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STUDY

THE ACQUISITION OF ERROR COMPETENCE AND THE VALUE OF (LEARNING FROM) ERRORS IN TEACHER EDUCATION FROM THE PERSPECTIVES OF TEACHERS IN FINLAND AND GERMANY

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ABSTRACT

Teachers' everyday error management in the classroom is one important aspect of their professional competence. This comprises conceptual knowledge about (the learning potential of) misconceptions and student errors, adaptive attitudes and orientations about errors as learning opportunities, and adaptive classroom management in error situations. The purpose of this study was to explore whether teacher education prepares teachers to meet these expectations and where teachers gain these facets of error competence. We analyzed 27 problem-centered interviews with Finnish and German teachers of different subjects and different school forms. Using MAXQDA, the data were coded into six categories, ranging from informal learning experiences to formal learning situations during teacher training. We identified various experiences and attitudes in the teachers' narratives. Our findings indicate that from the teachers' points of view and recollections of experiences, teacher education in both countries provides few intentional learning opportunities for developing professional error competence.

KEYWORDS

error competence; professional development; teacher education; interview; qualitative methods

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1 Introduction

In the dynamic landscape of contemporary education, the focus extends beyond mere content delivery to fostering meaningful student engagement, generating different solution strategies, adaptability, critical reflection, and other so-called future skills (Kotsiou et al., 2022). In this respect, it is increasingly important for the teaching profession to encourage students to face challenges and to support student personal growth through overcoming failures. One often overlooked yet critical aspect of this multifaceted role and professional competence of teachers is everyday error management in the classroom. Teacher practices surrounding student errors encompass the ways of recognizing, addressing, and learning from errors or mistakes,[1] by both educators and their students. The significance of effective error management extends far beyond correcting factual inaccuracies; it shapes the very foundation of student learning experiences and their ways of handling challenging problems (cf. Kapur, 2010). Teachers (or supervisors, in the work context) who skillfully manage errors create a climate that encourages risk taking and fosters help seeking and resilience among learners (Frese & Keith, 2015; Grohnert et al., 2019). The ability to transform errors into valuable learning opportunities is a hallmark of teaching quality, and it depends on the teacher's proficiency in error management. However, it is an open question whether, when, and where teachers gain professional error competence. The contribution of this study is the exploration of the experiences of teachers with different work experiences and educational backgrounds in this regard. The use of a qualitative approach enables the exploration of teachers' concepts and views on errors by analyzing the entirety of the participants' narratives about their experiences during teacher training and afterward, rather than being limited to the answers to a set of pre-defined questions.

[1] Both terms refer to doing something wrong. However, in academic settings, a "mistake" is less significant than an "error," which refers to a deviation from accuracy or correctness. Individuals make mistakes when they already have the knowledge but, for instance, lack concern and attention. In contrast, errors are based on a lack of proper knowledge. In this text, we consistently use the term "error" as errors are more important to learning and knowledge acquisition in the school context. However, it is just as important for motivation and teacher-student-relationships that teachers competently respond to student mistakes.

1.1 Professional error competence

Teachers' professional competence in managing student errors has been found to be important for student learning (e.g., Soncini et al., 2020; Türling, 2014; Wuttke et al., 2008). Overall, errors are a natural part of learning, they accompany challenging tasks, and they can serve as a diagnostic tool for teachers. Helmke (2014) stated that errors offer insights into student thinking. Seifried and Wuttke (2010b) defined professional error competence as a three-pillar construct with (1) conceptual knowledge about error types, error causes, and student misconceptions, (2) strategic knowledge for handling student errors, and (3) adaptive beliefs about the value of errors as learning opportunities (also see Wuttke & Seifried, 2017). With respect to knowledge, teachers need to be able to identify student errors, including subject-specific didactical knowledge about task difficulties, typical student misconceptions and errors, and in particular the causes of errors (Türling, 2014), as well as their impact on learning and motivation. Building on this, teachers should have a flexible repertoire of actions for handling student errors, and they should apply appropriate feedback strategies depending on the error type or cause (Oser & Spychiger, 2005). Finally, appropriate teacher views on (student) errors, in accordance with their own motivational orientations (e.g., self-efficacy, goal orientations), are considered a prerequisite for successful and adaptive error management in the classroom (Türling, 2014).

1.2 Where and when do (prospective) teachers acquire professional error competence?

The monitoring and evaluation of student learning processes and performance (i.e., diagnostic competence) is an essential part of teachers' professional activities (Baumert & Kunter, 2006; Helmke, 2014). Considered a key aspect of teacher professionalism, the acquisition of diagnostic competence is highly emphasized in initial teacher education (McElvany et al., 2019). Student errors during their learning process may inform teachers about possible misconceptions, but this information can only be used in pedagogy if teachers are able to identify the causes for specific error types and to adapt their instructional strategies and provide appropriate support to their students (Kaiser et al., 2015). Thus, domain-specific knowledge about errors – the first facet of error competence – is part of teachers' diagnostic competence. However, research findings on teacher competence to identify, analyze, and respond to student errors confirm that this is a challenging endeavor for teachers (e.g., in mathematics: Larrain & Kaiser, 2022).

