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Novice and Expert Teachers' Content-Related Pedagogical Reasoning

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Abstract

In this exploratory study, we seek to contrast the content-related pedagogical reasoning shown by prospective and experienced teachers – i.e., their reasoning for or against the use of subject-matter representations that draw on content knowledge or pedagogical content knowledge. We conducted think-aloud interviews with seven prospective teachers and seven experienced teachers based on a situation of planning to teach with a specific task. The teachers' pedagogical reasoning was analysed by means of content analysis. The data showed that expert teachers engage substantially more in content-related pedagogical reasoning than novices. In particular, expert teachers' reasoning is predominantly based on their knowledge of content and students and on curricular knowledge.

Keywords

content knowledge, pedagogical content knowledge, pedagogical reasoning, expert–novice teachers, verbal data analysis

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1 Introduction

Distinguishing between *content knowledge* (CK) and *pedagogical content knowledge* (PCK) as components of teachers' knowledge is one of the most influential ideas in research on teacher professionality. Many studies have modelled and measured CK and PCK as aspects of teachers' professional knowledge. Recent research has also explored teachers' *use* of CK and PCK in specific teaching situations in order to better understand the relationship between knowledge and practice (e.g., Escudero & Sánchez, 2007; Krepf et al. 2018; Stahnke & Blömeke, 2021; Tigelaar, Sins, & van Driel, 2017).

Particularly, it appears fruitful to explore teachers' use of knowledge and how it influences their practice by analysing their pedagogical reasoning. This is based on the assumption that teachers have to select constantly between alternative instructional moves (cf. Kavanagh, Conrad, & Dagogo-Jack, 2020; Loughran, Keast, & Cooper, 2016; Loughran, 2019; Shulman, 1987). For instance, with respect to lesson planning, teachers need to decide which tasks, questions, or explanations to use in order to foster students' learning. According to recent studies, *pedagogical reasoning* is often described as teachers' reasoning (with oneself), through which potential moves are attached with arguments for or against their use in a given situation (e.g., Kavanagh et al., 2020; Loughran, 2019). Hence, the investigation of teachers' pedagogical reasoning may enable us to come to a better understanding of the knowledge related to their practice.

Previous research on pedagogical reasoning has particularly focused on the role of teachers' individual experience-based knowledge and beliefs (Cornett, Yeotis, & Terwilliger, 1990; Kettle & Sellars, 1996; Levin & He, 2008; Levin, He, & Allen, 2013; Tiilikainen, Toom, Lepola, & Husu, 2019). Less is known about the use of content-related knowledge, such as CK and PCK, during pedagogical reasoning. CK and PCK are often acquired in formal teacher education and relate to specific content. Their use may be assumed crucial and therefore it is reasonable to systematically include them in an analysis of pedagogical reasoning. As outlined above, there is a growing body of research that also focuses on teachers' use of CK and PCK in specific teaching situations. However, there are hardly any studies that focus on their thinking in terms of pedagogical reasoning and, at the same time, distinguish between their knowledge in terms of CK and PCK (see Section 2.1 for details). Both would be necessary, however, to shed light on teachers' *content-related pedagogical reasoning* – i.e., their argumentation that underlies the selection of content-related instructive moves *and* that draws on content-related knowledge.

The belief that professional teaching is based on teachers' ability of pedagogical reasoning also has consequences for teacher education. For instance, Kavanagh et al. (2020) argue that practice-based teacher education can be aimed at helping teachers develop pedagogical reasoning. However, developing prospective teachers' pedagogical reasoning has proved to be a challenge. As Nilsson (2009) points out, "[s]tudent teachers are often interested in knowledge that is practical and can be applied in the classroom … student teachers do not always manage to make explicit connections between teachers' actions and the pedagogical theories that inform practice" (p. 239). Therefore, content-related pedagogical reasoning (based on CK and PCK) could be even more challenging

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for prospective teachers. Unfortunately, hardly any empirical studies so far demonstrate to what extent and in what way prospective teachers differ from experienced teachers regarding their engagement in content-related pedagogical reasoning (see Section 2.1). However, findings from such studies are required to clarify what constitutes expertise in this respect and to create or improve respective learning opportunities in teacher education programs.

