themes with more than one component, cumulative $Q^2$ in the top model is given for each component of the single theme model..

Table 2. Statistics from PCA modelling of themes (single theme models) and relations between themes (top model). Table showing the number of components in the respective PCA model (A), the number of students (N), and the proportion of variation that is described (R2) and predicted $(Q)^2$ by the models.

Because the students' work with mathematics at secondary level was experienced as mainly individual or interactive, we looked for a characterization of the students as learners in terms of individual or interactive. This was obtained through some of the questions in Theme 11, focusing on the students' preferences to work alone or with others. Then, we divided these into sub-groups according to different themes: the nature of mathematics, learning style, task-solving strategies and self-efficacy. The PCA showed that the students with an individual learning style also had a higher score on self-efficacy and believed tasks could be solved if enough time was provided for thinking. To a lesser extent, these students asked teacher and peers for help or had discussions. The students with higher grades, in this case mainly the TU2 students, had a more individual learning style than the others in the study. The students with a more interactive learning approach and task-solving strategies preferred to work with their peers and ask the teacher for help and discussion. These students also showed a lower level of self-efficacy and regarded it as more important to get acquainted with new learning materials in collaboration with others.

## Discussion and concluding remarks

In this study, we have given an account of students' previous experiences of studying mathematics at secondary level, their views on mathematics and learning mathematics, and their expectations concerning their forthcoming mathematics studies. An unequivocal result of our study is that the teacher and the textbook are perceived by students as the most important mathematical resources. Moreover, the students' experiences of mathematics studies at secondary level are dominated by a short introductory lecture by the teacher, followed by work with textbook exercises. From this study, we cannot draw conclusions as to the mathematical learning objects that refer to different mathematical subjects. However, the students' strong preferences for the textbook exercises are likely to predict strong preferences for a procedural understanding and an instrumental approach to solving exercises. The consequences this will have on the students' transition will probably differ between the three seats of learning and will be examined in the second questionnaire.

The results also indicate that the students' work with textbook exercises could be characterized as mainly individual or interactive, and the outcome of the PCA analysis indicates that the students can actually be characterized as having an individual or interactive learning style. Concerning their use of mathematical resources, we conclude that the more individually oriented students tend to use mathematical resources that are more static and available, and rely on their own capacity to think and learn for themselves. On the other hand, interactive students tend to focus on interactive, mutual and dynamic mathematical resources, for example their teacher and peers. A related result from the qualitative study (Stadler, 2009) showed that students can be characterized as independent or dependent as learners, whereby the latter group encountered more transition-related difficulties when the demands on independence in mathematics studies at university increased. This can also be related to the results showing that students with higher grades tend to be more individual. Thus, in the second questionnaire we also want to determine whether there is a correlation between individual and independent students and interactive and dependent students, and how these two groups of students experience the transition.

In particular, a re-orientation towards partly new and different mathematical learning objects, for example a more structural mathematical understanding and the use of supplementary mathematical resources, is needed. This certainly raises the question of which group will handle the transition in the most favourable way, the individual or the interactive students? We will consider this question when designing the second questionnaire.

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