The literature on feedback and teaching quality has emphasized the importance of teacher professionalism in error management for student learning (for an overview, see Türling, 2014). Therefore, it would be reasonable to assume that this topic should be an integral component of teacher education.

However, adaptive strategies for dealing with student errors – a second facet of error competence – seem to be scarcely addressed in teacher training (Seifried et al., 2015). In this regard, Fiegert and Solzbacher (2014) referred to the important but yet unanswered question of whether teachers' pedagogical actions are influenced more by their own biography and experiences with errors and mistakes (Hierdies, 2006) and less by teacher training and guided knowledge acquisition (Czerwenka, 2005). Türling (2014) differentiated three phases within teacher education in which professional error competence can be developed: university, traineeship, and professional activity. Previous studies on teacher error competence suggested the development of related attitudes, knowledge, and skills as a result of their professional activity (Türling, 2014). In Türling's framework on professional error competence, based on Seifried and Wuttke (2010a), he further considered individual factors (prior knowledge, gender, and professional experience) and institutional factors (place of study and teacher education program). In our study, we considered these differences by interviewing teachers with two different educational backgrounds in teacher training as well as different ages, genders, and professional experiences. Cross-cultural studies have emphasized that error-related beliefs are embedded in and influenced by broader structural and cultural contexts (e.g., Eriksson et al., 2020; Santagata, 2004). Schleppenbach et al. (2007) observed such differences between Chinese and U.S. teachers, but also an ambivalence in the teacher beliefs, regardless of their cultural background: on the one hand, the teachers held the belief that effective learning processes necessarily involved making errors; on the other hand, they described making errors as not always helpful for acquisition of knowledge.

1.3 A comparison between Finnish and German teacher education

Since PISA, the Finnish education system has been considered a role model in several ways, particularly because of its focus on learning rather than testing (Matias, 2019). Furthermore, some studies indicated that a growth mindset (entailing a view of errors and failure as opportunities to learn and improve) is typical of Finnish teachers (Laine & Tirri, 2016). By contrast, recent studies with German teachers (Heyder & Brunner, 2018; Heyder et al., 2020) revealed a rather strong belief in the role of students' innate abilities and aptitudes for their achievements in math. In addition, their results provided evidence of the negative effects of teacher belief on intrinsic motivation, especially in low-achieving students.

There are some differences in the school systems and in teacher education in Germany and Finland. Due to the cultural sovereignty of the federal states and for historical reasons, teacher training in Germany has a high degree of diversification according to school types and school levels. Responsibility for

teacher education lies with the Ministries of Education and Cultural Affairs of the federal states. In contrast, in Finland there is a more uniform structure of teacher education that strongly combines theory and practice (Kricke, 2015). Furthermore, the Finnish comprehensive school system was often seen as a positive factor for the high performance of students (Waldow, 2010). By contrast, the school system in the German federal state of North Rhine-Westphalia (NRW) is particularly selective – even compared to some other federal states (e.g., Berlin) – but the structure of teacher education is similar to that in many other federal states and is therefore suitable as a contrastive example to teacher education in Finland. In addition, supportive structures play an important role in Finland; for example, teachers work together in multi-professional teams, and they are encouraged to foster individualized learning (Kricke, 2015; Sihvo, 2019). In contrast, in the study by Kricke (2015, p. 408), respondents from NRW reported "a lack of resources (...), overcrowded and overly generalized curricula and a teacher training that is not focused on individual support."

Therefore, it would be of interest to investigate the Finnish teacher education, teaching practices related to error management, and teacher attitudes toward errors in comparison to German teachers, particularly from NRW, and their experiences in teacher education. In the following, we briefly summarize the main differences between teacher education in Finland and in the German federal state NRW, as the German subsample was recruited from this state, by means of three basic comparison criteria: (1) structure of teacher education program, (2) study/profession related to the school system, and (3) study admission.

(1) The current structure of the teacher education program in NRW basically consists of two consecutive phases: First, students are enrolled in the Bachelor's degree program (duration of three years) and the Master's degree program (duration of two years) at university. This is followed by an 18-month preparatory service ("Referendariat"). University teacher training is tailored to two school subjects, accompanied by school practice in public schools, depending on the chosen school type (see below) and the two school subjects. In Finland, the faculties of education at the universities include the teacher training school (FTTS, 2023a, 2023b). All teachers obtain a Master's degree, accompanied by a continuous school practice and traineeship that lasts five years (SOOL, n.d. a).

(2) As already noted, the German school system is federalist and thus differs among the federal states, unlike Finland. The option of studies reflects the respective differences in the school systems. The schools in the German state of NRW comprise primary school (first through fourth grade, 6- to 10-year-old students), followed by different school types for fifth through tenth grade, to be selected after completion of primary school: "Hauptschule"

(the school type with the lowest academic demands in the German school system, completion at ninth grade), "Realschule" (middle track of the German school system, completion at tenth grade), "Sekundarschule" and "Gesamtschule" (comprehensive schools), and "Gymnasium" (the school type with the highest teaching level and academic demands, completion at twelfth or thirteenth grade) (MSB NRW, 2023). The last two school types enable the achievement of the A-level (MSB NRW, 2023). In NRW, students choosing a teacher education program can opt for either primary school, or one of the four school types with a middle school graduation at ninth or tenth grade), or for the school types for the A-levels (MSB NRW, 2009).