In this exploratory study, we therefore seek to analyze the content-related pedagogical reasoning and, in particular, contrast the content-related pedagogical reasoning shown by prospective and experienced teachers, as exemplified in the field of mathematics education. Our goal is to arrive at (and not to test) hypotheses that show whether and, if so, how prospective teachers differ from experienced teachers in this respect. The hypotheses, if any, are intended to provide a starting point for future research with respect to content-related pedagogical reasoning. Although the context of our study is mathematics, we seek to contribute to a broader discussion among researchers working with different school subjects and teacher education in general.

2 Theoretical Background

2.1 Pedagogical Reasoning in Subject-Matter Education

To date, only a few studies focus on teachers' thinking in terms of pedagogical reasoning and, at the same time, distinguish between their knowledge in terms of CK and PCK. Cunningham (2007), in the field of history education, and Elliott (1996), in the field of language education, used a grounded theory approach to identify the knowledge components that were activated during the pedagogical reasoning process of expert teachers. A result of their analysis is that these teachers activated CK in addition to further components, such as knowledge about students' conceptions or instructional strategies, which can be summarised as PCK. Sánchez and Llinares (2003) focused mathematics-related CK and demonstrated its influence on prospective teachers' pedagogical reasoning. It is reasonable to assume that these strategies of analysis are feasible and fruitful in other fields of subject-matter education and that findings also may (partially) carry over to other domains and content areas, pedagogical situations and teacher groups. In our study we want to contribute to this recent strand of research and to demonstrate, that it is reasonable to differentiate between CK and PCK as knowledge components that are applied during pedagogical reasoning.

More specifically, hardly any empirical studies so far have demonstrated how prospective teachers engage in content-related pedagogical reasoning and to what extent they differ from experienced teachers in this respect. Peterson and Treagust (1995) report the limited pedagogical reasoning ability of prospective teachers in the field of science education. Ball (1988) compared the pedagogical reasoning of one experienced primary teacher and two prospective primary teachers in the field of mathematics education. Her case study suggests that, when compared to the experienced teacher, the prospective teachers' reasoning appear to be "skewed in the direction of particular warrants other than mathematics, omit critical warrants, and include bases that are outside of the central thrust of mathematical pedagogy" (p. 186).

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We conclude that existing research indicates potential deficits of prospective teachers' content-related pedagogical reasoning.

Indications from prior research, however, must be considered carefully since the term "pedagogical reasoning" is used with varied implications. Shulman (1987) introduced a framework for pedagogical reasoning practiced by teachers by referring to comprehension (of subject matter), transformation (of subject matter according to student needs), instruction, evaluation, and reflection as its constituting aspects. For instance, Peterson and Treagust (1995) refer to this framework by Shulman, whereas Kavanagh et al. (2020) and Loughran (2019) seem to focus on one particular aspect of Shulman's framework (the aspect of transformation – i.e., the process of teachers' decision-making with respect to instructional moves that are supposed to promote the best learning impact among students, see Section 1).

Apart from Shulman (1987) and the adaptions of his framework, Ball (1988) and Loughran, Mulhall, and Berry (2004) proposed a framework of pedagogical reasoning based on content-related knowledge. Ball (1988) describes a "framework of warrants for judging the products and process of pedagogical reasoning that underlie representing mathematics to students" (p. 171) within the field of mathematics education. It comprises mathematical warrants (which are needed to ensure the "conceptual essence" of the content), warrants of learning theory (which are needed to ensure students' learning), warrants based on the knowledge of students (which are needed to ensure students' accessibility and interest), and finally, warrants of the context (which are needed to ensure feasibility and sensitivity). The findings from Ball's case study must be analysed against this background. Furthermore, Ball's framework is related to the content but does not explicitly refer to a conceptualisation of CK and PCK.

