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Abstract

Cognitive activation is one of the central quality characteristics of teaching. Studies which analyzed cognitive activation in science instruction and its influence on the achievement and the interest of students, took most of the times place in higher grades. Since scientific thinking can be taught at a very early stage and, in particular, experimental situations should be designed cognitively activating so that they can be optimally used as learning opportunities. Therefore, this study examined cognitive activation in experimental situations. For this purpose, we video recorded five lessons in primary schools as well as five lessons in kindergartens in Germany. The results showed that in the investigated experimental situations, only a few cognitively activating measures were implemented by the kindergarten educators and the primary school teachers. It is noticeable that the category Challenging questions was used most frequently while the category Instructional dialogue was by far the rarest in the videos.

Introduction

There are many different definitions of the construct of cognitive activation. These range from more concrete ones like Klieme, Lipowsky, Rakoczy and Ratzka (2006) described cognitive activation as setting challenging tasks, practicing content-related discourse, and activating prior knowledge. Lipowsky et al. (2009) define three key elements of cognitive activation: cognitive level of students' activities, conceptual instruction and thoughtful discourse. Kunter and Voss (2011) see cognitive activation as the guiding of learner's goal-oriented cognitive activities and the creation of cognitive conflicts. A fairly general definition is formulated by Neumann, Kauertz and Fischer (2012) who describe cognitive activation as an accumulation of all features of instructional quality, which cognitively activate students. When considering the various definitions and descriptions of cognitive activation, recurring aspects emerge. On the one hand it includes cognitive challenging questions or tasks, on the other hand prior knowledge should be activated and cognitive conflicts generated.

Furthermore, the discourse should be thoughtful and content-related. Studies which analyzed cognitive activation in science instruction and its influence on the achievement and the interest of students, took most of the times place in fifth grade onwards (e.g. Förtsch, Werner, von Kotzebue, & Neuhaus, 2016; Klieme, Schümer, & Knoll, 2001; Vogelsang & Reinhold, 2013). Only few studies took place in primary school (Ewerhardy, Kleickmann, & Möller, 2012; Fauth, Decristan, Rieser, Klieme, & Büttner, 2014). So far, to our knowledge, there is no study investigating cognitive activation in kindergarten and no study that compares cognitive activation in kindergarten and primary school. Since scientific thinking and experimentation can be promoted early on and a cognitively activating design of experimental situations can have a positive effect on students' learning, the study reported here focuses on these aspects (Minner, Levy, & Century, 2010; Möller, 2004). In the kindergarten the first encounter with guided scientific experiments can take place, which can trigger an enthusiasm for them.

In addition, the course of a scientific experiment can be demonstrated and practiced already in kindergarten with very simple experiments. This can then be deepened in primary school and opened for free experimentation in individual cases. Furthermore, the enthusiasm created in kindergarten can lead to an individual interest in scientific experimentation in primary school. Therefore, the aim of our study is to close the research gap in the elementary and primary areas and to analyze the cognitive activation when doing experiments. On this purpose we video recorded and analyzed each five experimental situations from kindergarten and from primary school.

Theoretical Background

Measuring Cognitive Activation in Instruction

Because it is not possible to directly observe and measure whether learners are cognitively activated, various indicators are needed to capture this construct (Lipowsky, 2015). Studies often take two different approaches to measure the construct of cognitive activation (Förtsch, Werner, Dorfner, von Kotzebue, & Neuhaus, 2017). On the one hand, teaching can be indirectly analyzed by examining the material and the tasks that the teacher uses in class (Krauss et al., 2013). On the other hand, the lessons can also be analyzed directly, for example, by video recordings of the lessons and evaluation using a coding manual or an observation protocol of the lessons (Förtsch et al., 2017). For both options certain indicators are needed. These indicators can be found in teaching activities, which have a high potential for cognitive activation. Among these are: setting challenging tasks, provoking cognitive conflicts, point out differences in content-related ideas, concepts, interpretations and solutions, linking with prior knowledge, thoughtful discourse, encourage learners to present or explain their thoughts and ideas (Brophy, 2000; Förtsch et al., 2016; Klieme et al., 2001; Lipowsky et al., 2009; Lipowsky, 2015).