In contrast, comprehensive school in Finland is legally one unit. However, due to previous governance, it is still often divided into two levels (SOOL, n.d. b): "ala-koulu" (primary, first through sixth grades) and "ylä-koulu" (lower secondary, seventh to ninth or tenth grade).[2] Finnish students enroll in a study program for becoming either a classroom teacher (for first through sixth grade) or a subject teacher (for seventh through ninth grade) for comprehensive school. Upper secondary school (tenth through twelfth grade) also requires the subject teacher training (SOOL, n.d. b). In a growing number of comprehensive schools, all the instruction is given in one school building by one group of staff. Nevertheless, the division of class teachers and subject teachers still exists, and their training is organized through separate programs at the universities.

(3) In NRW, within teacher education, study admission is much less restrictive than in Finland. Entrance exams exist only for certain school subjects (such as sports or arts) (MSB NRW, 2009); for some subjects, universities set a *numerus clausus* (for example, by using an average final exam score calculated based on the scores of all current applications) that restricts admission to the degree program. In Finland, there is a selection procedure connected to subject-related aspects; applicants have to provide a letter of motivation to become a teacher including their pedagogical and didactic attitudes and communication skills (SOOL, n.d. b). Less than 20 percent of applicants are accepted into the teacher training program in Finland (Ministry of Education and Culture & Finnish National Agency for Education, 2022, p. 29).

[2] Learners can decide whether they want to do an additional year and can, thus, attend ten years at the comprehensive school.

2 Aims and research questions

To summarize, research on teacher beliefs about errors is scarce, and ambivalence has been poorly considered in analyses of teacher narratives (for an exception, see Soncini et al., 2023). Furthermore, there has been a lack of studies on the possibilities for acquiring professional error competence and differences in teacher training. This study explores the views and experiences of teachers from different educational backgrounds in order to shed light on whether teacher education in Finland and Germany (NRW) addresses teacher error competence and how (or where) teachers develop adaptive beliefs and behaviors for professional error management in their classrooms. We were interested in the teachers' experiences and perceived learning opportunities in teacher training and beyond. Against this background, we re-analyzed in-depth interviews with teachers from Finland and NRW in Germany employed in different types of schools, all of them part of the public general education system (Breternitz, 2021). We addressed the following research questions:

- What aspects of professional error competence (Wuttke & Seifried, 2017) do the teachers bring up in the interviews?
- Where and when do (pre-service) teachers acquire professional error competence (Fiegert & Solzbacher, 2014; Türling, 2014)?

Exploratory in nature, our study examines different sources of teacher error competence, ranging from personal experiences from one's own school biography to formal learning opportunities during teacher training and later professional teaching activities, and their association with teacher attitudes and knowledge about the importance of errors to student learning. By analyzing the interviews, we further aimed to explore whether there were shortcomings in teacher education in this respect. More specifically, besides the teachers' error-related beliefs, we were particularly interested in the proportion of the recollected learning opportunities for the development of error competence from the teachers' perspectives.

Based on the literature on professional error competence (Wuttke & Seifried, 2017) and Türling's (2014) framework described in section 1.2, we sought to identify (a) theoretical knowledge about errors (from a didactic, diagnostic, or motivation/learning theory perspective) that was taught in teacher education, (b) strategic knowledge about handling student errors in the classroom and perceived error feedback that was given in practical teacher training (school and university mentoring), and (c) error-related attitudes and beliefs. In addition, we were interested in indications of the acquisition of error competence outside of teacher training through personal (field) experience: in relation to (d1) one's own school biography as a student,

(d2) one's own professional activities in handling one's own errors as a teacher, and (d3) responses to student errors in the classroom as a teacher. In line with Fiegert and Solzbacher (2014) and in accordance with anecdotal evidence from numerous conversations with pre-service teachers, we expected more opportunities to arise from personal and professional practical experience (i.e., teachers "learning by doing" through their own handling of student errors in the classroom or through role models in their own school biography) than from formal learning opportunities during their university studies or traineeship. In addition, on an exploratory and descriptive level, we were interested in possible differences between Finnish and German teachers. In light of the benefits and encouraging research findings regarding the Finnish education system and teacher training, we expected a higher percentage of formal learning opportunities in teacher training in Finland than in NRW, Germany. Furthermore, we expected Finnish teachers to express more positive attitudes and valuable experiences toward learning from errors than German teachers.

3 Methods

The work presented draws on problem-centered interviews, a qualitative discursive-dialogic method that allows the reconstruction of knowledge and beliefs about relevant problems (Witzel, 2000, p. 4), and a better comparability by specification of topics. At the same time, individual viewpoints can be captured by open questions (Flick, 2014) rather than being limited to responses to a set of pre-defined questions. The emphasis in qualitative analysis is "sense making" or understanding a phenomenon, rather than predicting or explaining. We were interested in the teachers' concepts and (ambivalent) views on errors, their thoughts, and their expressed recollections of opportunities to acquire error competence; we analyzed the entirety of the participant narratives about their school experiences as students, during teacher training, and in their professional activities.