In comparison, the framework by Loughran et al. (2004) assumes pedagogical reasoning to be based solely on PCK. They introduced "content representations", which can be used to represent teachers' PCK. A content representation is given by prompts (and teachers' responses to the prompts) with respect to a certain topic and aspects of Shulman's (1986, 1987) conceptualisation of PCK. Moreover, Loughran et al. (2004) introduced "pedagogical and professional-experience repertoires", which are representations of teachers' narratives that combine knowledge elements from PCK. These repertoires are said to illustrate teachers' pedagogical reasoning. Content representations, however, do not explicitly consider CK as a knowledge component that can be activated during pedagogical reasoning.

To conclude, there is a need to revisit these approaches that strive to connect pedagogical reasoning and content-related teacher knowledge and to develop and apply a more systematic strategy of analysis.

2.2 Our Framework of Content-Related Pedagogical Reasoning

In this study, we adopt the framework of pedagogical reasoning by Ball (1988). To us, this framework seems suitable to focus Shulman's (1987) aspect of transformation. This focus is consistent with recent studies on pedagogical reasoning by Kavanagh et al. (2020) or Loughran (2019) (see Section 1). Furthermore, Ball's (1988) approach is content-related, because it refers to teachers' arguments for or against content-related instructional moves (the use of subject-matter representations). In this section, we describe a framework of pedagogical reasoning that additionally refers to a conceptualisation of CK and PCK. To achieve this, we draw on the conceptualisation of CK and PCK presented by Ball, Thames, and Phelps (2008).

According to Ball et al. (2008), CK comprises *common content knowledge* (CCK – referring to content knowledge also relevant in settings other than teaching), specialised content knowledge (SCK – referring to content knowledge only relevant to teachers), and finally, horizon content knowledge (HCK – referring to content knowledge about the connectedness of topics within that content domain). Furthermore, PCK is said to comprise the *knowledge of content and students* (KCS – relating to students' content-specific thinking or behaviour), *knowledge of content and teaching* (KCT – relating to all forms of representations of the subject matter, such as questions, tasks, pictures, explanations, and so on), and *knowledge of content and curriculum* (KCC – knowledge relating to content-related instructional materials, such as textbooks and national teaching standards).

We assume that during the teaching and lesson-planning stages, teachers essentially rely on their KCT when it comes to representations of subject matter (cf. Loughran, 2019). Moreover, we suppose that teachers must regularly decide between multiple (often more or less equally reasonable) representations of the subject matter and select one that will promote students learning in the most productive way. Based on this, we define teachers' *content-related pedagogical reasoning* as their argumentation (with oneself) for or against the use of representations in teaching the subject-matter to students, if it (the argumentation) is based on either CCK, SCK, HSK, KCS, or KCC. This means that the use of respective representations is warranted by propositions that can be assigned to one of the listed knowledge components. In contrast to the approaches by Ball (1988) and Loughran et al. (2004), our approach considers CK *and* PCK as a knowledge base for pedagogical reasoning.

The conceptualisation of CK and PCK by Ball et al. (2008) focuses on professional knowledge (institutionalised knowledge, as it is assumed to be shared by the mathematics education community). In this study, however, we do not assume that the knowledge (sub-)components are restricted to knowledge that is correct from a normative point of view. It can also comprise incorrect, incomplete, subjective, or experience-based knowledge (i.e., an individual teacher's knowledge), *insofar as* it relates to the descriptions of CCK, SCK, HSK, KCT, KCS, or KCC given above. This makes sense because prospective teachers still develop professional knowledge, and our study aims at describing and contrasting novice and expert teachers' forms of content-related pedagogical reasoning and the frequencies in which they are used (instead of focusing on the quality of CK and PCK).

2.3 Research Question

As outlined in the introduction, we seek to explore novice and expert teachers' content-related pedagogical reasoning. But who can be considered a novice or an expert teacher?

