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"There is no such thing as a mathematics classroom without elements of linguistic support"

Language education for future mathematics teachers in a research-based setting

1 Introduction

"There is no such thing as a mathematics classroom without elements of linguistic support" – this quote from a German mathematics student in 2019 sums up what has long been called for in teacher education for plurilingual classes: Teachers of all subjects should recognize language education as a necessary component of subject-specific learning and implement it in a subject-integrated manner (Ministry of Education Northrhine-Westfalia, 1999; Gogolin, Neumann, & Roth, 2003; Leisen, 2005, 2010; Benholz, 2012; Becker-Mrotzek, Schramm, Thürmann, & Vollmer, 2013). In a 2003 report on the promotion of children and adolescents with a migration background, Gogolin, Neumann & Roth noted that the view that every teacher is also responsible for teaching the linguistic means of learning the subject or learning in the subject is still not widely held in Germany and called for appropriate measures for the qualification of teachers (Gogolin, Neumann, & Roth, 2003). The question of how prospective teachers can be prepared for multilingual teaching does, of course, not only arise in the German context. The 21st ICMI Study on Mathematics Education and Language Diversity (Barwell et al., 2021) brings together contributions from 27 countries, among them Essien, Chitera and Planas (2021) on challenges of teacher education in Malawi, South Africa and Catalonia/Spain, and Thompson, Kersaint, Vorster, Webb and Van der Walt (2021) on teacher education programs adressing multi-language diversity in South Africa and the US. Further research includes, e.g., Planas (2021) on language-related pedagogic work with student teachers in Spain. In their study on supporting Spanish speaking prospective teachers to notice and name student language resources, Crespo, Bowen, Buli, Bannister, & Kalinec-Craig (2021) report on the potential of teaching scenarios using *LessonSketch* platform (Herbst & Chazan, 2015). The research indicates that massive support is needed to help prospective teachers to value linguistic diversity especially in the context of developing mathematical skills (Crespo et al., 2021).

In the field of initial teacher education, which is the focus of this paper, the goal of implementing language learning in the teaching of all subjects is nowa-

days supported by various measures. Teacher training universities in Germany offer optional or (more rarely) compulsory courses in language education and German as a second language or give students the opportunity to study German as a second language as an additional subject. Such courses are usually offered by the institutes for German as a Second Language, German Studies and/or Educational Sciences. The common goal is to provide prospective teachers with basic knowledge in the field of language education, e.g., on first and second language acquisition processes, on procedures of language diagnostics and support, or on possibilities to integrate multilingualism in the classroom (EUCIM-TE, n.d.). However, many students find it difficult to relate this often rather general knowledge in the field of language education to their subject contexts, e.g., during a teaching placement or when doing research for their BA/MA thesis. In a teacher study, Bredthauer & Engfer (2016) found a considerable discrepancy between positive attitudes towards multilingual approaches and the actual implementation in the classroom. Thus, there is a risk that the topic of language education, while considered meaningful in principle, might not find its way into classroom practice. Therefore, prospective teachers should be given the opportunity to deal theoretically and practically with language education in their subjects at an early stage, if possible, already during initial teacher training. Two aspects are important here: first, as educational researchers have long called for, cooperative interdisciplinary courses should be offered on a regular basis in which approaches from the fields of language education and subject didactics are dealt with in an integrated manner (Roth, Duarte, Broeder, & Stokmans, 2010; Benholz, 2012; Roth, Bainski, Brandenburger, & Duarte, 2012; Baumann & Becker-Mrotzek, 2014). Second, there should be opportunities for research-based learning, where students have the opportunity to conduct empirical studies at the interface of subject and language learning and, where appropriate, to practically test their learning designs (e.g., Kuckuck & Henrichwark, 2020; Beese, Kirstein, & Krake, 2022; Schacht & Guckelsberger, 2022). Thompson et al. emphasize that

> [i]t is one thing to provide teachers with information about language features that need to be considered and a range of practices to address them and to give teachers opportunities to experience these practices in their own learning. It is another thing to have teachers plan to implement these practices into their classroom in a way that becomes an integral part of their teaching and is not only considered a supplementary activity that can be ignored. (Thompson et al., 2021, p. 132)

In the following, we present a concept for the academic education of mathematics teachers that links these central aspects – integration of subject and language didactics as well as research-based learning – and ideally leads to students acquiring competencies in the field of action research that they can draw on beyond their studies. The concept has been developed and tested in

the context of the project "ProDaZ – German as a Second Language Across the Curriculum" at the University of Duisburg-Essen since 2016 in a cooperation between the departments of Mathematics Didactics and German as a Second Language.