The principles guiding a problem-centered interview aim to "gather objective evidence on human behavior as well as on subjective perceptions and ways of processing social reality" as impartially as possible (Witzel, 2000, p. 1). During the data collection phase, the interviewer's prior theoretical knowledge of the problem serves as a "heuristic-analytical framework for ideas for questions during the dialogue between the interviewer and respondent," which results in an "inductive-deductive mutual relationship" (Witzel, 2000, p. 3). The interview questions were as open-ended as possible, to enable interviewees to freely express what they deemed to be of relevance in relation to the topic, and to meet the concern put forward by Gläser and

Laudel (2004) around the risk that interviewers might impose preconceived patterns of interpretation on interviewees. "At the same time, this principle of disclosure is manifest in that through narration what the observed subjects determine to be relevant is stimulated" (Witzel, 2000, p. 3). The interview questions that served as a guideline revolved around interviewee approaches to handling their own and student errors as well as their attitudes toward errors. In accordance with Schilling (2006), the recorded tapes were converted into transcripts for content analysis. In this study, we particularly focused on episodes and questions related to the acquisition of error competence (e.g., *Let's go back to your school days – what memories do you have of how teachers dealt with errors back then?* and *What did you learn about errors during your teacher training?*). In each transcript, the respective (semantic) segments were treated as separate units of analysis. We used the different aspects of and sources for the acquisition of professional error competence from the literature as categories for the coding scheme and supplemented them inductively from the material. Finally, the coded data was analyzed qualitatively and also quantitatively to determine which topics (i.e., opportunities to acquire error competence) occurred most frequently in the teacher narratives. The study received the approval of the University Ethics Committee, all participants gave informed consent, and all interviews were conducted in the interviewee's first language.

The interviews (one-to-one settings, held by the first author, with experience from several university training courses) were conducted with 27 teachers (52% female) from 23 schools in Finland and Germany (12 interviews in Finnish and 15 in German). The German federal state of NRW was selected because the structure of teacher education is similar to that in many other federal states but differs in several ways from that in Finland (see section 1.3). The selection of schools and teachers – although convenience sampling – followed the principle of the most heterogeneous selection possible in terms of type of school and teacher age, professional experience, and gender. The interviewees taught different subjects (from mathematics to religion). Teacher age ranged from 27 to 60 years in the Finnish subsample, and from 31 to 65 years in the German subsample. The schools were located in various areas of NRW and in a comparable region of southern and central Finland. The selected schools were part of the general school system in both countries, representing the school types described above; vocational schools and special need schools were excluded. The interviewees decided where the interviews were to take place (e.g., in the school's counselling room).

3.1 Analysis procedure

Interviews were audio recorded and fully transcribed (Finnish interviews lasted on average 61 min, SD = 16.13 min; German interviews lasted on average 67 min, SD = 21.51 min). Interview transcripts underwent content

analysis (Mayring, 2010) and Flick's thematic coding method (2014) using MS Excel and MAXQDA (2020). Our approach combined theory-driven elements (using predefined categories based on the literature, see section 2), and inductive, data-driven elements for the experiences gained beyond teacher education (e.g., handling one's own errors as a teacher) and further distinction between positively and negatively evaluated experiences (cf. Flick, 2014).

In the first step of open coding, the transcripts were broken down into semantic sequences (units of meaning), and text segments relevant to the research questions were identified. In the subsequent selective coding, we assigned text passages or sentences to categories and, if necessary, further developed or differentiated categories to create a thematic structure (e.g., differentiation into negative versus positive experiences). During the coding procedure, it became clear that error-related beliefs and teaching practice were mutually entwined in many of the teachers' statements. In order to avoid double coding, these segments were divided into two units of analysis and then assigned separately to the respective category. The first author carried out the analyses and coding. A second, trained rater assigned the defined segments to the final categories (described below) again. Interrater agreement (Cohen's Kappa: $\varkappa = .71$) was satisfactory.

The data were coded into the following six categories, i.e., sources for the acquisition of error competence, expressed in the interviewee narratives: (a) acquired theoretical knowledge about errors (from a didactic, diagnostic, or motivation/learning theory perspective) in teacher education, (b) the use of error feedback by university and school faculty and the use of errors as learning opportunities in teacher education (school and university mentoring), (c) error-related beliefs, personal experiences with respect to (d1) one's own school biography (d2) one's own professional activities in handling one's own errors as a teacher, and (d3) responses to student errors in the classroom as a teacher.

4 Results

In total, this procedure yielded 2,151 codings (887 codings in the Finnish subsample and 1,254 codings in the German subsample). The interviewees expressed different error-related learning experiences within each category, and we identified attitudes and values of errors as an opportunity for professional improvement in the teacher narratives. In the following, we present the frequencies of codes for each category (Tables 1 to 3), and we provide sample statements from the interviews.