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Prospective teachers are often considered novices (Bromme, 1992). They have not completed teacher training and often have only few experience in teaching and pedagogical reasoning. According to Bromme (1992), experts, on the other hand, cope with so-called knowledge-rich tasks, such as pedagogical reasoning. Since pedagogical reasoning is a reflexive activity, teachers who also serve as teacher educators are appropriate candidates to serve as experts. These experts presumably have professional knowledge, particularly being qualified and experienced in teaching and pedagogical reasoning.

Our study is exemplified in the field of mathematics education, so we chose a topic from arithmetic that plays a central role in elementary mathematics. We also focused on the common task of lesson planning because it is an appropriate task that can facilitate teachers' pedagogical reasoning. A planning situation also better allows the researcher to sample and analyse verbalised processes of pedagogical reasoning (e.g., verbal reports based on think-aloud interviews; see Section 3 below) to generate hypotheses.

Based on the afore-mentioned considerations, we posed the following research question: How do novice and expert teachers differ in their mathematics-related pedagogical reasoning when they plan to teach arithmetic?

3 Methods

In this study, we collected qualitative interview data from novice and expert teachers (see Section 3.1) in terms of think-aloud protocols in reaction to a planning task to teach arithmetic that required pedagogical reasoning (see Section 3.2). The qualitative data were analysed with respect to processes of mathematics-related pedagogical reasoning by means of content analysis (see Sections 3.3.1 and 3.3.2). Content analysis produces quantitative data that can be used to arrive at hypotheses regarding differences between novice and expert teachers' mathematics-related pedagogical reasoning (see Section 3.3.3).

3.1 Participants

The data were derived from 14 participants: seven participants were novice teachers, and seven were expert teachers. All seven novice teachers were bachelor's students in the first year of preparation in a teacher training program in German-speaking Switzerland (which requires three years of full-time study). They also had little or no practical experience and took part in the study on a voluntary basis. However, they varied with respect to outcomes on a previous examination of mathematics in their teacher education program and their motivation to teach mathematics (based on self-assessment). All seven expert teachers were experienced mathematics teachers in primary classes (for more than 10 years), who obtained a teaching certificate (in Switzerland, a Bachelor of Arts for primary education). Moreover, the expert teachers were required to serve as teacher educators in a teacher education program in German-speaking Switzerland (as lecturers or mentors to prospective teachers with respect to mathematics education).

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We sent invitation e-mails to a large number of potential candidates. The selection of novice teachers took place in the order in which they responded to our e-mail. Additionally, as mentioned before, we sought to balance the novice sample with respect to prospective teachers' performances in mathematics and their motivation to teach mathematics. The selection of expert teachers took place after scanning the websites of schools in the German-speaking part of Switzerland; this allowed us to identify eligible persons and to contact them. Finally, we balanced our sample of novices and experts with respect to the size of both groups.

3.2 Interviews and Procedure

In the context of practice, teachers' pedagogical reasoning is mental work (Loughran, 2019). Hence, it is not possible to observe teachers' pedagogical reasoning directly. However, it is possible to analyse their observable behaviour, such as their verbalised pedagogical reasoning. In this study, we conducted think-aloud interviews to collect the required data. According to Leighton (2017), think-aloud interviews are suitable for providing the means to access mental processes.

In our think-aloud interviews, the participants were confronted with the task of planning a lesson introducing the subtraction algorithm (written subtraction) to fourth graders. We chose this task because planning to teach an introductory lesson requires special attention from participants to the selection of appropriate representations of the subject matter. Therefore, the task is appropiate to stimulate their mathematics-related pedagogical reasoning. The planning situation can also be captured better in the interviews. Moreover, it is a practice-oriented and authentic task.

