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Comparing and contrasting solutions to foster diagnostic competence

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A main focus in the field of research on competences of teachers is on diagnostic competence. Although it is stated that prospective teachers' diagnostic competences are trainable, they are still described as too low. Therefore, the present study aims to foster diagnostic competence of prospective primary teachers. In the study diagnostic competence is conceptualised with so-called epistemic activities. The treatment bases on empirically known factors about fostering diagnostic competence and follows the teaching and learning method of comparing and contrasting. The success of the method is proven for various fields but has not yet been researched in the field of professional development of prospective teachers. The article introduces the theoretical framework, the method and results of the data analysis.

Keywords: Diagnostic competence, developing diagnostic competence, measuring diagnostic competence, comparing and contrasting, inquiry-based learning.

Introduction

Within the field of teachers' competences an important focus lies on diagnostic competence that we understand as a teacher's ability to identify weaknesses and strengths in students' mathematical work. It is considered as an essential part of teachers' professional knowledge which impacts the quality of teaching and students' learning (Baumert & Kunter, 2006). Research showed that teachers' competences are trainable (Herppich et al., 2018) but it is also stated that teachers' diagnostic competences are too low (van Ophuysen & Behrmann, 2015). Therefore, the systematic development of teachers' diagnostic competence has become a relevant issue of educational research (Chernikova et al., 2020; Larrain, 2019; Hoth, 2017).

For this reason, the aim of this PhD-project is to design interventions that improve prospective primary teachers' diagnostic competence and to analyse the effect of these interventions. The PhD-project is called "KoVe-Dif" (Comparing and contrasting solutions to inquiry-based learning tasks as a basis for improving diagnostic competences of prospective teachers). The design of our interventions is particularly emphasising different processes of comparing and contrasting products of students' mathematical work (Alfieri et al., 2013). Comparing and contrasting is also an integral part of the diagnostic process of teachers (Philipp, 2018). The teachers' ability of identifying students' competences based on students' written mathematical work is the main focus referring to teachers' diagnostic competence. The project addresses the following main question:

(RQ): What is the effect of different interventions based on the teaching and learning method of contrasting and comparing on diagnostic competence?

Diagnostic competence

Competences are defined as "[...] context-specific cognitive dispositions that are acquired and needed to successfully cope with certain situations or tasks in specific domains" (Koeppen et al., 2008).

Context specificity can be interpreted in different ways. On the one hand, it can refer to different school classes and, on the other hand, to different subject areas. In the project described below we are focussing on a specific set of tasks from the arithmetic which will be described in the description of the treatment. We assume that the diagnostic skills developed in the context of the specific topic are transferable to different school classes.

In the past, diagnostic competence was conceptualised in three different ways (see also Philipp, 2018). First, there is research about cognitive dispositions such as knowledge or motivation. Focusing on the cognitive disposition such as knowledge, diagnostic competence is part of professional knowledge of teachers. For example, Brunner et al. (2011) conceptualised diagnostic competence as a part of pedagogical content knowledge and of pedagogical psychological knowledge. Second, diagnostic competence is equated with the so-called judgement accuracy (Südkamp et al., 2012). This research line focused on the performance of teachers regarding the comparison between a teacher's estimation of students' performance and the actual test scores of their students. This approach got criticized for being distant to a teacher's daily work (Praetorius et al., 2012). As an answer to this critique, the diagnostic competence started to get framed as a process. According to this conceptualization, research focuses on the diagnostic process itself (e.g. Klug, 2013) and on the cognitive process during the teacher's diagnosis (e.g. Philipp, 2018).