Section 2 discusses the paradigm of research-based learning, which is a central element of language-aware teacher education at the intersections of "subject learning – language learning" and "theory – practice". Section 3 outlines the institutional framework and course design of our approach to subject- and language-integrated university teaching. Since research-based learning in an interdisciplinary context needs to comply with special requirements, we also address support measures that facilitate student learning. Section 4 illustrates how research-based learning can be implemented in the interdisciplinary context of "language education in mathematics" and what insights students gain for their professional development. The examples are from the field of mathematics but can easily be applied to student research in other subjects.

2 Research-based learning as a central element of language-conscious teacher education

> I don't think that the university part of the practical semester is too scientific. I think it's an opportunity for students to work in this way. I wouldn't rule out the possibility of doing more research in my day-to-day job; after all, I learned the methods here.[1] (student, practical semester 2018)

A central goal of teacher education programs is to enable students to make meaningful connections between university education and teaching placements that contribute to their professional development. Research shows that a research-based approach to teacher education helps teachers make rational and theory-based decisions in their instructional practice (Afdal & Nerland, 2014; Cochran-Smith & Lytle, 2009; Darling-Hammond, 2017; Zeichner, 2010). According to Saunders (2017), research-based learning is "an academic means to help further long-term professionalization of future teachers" (Saunders, 2017, p. 4). Students should experience that theoretical concepts from different disciplines help them to comprehend learners' perspectives or problems and to derive possible actions for their teaching. Conversely, observations in school practice can generate new interest in scientific explanations (Weyland, 2019,

1 authors' translation; German original: "Ich empfinde den universitären Teil des Praxissemesters nicht als zu wissenschaftlich. Ich denke, es ist eine Chance für die Studierenden, so zu arbeiten. Das schließt nicht aus, dass ich im Berufsalltag noch weiter forsche, ich habe hier ja die Methoden kennengelernt."

p. 43). In Germany, research-based learning has become an important component of the training of future teachers in the context of teaching placements and is currently – although the concept itself is not new – experiencing a "heyday" in higher education didactics (Weyland, 2019, p. 28), especially in the context of long-term school internships. In contrast to scientific research in the narrow sense, research-based learning takes place "in the sense of a researching habitus" (MSW NRW, 2016, p. 5), and the focus is on gaining personal insights for professional development. Students should realize that, given the complexity of practice, answers are fundamentally provisional in nature and alternative solutions are always likely to be found. The goal is to initiate an exploratory, critical-reflective attitude that will also allow students to deal constructively with open questions and problems in their later everyday school life. In this respect, there is a connection to action research and to the idea of the teacher as a reflective practitioner (Altrichter, Posch, & Spann, 2018).

At the same time, the exemplary linking of "theory" and "practice" in research-based learning should contribute to overcoming a problem that is also evident in the field of language education: Scientific approaches are only rudimentarily implemented in professional practice, even if they are generally considered useful and relevant to practice. Regarding (second) language didactics, this may be partly due to the fact that subject teachers have not been sufficiently qualified in this field and do not feel responsible for "language". Another difficulty can be observed among prospective teachers who take general courses on language education as part of their initial teacher training: they do not know how to apply approaches and techniques for language-sensitive teaching (such as scaffolding, language reflection, writing tasks, or the inclusion of multilingual resources) to their specific subject context (e.g., maths or biology). Research-based and interdisciplinary learning, therefore, offers a great opportunity to support students in subject-specific transfer, experimentation, and reflection, and in this way contribute to long-term professional development in the field of language education. The important question is, however, under what conditions a research-oriented approach can have a lasting effect on the thinking and acting of teachers (Hansén, Forsman, Aspfors, & Bendtsen, 2012). Referring to a longitudinal study in Finland by Nyman (2009), Hansén et al. suggest that "in the current situation the outcome seems largely dependent on the individual teacher's capacity to apply critical thinking and reflection to understanding their work." (Hansén et al., 2012, p. 12). Research-based learning in practical phases offers the opportunity to initiate planned and reflected action in complex learning contexts at an early stage. However, intensive support is required: First, because research projects that have to be carried out at schools are often perceived as something that has little to do with professional interests (Börnert et al., 2014); the supposed contrast between theory and practice becomes particularly apparent here. Second, many students

feel overwhelmed when they have to become active as researchers during a practical phase with already many new impressions and tasks – even more so when it comes to subject- and language-integrated, interdisciplinary projects (Brew & Saunders, 2020; Hansén et al., 2012; Kozina, 2013). Thus, if one does not want to risk that students develop a research-skeptical attitude rather than the desired research-friendly mind-set, didactic support is necessary in all phases of research-based learning:
– in developing a clear and pointed research question,
– in finding suitable research methods,
– in the design of tools for data collection,
– in analyzing, presenting, and interpreting the collected data