The most frequent codings were made for the category comprising the teachers' professional activities: (d3) **handling student errors in the classroom** (see Table 1). This category had statements in which the interviewees described

their specific teaching behavior after student errors, their actual error management in the classroom, and their concrete responses to student errors. In general, the vast majority of teachers stated that they used student errors in a positive sense in their lessons, openly communicated about errors in the classroom, and supported their students after making errors. Student errors were used, for instance, as an opportunity for learning and improvement as the teachers responded to student misconceptions to pave the way for additional explanations. The various statements included error management situations in which teachers addressed student errors in order to clarify difficulties and achieve a deeper understanding:

> *So it is important to me that I try to explain to the students how the error happened, what went wrong in the process of understanding. And that I try to show them ways in which they can do better in the future, how they can avoid it, that is, how they can deal with it constructively, and for me, constructive dealing with errors involves, first of all, analyzing how it could have come about.* (Mr. S./male/German)

However, some interviewees expressed rather maladaptive ways of handling student errors in the classroom. These statements reflected the teacher view that the students alone are to blame for their errors.

> *Of course, they are allowed to make errors, but if things have been explained beforehand and they still don't get it because they simply didn't pay attention, then I can get really annoyed. Then I point out to the students – a bit more vigorously – that they have unfortunately failed in this case. I say it a little differently, but that they have not listened. I think teachers have to be allowed to do that. I can't always just be cheerful and say: "Yes, you did a great job, but unfortunately it wasn't quite right."* (Ms. S./female/German)

The teachers justified their decisions not to address their students' errors mainly by indicating the large number of errors that cannot all be discussed in class, or by saying that it was up to the students to use homework to do so. Others explained that they were tired of correcting the same mistakes over and over again, and that they were impatient or bored.

Interestingly, while all interviewees generally agreed on the importance of student errors for learning, many emphasized the challenges and their lack of confidence in appropriate error management in the classroom. This was also evident in the teachers' wording and in their views of the expected negative impact of error feedback on student motivation and on the teacher-student-relationship. Some teachers even avoided the term "Fehler" ("error" in German) or "virhe" (in Finnish) during the interview due to these negative connotations and the associated threat of discouraging students.

> *[In case of a wrong answer] I then say: No, who can add to it, or who can say it even better? Or I say: That's a good approach – especially when it comes to difficult or low achieving students – that's a good approach; who knows anything else about it?* (Ms. A./female/German)

Table 1 also provides the frequencies of codings for (d2) teachers' handling of their own errors and their experiences with teacher role models during their own school biography (d1). Regarding their own errors, the teachers reported different perspectives, ranging from open communication and transparency to concealment:

> *I can say that I made an error in his case, or maybe I made a mistake in front of the whole class, so, of course, in my own teaching I can identify a lot of things that I can develop, and it's not perfect by any means.* (Mr. J./male/Finnish)

> *I am a perfectionist and I want to do everything right, and I am impatient with myself because I think: this has to happen now. With the students, I can be much more patient and I can allow them much more during their learning process. With myself, I often think that everything has to go smoothly here and I'm just more impatient with myself.* (Ms. M./female/German)

Many of the interviewees expressed a change in course of their professional teaching activity.

> *Well, it has developed differently over time. Errors used to be unpleasant for me and hard to admit, but that has changed. Now I don't have any problems saying that I was wrong. And I think that doesn't detract from the authority, the positive authority that you have, that you are recognized by the students.* (Mr. H./male/German)

With respect to their experiences with teacher role models during their own school biography, the teachers reported more negative experiences in error situations than positive experiences. About two thirds of the statements (attributed to the responses of the teachers from the German subsample) referred to negative experiences during their time at school (in some cases these events took place more than 30 years ago, but the experiences were still present in the teachers' minds). Some examples:

> *There were of course very different, very different, types of teachers, I would say, the whole spectrum. So there were teachers who encouraged you again and again to participate and to join, those who didn't emphasize that there was an error when something was wrong, but who encouraged you to get involved and to discuss with others, for example, and there were others, who picked one student at the beginning of the lesson to repeat the content of the previous lesson, then recorded all the errors and straight away gave the corresponding bad evaluation.* (Mr. S./male/German)

> *I can only remember that my teacher used to do oral vocabulary tests, he always picked the people, if something was wrong, he used to say: "Rubbish" and picked the next person and said again: "Rubbish." Until he got the right answer. So this was someone who worked with fear. Fear and pressure. One who told the people: "You won't get anywhere," really unbelievable.* (Mr. H./male/German)

> *For me it was especially good that my math teacher in high school said, "you can do this thing now or at a later time," but this alternative that you can just never do it, that didn't exist – this later time can be in two seconds or two years, but it opened up the possibilities.* (Mr. M./male/Finnish)

In line with our expectations, most of the recollections originated from personal experiences and professional practice, i.e., from the teachers' "learning by doing" through their own handling of student errors in the classroom.

Table 1
Personal and professional field experiences

	Total *f* (%)	**German** *f* (%)	**Finnish** *f* (%)
Handling student errors in the classroom	**703 (32.7)**	**395 (31.5)**	**308 (34.7)**
Positive/adaptive error management	616	334	282
Negative/maladaptive error management	59	48	11
Residual	28	13	15
Experiences in one's own school biography	**165 (7.7)**	**77 (6.1)**	**88 (10.0)**
Positive experiences	54	17	37
Negative experiences	105	56	49
Residual	6	4	2
Handling one's own errors as a teacher	**270 (12.5)**	**161 (12.8)**	**109 (12.3)**

Notes. *f* = absolute frequencies of codings, % = relative to all codings. Residual = related to the category but cannot be clearly assigned, neither positive nor negative.