In the framework of Loibl and Leuders (2020) diagnostic competence is understood as a process of diagnostic thinking influenced by situation characteristics and person characteristics. While a situation is defined through framing and cues, the person characteristics include cognitive dispositions. The external diagnostic behaviour is either observable by process indicators (such as "think aloud") or by product indicators (such as a "decision"). Diagnostic thinking is the core of the framework, and Leuders et al. (2018) state that it is possible to conceptualise this thinking process similar to the "clinical reasoning". In our study we use this approach and follow Chernikova et al. (2020) as well as Fischer et al. (2014) who conceptualise processes of diagnostic thinking based on clinical reasoning by epistemic activities. These activities are characterised by "(a) identifying a problem, (b) questioning, (c) generating hypotheses, (d) constructing artefacts, (e) generalizing evidence, (f) evaluating evidence, (g) drawing conclusions, and (h) communicating process and results" (Chernikova et al. 2020, p. 161; see also Fischer et al. 2014). These epistemic activities are an adequate basis for modelling the process of a teacher's diagnosis of students' written solutions. For example, a teacher may identify a problem in a students' solution by perceiving an error. The teacher he/she asks for the reason of the error and develops a hypothesis. If possible, the teacher sustains his/her hypothesis by other errors and generalise the hypothesis by evaluating evidence. In this PhD-project, we analyse the diagnostic processes conceptualised with the epistemic activities of prospective teachers while looking at school students' solutions to tasks. In our research, we refer to students' solutions of inquiry-based tasks that are comprehensive and offer many possibilities for teachers to use their diagnostic competence to draw conclusions about the students' solutions.

Fostering diagnostic competence

Recently, Chernikova et al. (2020) published a meta-study investigating different approaches to foster diagnostic competence. The meta-study contains studies that investigate teacher or medical

education. In these studies, a special context, a specific problem or the method of scaffolding was used to foster diagnostic competence. While all aspects showed positive effects, orientation towards specific problems (problem orientation) stands out most positive. So-called inquiry-based tasks are specific problems and, particularly, diagnosing cases of extensive students' solutions of these inquiry-based task comprise the orientation towards specific problems of diagnosing. Therefore, the present study is based on recommendations on how to design a course aiming to foster diagnostic competences concerning problem orientation.

The epistemic activities that are the basis of diagnostic thinking rely more or less on contrasting and comparing. Chernikova et al. (2020) state: „More generally, diagnosing first focuses on comparing the current state of learners' knowledge and skills to predefined learning objectives“. Referring to Nickerson (1999), Philipp (2018) describes the ongoing comparison of a solution with relevant prior knowledge or further information as a central part of the diagnostic process. Beyond the specific subject of developing diagnostic competence, Alfieri et al. (2013) pointed out contrasting and comparing to be an effective teaching and learning strategy. However, it has not been investigated regarding the professional development of prospective teachers yet. With our research we target to fill the gap by addressing contrasting and comparing to foster teachers' diagnostic competence.

Method

The design of our study is shown in Table 1. Both, the three treatments and the control group were conducted in winter 2020 and in summer 2021. All three treatments (see Table 1) follow well-known characteristics to effectively support the development of teachers' diagnostic competence (Chernikova et al., 2020).

Table 1: Treatment-Design

Treatment 1 (n = 37)	Treatment 2 (n = 40)	Treatment 3 (n = 35)	Control group (n = 25)
Pre-test	Pre-test	Pre-test	Pre-test
Students solve inquiry-based tasks	Analysing primary school students' solutions to inquiry-based tasks	Students solve inquiry-based and analyse primary students' solutions to these tasks	Neither analysis of students' solutions nor analysing of arithmetic tasks
Post-test	Post-test	Post-test	Post-test

The main element of the three treatments were inquiry-based tasks. In each treatment group we provided the same inquiry-based tasks; one example is shown in Table 2. Those tasks are challenging for prospective teachers and primary school students. As our example in Table 2 shows also primary school students are able to provide substantial solutions. In addition, all solutions to be analysed are genuine, to make them as authentic as possible.

Table 2: Example

Task-Example	Solution example of a student
<p>How can you get to the number 20? Choose two numbers for the first and second position in the row. Add these two numbers up to get the third number. Finally, add the second and third number to get the number at the fourth position. Your goal is to reach the number 20 with this step (position 4).</p> <p>For example, you choose 3 and 4 the result will be: 3, 4, 7, 11. This means you cannot get to 20 if you start with the numbers 3 and 4.</p> <p>Task is to find all possibilities to get to 20.</p> <p>(Birnstengel-Höft and Feldhaus 2006)</p>	

In the first treatment group, prospective teachers got a brief introduction into inquiry-based tasks. Subsequently, they were encouraged to solve these tasks and to compare their solutions in pairs (first and second week). In the third week, the prospective teachers got the prompt to compare their approaches and solutions with the whole group. The prospective teachers repeated this proceeding for three inquiry-based tasks. Referring to Chernikova et al. (2020) the first treatment group followed the perspective of learners that solve mathematical tasks and got related prompts.