The research-based activities reported on in this section relate to a 5-month teaching placement ("Praxissemester") at the University of Duisburg-Essen. Research-based learning in this context is defined as a theory- and method-guided approach to the professional field of school and thus the processing and systematic reflection of specific conditions, challenges, and characteristics of acting in pedagogical contexts and interaction situations on the basis of planned surveys, observations, case studies, analyses of teaching materials, etc. (Teacher training universities and ministry of school and further education, Northrhine-Westfalia, 2015, p. 2)

Student research should be designed to maximize student learning for professional development. It goes beyond mere observation and often requires the inclusion of oral and/or written learner data (Section 4.). Intensive data analysis and the design, testing and reflection of content- and language-integrated learning opportunities should make it clear that research is not a contradiction to the work of the teacher, but can contribute to solving practical questions and improving the quality of teaching – not only during teacher training, but also in later professional life, as highlighted in the introductory student quote.

In the following section, we present an interdisciplinary course at master's level designed for prospective mathematics teachers with an emphasis on language education. We also discuss aspects that facilitate student research at the intersection of subject and language.

3 Facilitating research-based learning in an interdisciplinary setting

> An essence of research is that it is initiated in the minds of researchers, and in a similar way, learning in a research mode must be initiated in the minds of learners. Such learning is active and questioning in a way that traditional learning, in which learners react in the main to inputs from teachers, rarely is. The vital role of

> teachers, therefore, consists of a pedagogic understanding of how such questioning learning can be facilitated by them. (Elton, 2005, p. 111)

The concepts presented in this section tie in with Elton's (2005) quote. They describe a teacher training program designed to promote in student teachers an "active and questioning" (Elton, 2005, p. 111) attitude towards content and language integrated learning in the plurilingual classroom. The examples come from a two-semester master's seminar for future mathematics teachers which serves to prepare and accompany a 5-month teaching placement. During the practicum, student teachers conduct classroom observations and take charge of their own lessons. In addition, they carry out a small empirical project, which is supervised by the teacher educators at university. Due to the interdisciplinary approach of the seminar, student research takes place at the interface of mathematics and language education. Accordingly, all aspects of mathematics education are discussed from the perspective of language education as well.

In terms of university didactics, this poses the challenge of simultaneously providing students with insights into the connections between theoretical concepts and practical school experiences and making the various connections between mathematics didactics and language education tangible. In this complex situation, the potential of research-based learning becomes apparent: students develop a research question from their observations in school practice and pursue it using data they have collected themselves. The focus on language education draws attention to certain phenomena (e.g., linguistic characteristics of a selected mathematical content or task), helps to specify preliminary research questions and offers research methodological starting points (e.g., designing, testing and evaluating mathematically and linguistically rich learning environments). Through the intensive, practical, and constructive engagement with language and subject learning, many student teachers not only perceive "language" as an essential part of their work as teachers but also gain experience in implementing aspects of language education in their classroom practice.

Central seminar contents in the preparation seminar (1st semester of the master programme) are:

- aspects of mathematics teaching in multilingual settings
- sensitizing exercises for own language use in mathematical contexts and the needs of second language learners (Tajmel, 2010)
- analysis and adaptation of mathematics tasks using criteria from mathematics and language didactics
- communication in mathematical contexts: analyses based on audio/video footage and transcripts of classroom discourse or discourse in experimental settings

– diagnosis of oral and written learner data from a mathematical point of view (e.g., basic mathematical concepts and misconceptions) and from a linguistic point of view (e.g., separate assessment of mathematical and linguistic skills)

The second seminar (2nd semester of the master programme) focuses on the planning and implementation of research-based learning. The focus is on:

– observing and reflecting on connections between mathematical and language learning in school practice
– defining a practically relevant and theoretically grounded research question
– the planning and implementation of the research project
– the processing and analysis of the data obtained
– reflection on the research process

The seminar design considers that most students have little research experience, especially in an interdisciplinary context. To facilitate research-based learning, a number of supportive measures are included in the seminar.