A closer look at how the teachers described managing their own errors and student errors in the classroom revealed that their error management was closely related to their attitude toward errors. Many statements reflected adaptive or maladaptive error-related beliefs. (On a descriptive level, slightly fewer negative attitudes were reported in the Finnish subsample.) Codings regarding (c) **teacher error-related attitudes and beliefs** (see Table 2) basically comprised their views on errors as subject-specific learning opportunities, based on their definition of errors – which in many, but by no means all, cases were seen as a deviation from a given norm or standard,

implying a clear differentiation between correct and wrong. However, in the end, it seems the teacher decides whether something is considered an error:

> *There is, of course, a zone where you can perhaps even argue about whether it was a mistake or not. For someone else it might not be a problem or if someone has broken the rules, for example, by not doing the blackboard duty they were assigned to, then, uh, that might not be a problem for some teachers because they don't think it's important. But it was always very important to me that my classroom was tidied up and, uh, left with a clean blackboard.* (Mr. H./male/German)

> *In mathematics, the solution method is often standardized. But that's wrong. You have to be careful about labeling it an error, because the solution path is completely open, students can – there are students, uh, there was – or they always expect a certain, well, the student has to make the solution transparent, he has to put something on paper, there are students who solve something visually, for example. They make a sketch, sometimes very difficult to see through, what kind of logic lies behind it, but it's there and at the end you can see the result and there are others who do a lot of calculations. So, both solution pathways are okay, and you have to be careful that you don't define the errors, because he or she chose a different solution than you thought.* (Mr. A./male/German)

> *The error (...) doesn't exist. It is relative, it is something relative.* (Mr. A./male/German)

> *No, making errors is not a problem, and the world doesn't fall apart because of it, even if there's a miscalculation or something else. People always make mistakes and learn from them.* (Mr. L/male/Finnish)

Some teachers even recognize certain errors as necessary steps in the learning process. The following statement from a German primary school teacher illustrates this view: She described a situation in which the children first wrote SOFA correctly, but when the process continued, they wrote SOFER instead:

> *But this error is a "positive" mistake because the child has now learned that when I hear an "a" at the end, we actually always write "er" in German, mother, father, butter, and so on. We write all kinds of words with "er" at the end, even though we hear an "a" at the end. Thus, I also write sofa with "er" because I hear an "a". And I have learned that when I hear an "a", I write "er". This mistake demonstrates a child's learning progress. At some point the child then realizes the exceptions.* (Ms. M./female/German)

Negative/maladaptive error-related beliefs mainly centered around the anticipated negative effects on student motivation, learning processes, or exam performance and grades. Certain errors were even described as "stupid," unnecessary mistakes.

Table 2
Teachers' error-related attitudes and beliefs

	Total *f* (%)	**German** *f* (%)	**Finnish** *f* (%)
Teachers' error-related attitudes and beliefs	**487 (22.6)**	**291 (23.2)**	**196 (22.1)**
Positive attitudes and beliefs	249	131	118
Negative attitudes and beliefs	226	148	78
Residual	12	12	0

Notes. *f* = absolute frequencies of codings, % = relative to all codings. Residual = related to the category but cannot be clearly assigned, neither positive nor negative.

Table 3
Opportunities for the acquisition of error competence as part of teacher education

	Total *f* (%)	**German** *f* (%)	**Finnish** *f* (%)
Theoretical knowledge about errors (didactic, diagnostic, learning/ motivation theory)	**440 (20.5)**	**273 (21.8)**	**167 (18.8)**
Theoretical knowledge being expressed	354	204	150
Perceived learning opportunity (positive)	67	57	10
Perceived failed learning opportunity	19	12	7
Use of error feedback by university/school faculty (school and university mentoring)	**86 (4.0)**	**67 (5.3)**	**19 (2.1)**
Positive experiences	17	12	5
Negative experiences	65	52	13
Residual	4	3	1

Notes. *f* = absolute frequencies of codings, % = relative to all codings. Residual = related to the category but cannot be clearly assigned, neither positive nor negative.

Table 3 provides the absolute and relative frequencies of codings in relation to explicit learning situations for the acquisition of error competence in teacher education: (a) **theoretical knowledge about (student) errors** from a didactic, diagnostic, or motivation/ learning theory perspective, and (b) **the use of error feedback by university and/or school faculty** and the use of errors as learning opportunities in school and university mentoring. Statements were coded in the "theoretical knowledge" category if they had no obvious reference to the teachers' teaching activities or to their actual handling of student errors (those would have been coded in the category "handling student errors in the classroom"), but rather demonstrated general knowledge – either subject-specific, from a didactic perspective, or based on learning theory. Statements were coded in the "learning from and about errors

in school and/or university mentoring" category if they explicitly referred to this specific situation.