Particularly, the subtraction algorithm is a traditional topic from mathematics in German-speaking Switzerland, and it is dealt with in lessons held at several levels. It also provides a good opportunity to argue based on, for instance, CK (subtraction with regrouping, for instance, is a non-trivial case to many teachers; cf. Ma, 1999), KCS (students' errors or conceptions are well documented in the literature; cf. Fiori & Zuccheri, 2005; Kühnhold & Padberg, 1986), and KCC (the algorithm is dealt with in teaching standards and mathematics textbooks in Switzerland).

All participants were asked to think out loud for approximately 15 minutes – i.e., to verbalise everything that came to their mind with respect to the selection and arrangement of subject-matter representations within their lesson. The time restriction was chosen to trigger spontaneous reactions. It was also communicated that the interview was not a conversation between the investigator and the participant but a laboratory situation in which the investigator only served as an initiator of verbalised mental processes by providing the tasks. Only if a participant stopped thinking aloud did the investigator ask the participant to proceed thinking aloud ("What else comes to your mind according to the selection of teaching procedures?"). In some cases, the participants did not know what else to think about. These participants were asked to refer to anything that came to mind according to an excerpt from a textbook that they had to use in their lessons, which represented the subtraction algorithm.

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3.3 Analysis

First, all interviews were transcribed in full. Second, the transcripts were reduced to phrases that contained indications of argumentation (see Section 3.3.1). Third, we analysed the data by means of the content analysis method proposed by Mayring (2010). To elaborate, we coded the resulting data according to our coding scheme (see Section 3.3.2). The coding was carried out by two researchers. Training on the application of the coding scheme took place in a pilot study that we conducted in advance. Finally, the code frequencies were counted, and the mean values of the code frequencies were compared between the novice and expert groups in order to arrive at hypotheses of differences between the groups (see Section 4).

3.3.1 Searching the interview transcripts for occurrences of argumentation

First, we searched the transcripts for indications of argumentation through the application of non-content rules (Chi, 1997). More precisely, we searched for indicator words such as "because", "therefore", among others. These words typically occurred in phrases or sequences of subsequent phrases that were of a causal, consecutive, or final nature. Second, the resulting phrases or sequences of phrases were considered to be the segments to be coded in the next step of the analysis if they contained an argument for or against the (intended) use of a representation of the subject matter. Table 2 contains examples of segments (and codes assigned to the segments; see Section 3.3.2). Because searching the interviews for segments to be coded was a more formal procedure and due to the exploratory nature of our study we refrained from carrying out this step of analysis by a second researcher.

3.3.2 Content analysis

By specifying four processes of pedagogical reasoning, we present the coding scheme that we used to code all segments (see Table 1).

Tab. 1: Coding scheme

Code	*Arguing for or against the use of representations of mathematics …*	*Based on*
Proc1	… based on mathematical propositions (i.e., propositions that can, in principle, be justified by mathematical argumentation or definition).	CK
Proc2	… based on student-related propositions (i.e., propositions that can, in principle, be justified by the ordinary or scientific observation of students' behaviour with respect to engagement in mathematical tasks).	KCS
Proc3	… based on curricular propositions (i.e., propositions that can, in principle, be justified by comparison with mathematical teaching programs/standards, textbooks, and related materials).	KCC
Proc4	… based on any other sort of propositions.	OTHER

Obviously, our coding scheme does not take into account the differentiation of CCK, SCK, and HCK put forth by Ball et al. (2008). In the piloting of the coding scheme, it was found that it was not possible to reliably distinguish the corresponding processes of mathematics-related pedagogical reasoning. Therefore, we differentiate only between processes of pedagogical reasoning that are based on CK, KCS, and KCC (KCT is not used to argue for or against the use of representations according to our framework; see Section 2.2).

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Two researchers coded all interviews independently of one another. Overall, substantial inter-rater reliability (Cohen's kappa coefficient, *k*) was achieved, according to Landis and Koch (1977): *k* = .87. Below, Table 2 provides examples of segments from the interview data and the codes assigned to them.