Mix of student-centered activities, input, and reflection

Many of the tasks in the seminar context are designed to activate research-based learning. For example, students investigate their own (first, second, foreign) language use in mathematics; they use learner data (e.g., transcript excerpts) in a brainstorming activity to develop hypothetical research questions at the intersection of subject and language that are as nuanced as possible; they analyze video footage from classroom interaction and discuss alternative ways of teacher communication[2], and they categorize and interpret their own school observations and data with reference to theoretical or methodological approaches in the field of mathematics and (second) language didactics.

Student-centered activities can thus be usefully incorporated at different stages of the seminar. In addition, targeted theoretical input is necessary, for example, to explain specific research activities (coherent theoretical framework, precise research questions, appropriate research design, theory-guided evaluation) using interdisciplinary examples, or to present fundamental links between mathematics and language didactics.

The importance of an exploratory, critically reflective approach to teaching has already been highlighted in section 2. Therefore, reflective activities are conducted in the seminar to close the loop to school practice and open doors for later research activities (e.g., teacher action research). Reflective activities relate, for example, to student teachers' perceptions of their own language use

2 Planas (2021) for a similar activity with a focus on explicitness in classroom communication.

in a mathematical context or to the implementation of language education in lessons observed during the practicum as well as to the process and benefits of practical research.

Analysis of original classroom data

Student teachers should encounter the complexity of everyday (multilingual) school life in mathematics with a trained eye and be able to quickly perceive possible problem areas, but also starting points for problem solutions. Therefore, all activities in the seminars are closely related to the linguistic reality in the mathematics classroom. A wide range of original classroom data is included, e.g. audio/video footage, learner documents, learning materials, tasks from textbooks and exams. These data are analyzed in light of theories of mathematics didactics and second language didactics, so that awareness of relevant phenomena in the area of language education increases. At the same time, original classroom data is also suitable for sensitization and reflection tasks.

Collaborative research

Collaborative research activities have the advantage that students can support each other with their respective strengths. Not only expertise in the field of mathematics and mathematics didactics is relevant but also knowledge in the field of language pedagogy and linguistics, practical teaching experience (e.g., as a tutor), previous experience with empirical research (e.g., bachelor thesis) and, last but not least, one's own linguistic socialization – e.g., when it comes to analyzing problems of multilingual students linguistically.

The teacher educators have an important function not only as moderators but also as contact persons for the groups and "critical friends", e.g., when it comes to the theoretical classification of empirical data or to detailed questions of a task design or to possibilities of categorization and interpretation of collected data (Altrichter, Posch, & Spann, 2018, p. 300). This support is considered essential, especially in light of the interdisciplinary nature of the program.

4 Examples of student research in an interdisciplinary setting

"Research" seems so difficult for many students because it is often associated with elaborate data collection methods, large amounts of data, or complex analysis procedures. While this may be true (at least in part) for scientific research projects, an important feature of research-based learning and related action

research is its comparative ease of implementation: extensive and/or longitudinal data collection is de facto ruled out for reasons of time, capacity, and the resilience of schools. As mentioned earlier, some students are sceptical of the practical benefits of research for their professional development, especially if they have no research experience. Sometimes it is in retrospect that important insights emerge, as expressed in the following statement: "I think you often only understand the meaning [of student research] in retrospect. When I read through my own research project again, I only really understood what it actually meant to me. Sometimes you don't have that aha-moment until weeks or months later."[3] (student 2019, in: Schacht & Guckelsberger, 2022) Therefore, it is important to establish the connection between research and practice interests throughout the studies.

In the following, we present two student research projects on language education in mathematics. Both designs are relatively easy to implement in terms of research practice, but they provide rich data from which many insights for school practice can be gained.

Example 1: Mathematical and linguistic analysis of an example of oral task processing.

Tasks, especially math word problems, are at the heart of mathematics education in school. It is therefore not surprising that research questions arising from school experiences – whether from classroom observations or from student teachers' own classroom experiments – often concern aspects of task comprehension, such as:

- How do students interpret word problems?
- What could be the reason that tasks are not processed as expected – are there mathematical and/or linguistic reasons?
- What exactly do students do when working on tasks?
- What can I do as a teacher to better support the learners?

In class, these essential questions can hardly be dealt with in detail, since usually only the learners' written solutions are available. Although these solutions can provide important diagnostic information, they often do not allow reliable conclusions to be drawn about previous thinking and working processes. Therefore, it can be very useful for student teachers to create audio or video recordings to track the learners' solution processes as they work through the tasks.