The second treatment group did not get the prompt to solve the inquiry-based tasks. Instead, there was a brief introduction in the process of diagnosing students' solution based on epistemic activities. Subsequently, the prospective teachers got the prompt to individually analyse the solution of school students and to afterwards compare their analysis of students' solutions in pairs (first and second week). In the third week, the analyses of all pairs were compared in the whole group. In this treatment group the same inquiry-based tasks were used as in treatment group 1. Similar to group 1 the procedure was repeated three times. Referring to Chernikova et al. (2020) the second treatment group followed the perspective of teachers that analyse primary school students' solutions to mathematical tasks and got related prompts (problem orientation).

The third group firstly got a brief introduction to inquiry-based tasks as well as in diagnosing students' solutions according to epistemic activities. Further, this group solved one inquiry-based task and compared their own solutions in the same way as treatment group 1 (weeks 2 and 3). Afterwards the group analysed the students' solutions and compared their analyses in the same way as treatment group 2 (weeks 4 and 5). Finally, the prospective teachers in the third treatment group solved a second inquiry-based task, analysed related students' solutions and compared their own solutions with the solutions of primary students (week 6 and 7).

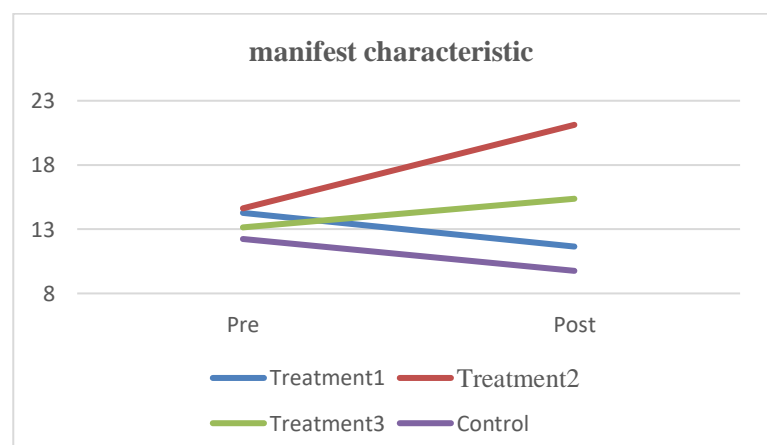
We conducted the pre-test before the semester started and the post-test after eight weeks. We developed these tests to measure diagnostic competence. Each test comprises three items with solutions of primary school students. The three items refer to three different inquiry-based tasks (in Table 2 an example of the pre-test is displayed). To prevent learning effects, we changed two items by slightly modifying the external form of primary school students' solutions, and we exchanged one item completely. Primary school students' solutions of the inquiry-based tasks provided in the pre- and post-test are analysed by the prospective teachers who participated in the treatment and control groups. The prospective teachers' analyses are the basis to investigate their diagnostic competence. Therefore, these analyses are categorized with content analysis regarding two dimensions. In the first dimension we distinguish between statements about manifest characteristics and hypotheses. Manifest characteristics are for example a student's wrong solution, a specific way of a student to write something down, or a specific way of a student to develop different examples regarding a problem. Statements that we classify as hypotheses are for example, prospective teachers' interpretations of (school) students' abilities shown in their solutions that were sometimes backed by manifest characteristics. With this dimension we want to measure the diagnostic thinking conceptualised by the epistemic activities described earlier. In the second dimension we assigned single statements to spheres of competence inspired by Rathgeb-Schnierer and Schütte (2011). The coded data was further analysed by descriptive and inferential statistics.

Results

In the following, the data is analysed regarding the two epistemic activities "identify manifest characteristics" and "generate hypotheses" while comparing the three treatment groups and the control group.