Tab. 2: Examples of segments and codes assigned to the segments (formal indications of argumentation in italics)

Example of a segment	*Code assigned to the segment*
"In written subtraction, the size of numbers is lost. It's actually 80 minus 50, but you calculate 8 minus 5. *That's why* I would rather let the students have to calculate semi-written subtractions."	Proc1 (CK)
"As a first step, I would set the numerical material or the task in such a way that I do not have any transitions between the place values at the beginning, *because* that is so prone to error to students."	Proc2 (KCS)
"In the textbook, the roll is used as an odometer (as a means of illustration of indirect addition as a procedure of written subtraction). *Therefore*, I would have to start from a situation that the children themselves already know, preferably a bicycle odometer."	Proc3 (KCC)
"I would present written subtractions right from the beginning and students have them solve them or at least to try *so that* I know what the children are already able to do."	Proc4 (OTHER)

3.3.3 Statistical analysis to arrive at hypotheses

In order to compare code frequencies between both groups (novice and expert teachers) and to arrive at difference hypotheses, we applied statistical analysis. We used the open-source software and programming language R (version 4.1.2) and compared both the means of absolute and relative frequencies of codes (relativised to the interview length in terms of time). Due to the design of data acquisition, we expected the length of the interviews to be comparable. Nonetheless, we decided to analyse both the frequencies and relative frequencies to account for the potential influence of the interview length on the frequencies of the codes in an interview.

All dependent variables were tested for a normal distribution (the Shapiro–Francia test) and the homogeneity of variances (Bartlett test) in all groups. Whenever possible, we applied a (directed) t-test. If a normal distribution was not given, we applied the (directed) Wilcoxon test (Mann–Whitney U test). Strong effect sizes (Pearson`s *r*) according Cohen (1992) were taken as an occasion to arrive at hypotheses. Significant differences in code frequencies between both groups were interpreted as an additional support for the generation of hypotheses. However, due to the absence of an hypotheses testing design, significant differences were not considered as inferential support for the hypothesis. The effect size was chosen as an indicator because, according to our research objective, we are rather interested in selecting empirically grounded hypotheses for future research, instead of making decisions about which hypotheses are true or not.

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4 Results

4.1 Descriptive Statistics

Due to the design of data acquisition, as expected, the length of the interview protocols is quite comparable between the novice and expert groups ($t(12) = .81$, $p = .74$). Table 3 below displays the interview lengths per participant and mean values per group.

Tab. 3: Interview lengths per interview and mean interview length per group (N: novice teachers, E: expert teachers, data in minutes, standard deviations in brackets)

	N1	**N2**	**N3**	**N4**	**N5**	**N6**	**N7**	**N mean**
Time	12:33	13:20	15:40	14:20	13:25	07:54	11:34	12:41 (02:28)
	E1	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E mean**
Time	11:24	15:20	11:15	18:35	14:14	14:20	11:46	13:51 (02:39)

The frequency of a certain code (see Section 3.3.2) in an interview can be interpreted as the measure of a participants' pedagogical reasoning which is based on the respective knowledge component (CK, KCS or KCC). Because the lengths of interviews are comparable, it is possible to contrast code frequencies of participants or mean code frequencies of the groups directly. Table 4 provides the mean code frequencies per group.

Tab. 4: Mean code frequencies per group (standard deviations in brackets)

Participant	**Proc1 (CK)**	**Proc2 (KCS)**	**Proc3 (KCC)**	**Proc4 (OTHER)**	**Sum of Proc1–3**
Novices mean	.57 (.79)	.71 (1.25)	0 (0)	1.14 (.9)	1.29 (1.38)
Experts mean	1 (.82)	6.29 (3.35)	1.14 (1.35)	1.43 (.79)	8.43 (3.82)

For completeness, we also report the mean values of the relative frequencies of the codes (relativised to the interview length; see Table 5).