The research project presented in the following was conducted by a student teacher with two grade-8 students at a secondary school (2018). The theoretical

3 authors' translation

basis was provided by research evidence of learners' difficulties in solving word problems compared to calculus tasks (Prediger, 2009) and various explanations for this – such as lack of problem-solving skills (Pólya, 1945), lack of modeling skills (Pólya, 1945), and insufficient academic language skills (Gürsoy, Benholz, Renk, Prediger, & Büchter, 2013; Meyer & Tiedemann, 2017). The student wanted to gain more detailed insights into the professional and linguistic processes that (can) occur when working on text tasks and posed the following research question: "How do learners structure the process of working on context-bound tasks and what inner-mathematical and linguistic hurdles do they encounter?"

She presented two 8th-graders with a word problem on linear equations with four subtasks (fig. 1):

> There are 168 seats in a movie theater, divided into seven rows. In each row there are three more seats than in the row in front of it.
>
> a) How many seats are in the first row?
> b) How many seats are in the last row?
> c) Draw a sketch.
> d) Which row has 27 seats?

Figure 1: Word problem "movie theater"

The two 8th-graders worked on the tasks together at a time of their own choosing and created an audio recording (approx. 6min 30s) of their discourse using their smartphones, which they shared with the student teacher for research purposes. The student teacher transcribed the audio recording and analyzed how the learners proceeded in solving the tasks and what linguistic and mathematical difficulties they encountered. She found the following:

- Although the same word problem had been covered in class a few weeks earlier, the students do not employ a problem-solving strategy. They do not recognize the role of the unknown x and cannot set up an equation that leads to the solution of the mathematical problem. Instead, they solve the problem by trial and error, which in this case is possible but ineffective and only contributes to the development of mathematical problem-solving skills to a limited extent. As the student teacher writes in her research report: "Students handle the numbers without understanding the context."
- The two learners have difficulty translating the "real world" situation formulated as text (verbal literacy register) into mathematical symbolic language (symbolic-numeric register). In particular, the adverb "jeweils" (which occurs in the second sentence of the word problem: "In jeder Reihe gibt es *jeweils* drei Plätze mehr als in der Reihe davor.") – which in English can only be roughly translated as "each", "respectively" – that learners need to grasp to form the linear equation seems to be a linguistic challenge.

– After initial efforts, the learners do not work through the subtasks in the given order, but start with subtask c), which involves making a sketch. The student teacher links this observation to considerations about task sequencing: "The order of the task parts is problematic. From a didactic and logical point of view, pupils gain considerable advantage from making a sketch first to visualize the context."

The two 8th-graders eventually arrive at the correct solution through trial and error and write down the required answer sentence: "There are 15 seats in the first row. There are 33 seats in the last row." It is usually difficult to capture the processes that precede such solutions. Transcripts of task processing therefore offer a very good insight into how learners understand tasks, how they organize task processing, which questions arise, and which attempts at clarification there are, which assumptions are made and revised. Students as researchers thus have the opportunity to understand the cognitive and linguistic actions of the learners in detail, to assess their relevance for mathematical learning as well as language learning in mathematics, and to consider and examine potential implications for lesson planning. Taking into account the paradigm of research-based learning, it becomes apparent that theoretically based and practically relevant insights can be gained even from a small amount of data that is, moreover, easy to collect. In retrospect, the student teacher also considers the project to be very beneficial herself:

> I found it super exciting to record the learners and then analyze the recording. It allowed me to understand their approaches to tackling the tasks. In class, you usually only see the results afterwards and can't trace the thinking process that takes place in their head. I could imagine using this method for case studies in the classroom later on. (Schacht & Guckelsberger, 2022, p. 131)

Example 2: Students' conceptions of probability

Another interesting field of research at the interface of language and mathematics education is the formation of mathematical concepts. In mathematics, many phenomena are captured in terms of everyday language. The adequate use in the subject context requires "not only a semantic reinterpretation, but in many cases also a contextual rethinking of the terms" (Roll et al., 2019, p. 26). Teaching is not about replacing initial learner conceptions; rather, successful learners "learn to utilize different conceptions in appropriate contexts. That is, the status of one particular conception may change in differing contexts" (Tyson, Venville, Harrison, & Treagust, 1997, p. 402).

