Chapter 1

Introduction: Encountering the Problem

All science requires mathematics.

Roger Bacon

University courses that are (albeit remotely) related to a technical subject such as science or engineering involve a basic knowledge of mathematics. Although this is a subject all students come into close and continual contact with during their schooldays, the passage from secondary to tertiary education is considered particularly problematic regarding the challenges students encounter when being confronted with university mathematics (cf. Bruder et al., 2010; Gueudet, 2008). Students’ failure rates in STEM (science, technology, engineering, and mathematics) subjects are alarmingly high in many countries. In Germany, for instance, almost 48% of engineering students fail in their first year of university studies (Heublein, Richter, Schmelzer, & Sommer, 2012). For the USA, Knight, Carlson, and Sullivan (2007) cite retention rates of 47% for the 1990s and an average of 56% for later studies, which is comparable to the German dropout rate. The United Kingdom has much lower dropout rates on the whole (usually single figures), but they are highest for engineering, technology, and computer science¹. The reasons given

are the same across countries, many relate to the difficulty to meet the demands, the extensive preparations and follow-up work needed, and many specifically mention mathematics as the subject that constitutes the main obstacle.

As the challenges are similar everywhere, many universities attempt to support their first-years in various ways. This was also the intention at Ruhr-Universität Bochum when MP²-Math/Plus was introduced, the project that lies at the heart of this study. Its objective is to remedy the problem described above, to prevent engineering students from dropping out of their course. The concept idea of MP²-Math/Plus is to do so by advancing students’ learning strategies with respect to mathematics. The planning, re-designing and assessing of MP²-Math/Plus necessitates a detailed description of the design and re-design of the interventions in the successive project cycles, so the composition of this thesis does not strictly follow the traditional structure of presenting empirical studies. Figure 1.1 relates the respective standard chapters (in the right column) to the titles of the main chapters (in the left column). The shapes in the centre illustrate their interconnections. An orientation figure referring to Figure 1.1 will appear at the beginning of the main chapters in the course of this thesis, and offer additional guidance through its structure.

This short introduction (Chapter 1) is followed by a broad description of the theoretical concepts (Chapter 2) relevant for the research purpose. Here, the theoretical background in the form of models for the transition from secondary to tertiary education in mathematics is inspected (section 2.1.1), the learning of advanced mathematics is conceptualised in various ways (section 2.1.2), together with its obstacles and approaches to overcome them (section 2.1.3). Apart from cognitive aspects of transition, affective and social factors are likewise introduced. This also involves contemplating and structuring the specifics of engineering mathematics (section 2.1.4), other universities’ initiatives to support their students (section 2.1.5), and the concrete conditions at Ruhr-Universität Bochum (section 2.1.6). The

Inside this work, the project name is given in its Americanised form, Math/Plus/Practice, used in previous publications. The original German Mathe/Plus only appears in the title of this thesis and on the project website, www.rub.de/matheplus.
Figure 1.1: Structure of this Thesis with Keywords and Specifications

1. Introduction: Encountering the problem
2. Problem identification: Theoretical concepts
3. Research approaches and objectives
4. Design development
5. Evidence level: Methodology and results
6. Project evaluation: Summary and discussion

Keywords and Specifications:
- 2 Theoretical background, literature review, previous approaches, local conditions
- 3 Design Research, research questions
- 4 Project conception, design and re-design, project procedures
- 5 Methodology and results: sample description, examination statistics, learning strategies and their development
- 6 Summary and discussion of MP³-Math/Plus
project focus, learning strategies (section 2.2), is analysed next, and their assessment with the help of the LIST questionnaire is explored. Reviews of the relevant literature are incorporated in the respective sections.

Then, the Design Research approach and the research goals are elaborated upon (Chapter 3, which also contains the research questions). This chapter interacts with the two following ones that comprise the project conception and (re-)design (Chapter 4) and the empirical investigations (Chapter 5); the three chapters refer to and induce each other. Chapter 4 elaborates on the project conception (section 4.1) and preconditions for the first project cycle (section 4.2), and it comprises a detailed description of the project procedures (section 4.3). The adaptations decided upon for the ensuing project cycles are presented (section 4.4) and described in detail (section 4.5). Additional modifications for subsequent project cycles are also depicted (section 4.6).

The basis for the changes and the later overall evaluation of MP²-Math/Plus is established by diverse empirical analyses (Chapter 5, which covers both methodologies and results). This involves a description of the project applicants (section 5.1), the sample as a whole (section 5.2), students’ feedback to the project interventions (section 5.3), and their progress through the most difficult modules of their engineering course (section 5.4). Furthermore, the examination statistics of MP²-Math/Plus participants and non-participants are explored in detail, including gender aspects (section 5.5). Before the impact of learning strategies on academic success (section 5.7) and their development in the course of the first months at university (section 5.8) are investigated, the factor structure of the data is examined in detail (section 5.6).

Some of the deliberations in Chapter 5 are of a rather technical nature, so the focus is shifted back to the overall picture in the final summary and discussion (Chapter 6), which sums up the findings, reviews them under different aspects (sections 6.1 to 6.3), concludes with a reflection of the research approach and methodology, and casts a glance ahead at possible future implications (section 6.4).