Tab. 5: Means of relative code frequencies per group (standard deviations in brackets)

Participant	**Proc1 (CK)**	**Proc2 (KCS)**	**Proc3 (KCC)**	**Proc4 (OTHER)**	**Sum of Proc1–3**
Novices mean	.04 (.06)	.05 (.08)	0 (0)	.09 (.07)	.09 (.09)
Experts mean	.08 (.06)	.44 (.17)	.08 (.09)	.11 (.06)	.59 (.17)

4.2 Derived Hypotheses

The statistical data in Section 4.1 is used to arrive at hypotheses regarding the differences between novice and expert teachers' mathematics-related pedagogical reasoning (see Section 3.3.3). The following hypotheses can be made due to rather strong effect sizes (Pearson`s *r*) according to Cohen (1992), along with significant differences between the mean values of code frequencies (E mean and N mean with respect to the variables

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displayed in Table 4/5). Because all results can be reproduced by analysing mean relative frequencies (Table 5), we present only the statistical data resulting from absolute frequencies (data in brackets).

H1: Compared to novice teachers, expert teachers engage substantially more in mathematics-related pedagogical reasoning ($t(12) = 4.65$, $p = .001$, $r = -0.78$).

H2: Compared to novice teachers, expert teachers use substantially more KCS during mathematics-related pedagogical reasoning ($W(12) = 48$, $p = 0.001$, $r = 0.83$).

H3: Compared to expert teachers, novice teachers hardly use any KCC during mathematics-related pedagogical reasoning ($W(12) = 42$, $p = 0.005$, $r = 0.7$).

5 Discussion

5.1 Summary and Classification of Results

The findings of our study correspond to and extend prior research on content-related pedagogical reasoning. According to hypothesis H1, expert teachers engage more in mathematics-related pedagogical reasoning. This is in line with the assumption that novice teachers' ability and interest in pedagogical reasoning is limited (Nilsson, 2009; Peterson & Treagust, 1995). Based on prior research (see Section 2.1) and our findings, we interpret H1 as carrying over to other fields of subject-matter education. To elaborate, we believe it is reasonable to claim that prospective teachers' content-related pedagogical reasoning is weakly developed and, consequentially, needs to be addressed through teacher education programs.

We are also able to concretise claims by Ball (1988), Cunningham (2007), and Elliott (1996). According to Cunningham and Elliott, expert teachers draw on CK and PCK during pedagogical reasoning. According to Ball, the mathematics-related pedagogical reasoning of prospective teachers is "skewed in the direction of particular warrants other than mathematics" (p. 186). According to our hypotheses H2 and H3, prospective teachers particularly seem to miss pointing at arguments associated with the use of KCS and KCC, when compared to experienced teachers. We tentatively see this as a hint that future learning opportunities with respect to content-related pedagogical reasoning (in teacher education programmes) should pay special attention to the use of arguments based on KCS and KCC (see Section 5.3).

5.2 Limitations of Our Study

5.2.1 Limitations due to sample and design

Due to the small sample population and our chosen methodology, our findings cannot be considered representative or generalisable. Moreover, finding support for hypotheses in the case of moderate- or low-effect sizes (e.g. the use of CK according to Proc1) would require larger sample sizes. Nonetheless, our exploratory study is suitable

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for arriving at empirically grounded and detailed hypotheses that can be tested in future research.

Obviously, the participants’ pedagogical reasoning is influenced by the task used in the interview. Because all participants were confronted with the same task, however, we believe it is possible to compare the pedagogical reasoning between the groups (interindividual differences). As Bromme (1992) argues, a task may appear differently to novices and experts. Therefore, it may be helpful in future research to triangulate the use of tasks.

Based on our findings, we interpret our framework of content-related pedagogical reasoning (see Section 2.2) as valid and methodologically helpful for research similar to ours. It is worth mentioning, however, that compared to other frameworks (cf. Shulman, 1987; Loughran et al., 2004), our framework focuses on teachers’ content-related arguments for or against the use of representations of the subject matter. Hence, our framework does not pay attention to arguments for or against the use of social forms in classes or methods of assessment etc.