Overall, the teachers were aware of the theoretical importance of the analyses of student errors for learning processes, i.e., in order to find the underlying cause of student misconceptions. Many interviewees expressed their knowledge about different causes for student errors and their various types, levels, or taxonomies as well as didactical implications. The following two examples stem from a math teacher and a teacher of English as a foreign language:

> *In math, someone writes down the wrong number. We then already have an error at hand. Yes, it is not uncommon: the default information is taken incorrectly from the task, which I would describe as a careless mistake; on the other hand, there are transfer errors, logical errors, and so on.* (Mr. A./male/German)

> *[…] especially with the 3rd person singular "s" at the end, that is a very high developmental stage in English as a foreign language. There are 5 levels and I think that's level 4 where you use it properly, [...] and in elementary school with good teaching some pupils might reach level 3, more likely level 1 or 2.* (Mr. B./male/German)

Only 7 out of 27 teachers (five Finnish teachers, two German teachers) attributed the cause of student errors to their own teaching activities – for example, because their teaching was not motivating enough, they did not provide clear explanations, or their instruction or the tasks were not comprehensible. However, most of the knowledge was related to student errors from a diagnostic perspective. Theories, such as the "theory of negative knowledge" (Oser & Spychiger, 2005) or specific instructional designs for learning from errors were virtually not mentioned at all, only by a very few teachers. Some interviewees reported specific learning experiences during teacher training at university in which the focus was on (adaptive error management of) student errors. These codings were divided into positive learning experiences, in which participants perceived individual improvement, and negative or failed learning experiences, in which participants felt they had learned nothing about adequately handling student errors and learning from them (see Table 2). There were also teachers who stated that they had never heard of adaptive error management during their teacher training. Overall, the data suggested that little effort and focus was placed on theoretical knowledge about learning from and handling student errors in teacher education. Instead, it often seems to be, as one German teacher said, "…you grow into it like that." The relatively few codes for explicit learning opportunities, which only a few interviewees linked to teacher training, support this assumption.

In addition to university courses, school practicum and mentoring may offer various learning opportunities for adaptive error management – in particular, the use of error feedback by school or university faculty, related to practical field experiences. However, those seem to be associated with predominantly negative experiences, especially in the German subsample (see Table 3). Many of the teachers recalled negative experiences, and significantly fewer reported valuable learning experiences in this regard. Most of them described their school traineeship as a stressful, exhausting, and frustrating time, accompanied by maladaptive error management by their mentors. Some examples:

> *It is clear, that, of course, what you notice is that ultimately the mentor, who evaluates [your professional development] decides what is an error or not. And I found that in teacher training or in the teacher traineeship, you couldn't always say that this is right or this is wrong. There are different ways of planning lessons, for example, or in any other way. You are at the mercy of your mentor who defines what is wrong or what is a mistake and so on; an extremely stressful situation.* (Mr. S./male/German)

> *Well, you shouldn't make any errors and mistakes in the traineeship anyway, that's how it's presented. But I found it – and I still continue to find it – not conducive to learning in such a traineeship, where people only look at your errors. Of course, that's part of it, it's part of the learning process, but if you have the feeling that the lesson observed by your mentor didn't go so well and that's why I'm no longer taken seriously by them, then that's not conducive to learning and, in that respect, I've just been through a tough school during my traineeship.* (Ms. M. /female/German)

> *I remember my seminar teacher/mentor always gave me a huge mind-map and whenever there were flashes on it, it went really badly and the more flashes you had, the more depressed you were, and I was one of the front-runners at some point with 14 flashes in a lesson and I thought I had to shoot myself.* (Ms. S./female/German)

However, a few teachers (see Table 3) emphasized the positive aspects of their practical school experience during teacher training and remembered mentors who modelled an adaptive approach to errors or used them as a learning opportunity.

> *During my traineeship, I was lucky to have very great mentors who had a similar attitude, and (…) I actually experienced it in such a way that errors could actually seem useful for the class, or at least as a way of moving on, so that you could really experience the class, experience it in a very practical way. You can learn from errors and you're allowed to make errors, you're also allowed to express errors, that's part of it.* (Ms. M./female/German)

> *I once had a mentor myself who I thought was brilliant. Who, if someone answered something funny as an adult student, so that (…) so the teacher shook his hand that he gave this "excellent wrong answer," congratulated him and that was a good example of how, at least among adults, that's how the discussion always went on.* (Ms. L./female/Finnish)

> *Yes, and then, I mean, ok, my mentors took a lot of time to reflect and try to show me how I could have done things better, that was okay, so it was a constructive way of dealing with it.* (Ms. R./female/German)

In sum, the data indicate that there is limited opportunity to gain error competence during teacher education, but the teachers of both subsamples did express (subject-specific) theoretical knowledge about student errors.

5 Discussion and implications

Our findings indicate that from the teachers' points of view and recollections of experiences in both countries, teacher education provides few intentional learning opportunities to develop professional error competence. This is in line with other research findings (Türling, 2014). The narratives of the interviewees showed limited professional knowledge with respect to adaptive error management and indicated that teacher error competence is mainly acquired during professional activity and "learning by doing" in handling student errors, with this category showing the highest amount of codings (32.7% of all codings; 42.2% of all codings if the category of teachers' error-related attitudes, which comprises no learning opportunity, is not taken into account). Only a few participants recalled explicit learning opportunities during their university courses or school traineeships.