The following example on the concept of "probability" is part of a student research project in a grade-8 mathematics classroom, carried out during the teaching placement (2019). The student teacher was interested in learners' initial conceptions of the mathematical terms probability and chance. Since both terms

are common in everyday language, he assumed that the everyday meaning of the terms would influence learners' mathematical conceptualization. The student teacher asked the class to explain "probability" and "chance" in writing during an introductory phase; the terms had not been discussed in class before. The students wrote very short texts including statements like the following (Figure 2):

Probability:

– what is almost perfect in % (Soccer News)
– what happens 75 % of the time
– a probability is when something is likely to happen
– probability is when e.g., someone rolls a dice and hopes that it will be a 6
– when you know something but are not sure
– when something can happen but does not have to

Chance:

– like being blindfolded and drawing cards
– when something happens suddenly
– when you expect a 2 on the dice but get a 3
– if you are lucky or unlucky is chance

Figure 2: Student texts on "probability" and "chance"

In most student texts, "probability" is equated with "high probability" (e.g., "what is almost perfect in %"; "what happens 75 % of the time"; "when something is likely to happen"). Some students make the connection to everyday experiences (and the hope of a high probability of winning), e.g., the soccer news or the dice game. A neutral approach, on the other hand, is evident in the last example "when something can happen but does not have to".

The student texts on "chance" draw on experiences in games (e.g., "like being blindfolded and drawing cards") but also refer to expected and unexpected events (e.g., "when you expect a 2 on the dice but get a 3"; "when something happens suddenly"). The idea that "chance" cannot be influenced becomes apparent in the last text: "if you are lucky or unlucky is chance".

The written texts were an important key for the student teacher to reconstruct the individual conceptions in the learners' minds. For theoretical grounding, he referred to different mathematical models of probability and chance (Krüger, Sill, & Sikora, 2015; Laakmann & Schnell, 2015) and included linguistic and mathematical research on concept formation (Pimm, 1987; Weinrich, 1989; Moschkovich, 2002; Schütte, 2014). Because the data were collected before the new topic was introduced in the classroom, the results also had practical implications: They allowed the student teacher to prepare his lessons in a way that specifically addressed his learners' initial concepts.

This example, like Example 1, shows that empirical student research can provide important insights that link theory to practice and emphasize the close connection between mathematical and language learning.

5 Conclusion

Awareness of linguistic diversity at schools in Germany has increased significantly in recent years, and the topic of language education across the curriculum has equally gained importance. As a consequence, teacher training courses at university level in Germany are being adapted as to better prepare future teachers for plurilingual classrooms. Due to the federal structure of the German education system, university courses vary considerably from one federal state and university to another, from optional or additional classes to obligatory modules such as "German for migrant learners/Language education". The common aim is to provide future teachers with a basic knowledge of language education. However, to help student teachers apply this linguistic knowledge to their subjects and deepen their understanding of the relation between content (education) and language (education), integrated teaching programs at university level are necessary.

In this paper, an interdisciplinary university teaching program for prospective mathematics teachers was presented (Schacht & Guckelsberger, 2022). The aspect of research-based learning was highlighted as particularly important: small empirical projects, it was argued, help student teachers to make the connections between theoretical approaches and school practice while exploring the close link between language and subject learning. Student research therefore seems to be a promising approach to anchor language education in school practice in the longer term. Moreover, "easy-to-handle" research methods inspire students to carry out similar projects when they encounter open questions or problems as teachers, leading to "reflective practice". An important prerequisite is close supervision in the seminars that prepare and accompany the research projects.

To sum up, we identify three dimensions relevant to language-aware mathematics teacher education on the university level:

– *Analytic dimension relating content and language*: By carrying out research-based projects, prospective teachers gain important insights concerning the relation of central aspects of content- and language-learning. The findings presented in this paper can hopefully be used to enhance the professional development of prospective teachers but may also help to identify relevant research desiderata in the field of language-aware mathematics teacher education.

– *Practical dimension*: Research-based (mathematics) teacher training programs shape the actual teaching practice of prospective teachers in various ways. The examples discussed in this chapter show the diversity of preconceptions concerning the concepts "probability" and "chance" that students may have. This diversity becomes even more complex when such concepts are dealt with not only adopting an everyday (informal) register but the mathematical (formal) type of language. Such insights raise awareness of the close relation between content- and language-related issues when teaching mathematics.
– *Scientific dimension:* The insights into the scientific dimension concern in particular the question of the relevance of such research-based projects. This chapter discussed examples of students evaluating their research experiences as a relevant part of their professionalization and future teaching practice. Such examples not only show the relevance of language-aware mathematics teacher education for the practice of the future teachers, but also the relevance for progress in scientific research and development at the interface of mathematics and (second/foreign) language education.

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