5.2.2 Limitations due to focus on mathematics education and specific content

Obviously, there is no straightforward way to determine to what extent our research can be applied to other areas of subject matter education. In particular, our hypotheses must be adapted to further testing and possibly modified to suit other populations and situations.

As demonstrated in Section 2.2, our framework of content-related pedagogical reasoning is linked with the conceptualisation of CK and PCK put forth by Ball et al. (2008). Although the used conceptualisation by Ball et al. (2008) is initially mathematics related, we believe it is indeed possible to apply it – and therefore also our framework – to other fields of subject-matter education in the future (see Section 5.3).

5.2.3 Limitations due to missing assessment of participants professional knowledge

Note that it is also possible that there exists a relation between expert or novice teachers’ (existent or nonexistent) professional CK or PCK and their content-related pedagogical reasoning. However, we are not able to highlighting such a relation based on our data. For instance, it is conceivable that novice teachers engage less in content-related pedagogical reasoning, because they do not have the professional knowledge at hand that is necessary to apply appropriate arguments from a more normative point of view. Investigating such relations would require to assess participants’ professional CK and PCK (which did not take place in our study).

5.2.4 Limitations due to data analysis

The codes of processes of pedagogical reasoning (Proc1–4) are different with respect to their levels of abstraction. For instance, Proc2 (KCS) is operationalised in a way that many more segments in the interviews can be coded with this code. Compared to Proc2 (KCS), for instance, the Proc3 (KCC) code is much more specific and, for this reason, appears

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much less frequently during the analysis. Because the frequency of codes is dependent on both the task used in the interview and its level of abstraction, it is not possible to analyse the lines in Tables 4 and 5 (intraindividual differences) but rather only its columns (interindividual differences). For instance, the fact that a participant in our study used Proc2 (KCS) more times than Proc3 (KCC) during their pedagogical reasoning could be an artefact of the task used in the interview and the different levels of abstraction of these codes.

Because we searched the transcripts for indications of argumentation through the application of non-content rules (search for indicator words such as “because”, “therefore”, among others), it is possible that some text passages were not identified as segments to be coded. In this respect, our approach represents a compromise to obtain segments in a traceable and reproducible way.

Finally, in this study the design of analysis was set up in a way to produce quantitative data. This enabled us to generate hypotheses about differences between the groups with respect to the frequencies of processes of content-related pedagogical reasoning. However, this way it is not possible to generate more “qualitative hypotheses” (see consequences for future research in the next section).

5.3 Consequences for Research and Teacher Education

As discussed above, the limitations of our study naturally lead to an outlook for potential future research. Among the indications for further research, we would like to emphasise the need for empirical studies that test our hypotheses with respect to different populations and other subject references.

Apart from the differences between novice and expert teachers’ frequencies in their processes of content-related pedagogical reasoning (as focused on in this study), it also appears important to investigate differences in terms of quality. A case study by Ball (1988) indicates that there are presumably also differences between the quality of novice and expert teachers’ processes of content-related pedagogical reasoning: compared to expert teachers, novice teachers’ arguments may also include statements that appear to be false or at least worthy of discussion within the (mathematics) educational community. Our pre-scientific impression of the reasoning processes in our data does not necessarily confirm this impression. The arguments put forward by novices rarely seem fundamentally wrong to us. We conclude that further research is necessary to determine typical differences with respect to the quality of processes of content-related pedagogical reasoning. In a next step, therefore, we seek to reanalyse our data in a more qualitative way.

As Kavanagh et al. (2020) argue, developing prospective teachers’ pedagogical reasoning during teacher education programs has proved to be a challenge. Our study supports the view that this assumption particularly holds water with respect to content-related pedagogical reasoning. It may be helpful in teacher education to provide prospective teachers with opportunities to build and reflect upon processes of reasoning, as differentiated within our framework. We argue that the role of the content must be strengthened in this regard during practical training phases within teacher education

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programs. As an additional effect, these opportunities may also foster the development of CK and PCK and the coherence experience of prospective teachers during teacher training programs.

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