Previous studies have identified significant differences in the error competence of teachers compared to students and trainee teachers and have suggested that error competence seems to be acquired only during professional activity (Türling, 2014). Both theoretical knowledge and the quality of handling student errors appear less pronounced in students and trainee teachers than in teachers. Our interview data point to the likelihood that error-related knowledge is also mainly acquired during professional activity, as only few participants explicitly reported learning experiences during their university courses or school traineeships. In addition, many of these recollections had negative connotations, and, in some cases, even reflected unfavorable models and failed learning situations for gaining professional error competence. With regard to knowledge about the causes of student errors, which was coded very frequently in our interview data, Türling (2014) provided evidence for differences between pre-service and already practicing

teachers. These findings together could indicate a lack of effectiveness in teacher training. This shifts our focus to the importance of further developing teacher education in order to improve teacher knowledge about and management of errors as a relevant aspect of the professional competence of teaching.

Indeed, empirical results suggest that teacher competence and teacher professional knowledge are not acquired sufficiently during the course of teacher education. In the beginning, many teachers show deficits in content knowledge (Abell, 2007) and these deficits negatively impact their pedagogical content knowledge. For example, teachers have difficulties identifying student misconceptions or recognizing learning difficulties (Halim & Meerah, 2002).

It became clear from the teacher narratives that their error management behavior in the classroom is intertwined with their attitude toward errors and the perception of the error cause. Many teachers justified their specific responses to student errors with their assumptions about the cause of the error (e.g., student lack of effort versus difficulty in understanding). This raises the question of whether the three components of professional error competence (Wuttke & Seifried, 2017) – conceptual knowledge about error types and causes, strategic knowledge about handling student errors, and attitudes toward errors – are, in fact, separable. Positive and negative/maladaptive error-related attitudes were similarly balanced; on a descriptive level, positive attitudes tended to be more common among the Finnish interviewees. However, in many cases errors were still attributed to student laziness, incompetence, or lack of motivation, which limits adaptive error management and the use of errors as learning opportunities in the classroom. Maladaptive attitudes also hinder the development of a positive error climate, which is a complex construct that affects teachers and students as well as their interactions (Steuer et al., 2021). Besides concrete behaviors on the teacher and student levels, the error climate also pertains to attitudes and potential behavioral intentions toward errors. Teacher training should therefore raise teacher trainee awareness of their own error-related beliefs, based not only on their own school biographies and through the use of errors as learning opportunities by their mentors during traineeship, as these aspects are also assumed to impact the development of error competence. Future qualitative research should investigate the semantic connections between the individual facets of error competence in more depth.

All the interviewees agreed with the importance of errors for learning, but they also mentioned the challenges and their own lack of confidence in dealing with student errors. The teachers from both subsamples considered student motivation as key for learning from errors. In particular, the Finnish interviewees pointed out that they have access to a multi-level support system

so that there is additional time to learn from errors in remedial lessons and in lessons with special needs-teachers.

Our study has some limitations: First of all, interview data was based on a convenience sample of teachers from NRW, Germany, and a comparable region from southern and central Finland. Our findings are neither representative nor generalizable. However, they provide initial insights and add to our understanding on which occasions teachers gain professional error competence (or not), from their point of view. In order to develop teacher education, more in-depth qualitative studies – interviews combined with classroom observations, for example – or longitudinal questionnaire studies are needed to gain a better understanding of the learning opportunities in which (pre-service) teachers acquire error competence and how their experiences influence their pedagogical thinking and teaching behavior. Second, our findings rely on retrospective data and teacher self-reports. They represent only a snapshot of the teacher views and recollections expressed in the interviews. We cannot rule out the possibility of social desirability, but several teachers also described their difficulties with adaptive error management and their negative attitudes toward student errors, and in some cases, they critically reflected on their own professional competence. Finally, most of the codings in the category "theoretical knowledge about errors" cannot be exclusively assigned only to formal learning experiences during teacher training. Only some of the statements made explicit reference to this. It is possible, even likely, that this knowledge was acquired only in the course of their professional activity. However, this would further underpin the need for more development of teacher education programs in this regard.

Thus, our findings raise the question of whether there is a shortcoming in teacher education and what should be considered in future teacher training. In contrast to our expectations, on a descriptive level, we found only marginal differences between Finnish and German teachers in their experiences with respect to teacher training. However, the Finnish teachers reported less negative error-related experiences and beliefs in general than the German interviewees did. Emotionally negative experiences may cause feelings of helplessness in error situations and reinforce a negative attitude. Both in the classroom and in teacher training, emotionally safe learning environments and an error climate should be created in which adaptive approaches to errors are practiced and perceived as a natural part of learning processes. We need to develop new conceptions and curricula for the acquisition of teacher error competence. Finally, from our point of view, error management and learning from errors should be introduced from different perspectives (professional/subject-specific, pedagogical, and psychological) in teacher education.

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