Table 3: identify manifest characteristics

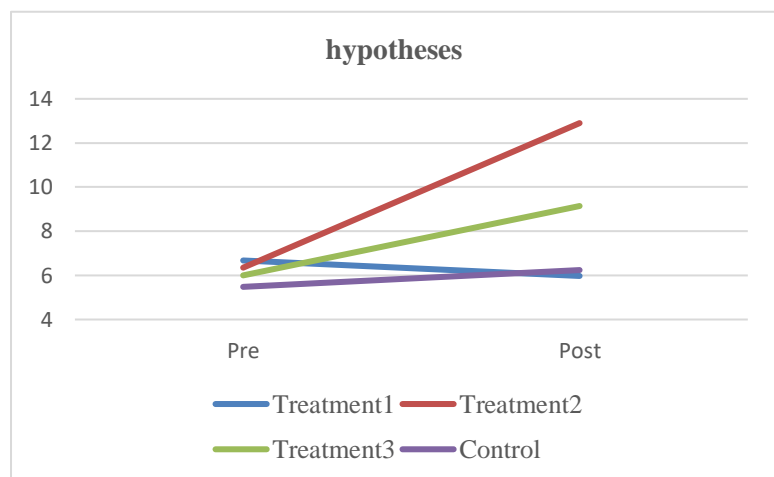
Treatment	N	Pre-M	Post-M
1	37	14,27	11,65
2	40	14,62	21,12
3	35	13,14	15,37
C	25	12,24	9,76



Regarding the identification of manifest characteristics (Table 3) in primary school students' solutions our results exhibit that all groups start at nearly the same level but differ at the post-test. Mixed-anova shows a significant interaction effect between time and group ($F(3,133) = 11,253$; $p < 0,00001$, $\eta^2 = 0,202$). Pairwise t-tests reveal that the difference between the groups is not significant in the pre-test ($p = 1$ with Bonferroni correction), but in the post-test significant differences were revealed. For example, treatment group 2 and treatment group 1 differ significantly (pairwise t-test $p < 0,0000001$ with Bonferroni correction). Only the pairwise t-tests between group 1 and the control group ($p = 1$ with Bonferroni correction) and between group 1 and group 3 ($p = 0,0548$ with Bonferroni correction) reveal no significant differences.

Table 4: generate hypotheses

Treatment	N	Pre-M	Post-M
1	37	6,68	5,97
2	40	6,35	12,9
3	35	6	9,14
C	25	5,48	6,24



Similar results are shown concerning the generation of hypotheses (Table 4). Mixed-anova shows a significant interaction effect between time and group ($F(3,133) = 12,209$; $p < 0,000001$, $\eta^2 = 0,216$). Again, all groups start on a close level in the pre-test (pairwise t-test $p = 1$ with Bonferroni correction) but differ in the post-test. For example, the difference between group 2 and group 1 is significant ($p < 0,0000001$ with Bonferroni correction). Again, the difference between treatment group 1 and the control group is not significant ($p = 1$ with Bonferroni correction).

In the presented study, diagnostic competence is conceptualised and measured with epistemic activities (Fischer et al., 2014). Presented results indicate that the analysis and the contrasting and comparing of primary school student solutions (treatment 2) have a significant impact on the development of diagnostic competence. In contrast, creating and then contrasting and comparing the own solutions with peers (treatment 1) does not seem to have influence on the diagnostic competence. Finally, creating and then contrasting and comparing the own solution with peers followed by analysing primary school students' solutions (treatment 3) also leads to an increase regarding the epistemic activities. Although this increase is not as high as focussing only on the analysis of primary school students' solutions (treatment 1). The results presented allow the interpretation that this applies independently of the specific epistemic activity. Accordingly, contrasting and comparing student solutions seems to be another aspect of effectively promoting the diagnostic competence of prospective teachers (Chernikova et al., 2020). We are left with the open question: Why is solving tasks and contrast and compare the solutions to peers not increasing or even decreasing the amount

of epistemic activities? At this stage, only hypotheses are possible. It could be due to motivational reasons. Or the fact that it is about peers with whom is compared, hinders the development. In the future, we want to use different research approaches to gain deeper insight into how our treatments change diagnostic competence.

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