Cognitive Activation and its Impact on Student Achievement and Interest

Studies on cognitive activation in instruction often investigate the influence of pedagogical content knowledge (PCK) on cognitive activation in class and what impact it has on student achievement or interest. In studies such as TIMSS and the project Instructional Quality and Mathematical Understanding in Different Cultures, a positive correlation was found between cognitive activation in class and student achievement (Klieme et al., 2001; Rakoczy et al., 2007). A positive correlation between PCK and cognitive activation in class was shown in the QuiP Project and in the study by Vogelsang and Reinhold (2013) in the context of video studies from physics lessons. The COACTIV study was able to determine the complete path of action from the teacher (PCK) through cognitive activation in class to student achievement. However, the COACTIV study did not include a video recording of the lessons, but an analysis of the teacher's tasks. All these studies took place in mathematics or physics classes. Recent studies by Förtsch et al., (2016) in the ProwiN study were also able to show the complete path of action in biology lessons by means of a video study. Thus, the PCK of the biology teacher has a positive influence on the cognitively activating design of instruction and the degree of cognitive activation in class has a positive influence on the interest and achievement of the students.

Fauth et al. (2014) have conducted one of the few studies in primary schools in which the students should, among other things, rate the cognitive activation by their teacher. It was found that cognitive activation has an influence on the development of interest but not on student achievement. The latter result is surprising, but could also be based on the knowledge test, which only referred to the current unit (Fauth et al., 2014). Other studies showed a positive influence of cognitive activation on student achievement. However, these studies related to long-term effects or took place among students from fifth grade onwards (Baumert et al., 2010; Förtsch et al., 2016; Fraser & Fisher, 1982). Ewerhardy and colleagues could show that constructivist teaching had a positive impact on the conceptual understanding in science of fourth graders. Under constructivist teaching they count consisting of encouragement of conceptual change, communication and negotiation of meanings, structuring, embedding in naturalistic and meaningful contexts (Ewerhardy et al., 2012). These aspects can also be found in descriptions of cognitively activating teaching.

Early Science Education: Experimenting in Elementary & Primary Education

An early promotion of scientific thinking can be implemented under certain circumstances (Möller, 2004). Recent research findings show that children between the ages of three and five are already able to deal with topics from sciences from a developmental psychology perspective (Gopnik, 2012). They already have differentiated thought patterns and are capable of establishing if-then relationships (Sandoval, Sodian, Koerber, & Wong, 2014). This means that they are already capable of causal and deductive thinking (Gopnik, 2012). These fundamentals enable children to understand scientific interrelationships. For example, the Bavarian Education Plan describes problem-solving skills as a competence that can be acquired as early as kindergarten age. This can be implemented, for example, by questions within the framework of experiments (Bayerisches Staatsministerium für Arbeit und Sozialordnung, Familie und Frauen & Staatsinstitut für Frühpädagogik, 2016).
Children in elementary and primary education already have everyday experience in the natural sciences and thus an idea of concepts and phenomena (Carey, 2000). Since these often do not correspond to scientific facts,

scientific teaching or learning, situations are often associated with a conceptual change (Carey, 2000). One aim of science teaching in primary schools is therefore to incorporate the pupils' ideas into their lessons (Mikelskis-Seifert, & Wiebel, 2011). This goal also applies to scientific learning situations in kindergarten (GDSU, 2013). Another goal is to familiarize children with the first scientific concepts and working methods (Mikelskis-Seifert & Wiebel, 2011). A typical example of this is experiments that play a central role in the natural sciences. According to Hardy, Jonen, Möller and Stern (2006), a lesson in which the children can at least partially experiment themselves can only work if supporting and structuring measures are implemented. If this is fulfilled, cognitively activating instruction is already possible in primary school (Möller, 2016). Experimental situations can also be used in kindergarten to cognitively activate the children (Steffensky, Lankes, Carstensen, & Nölke, 2012). However, structuring and supporting measures are also necessary here in order not to overburden the children (Steffensky et al., 2012). In independent, albeit guided, experimentation, students are cognitively activated. Hartinger, Grygier, Tretter and Ziegler (2013) also see in the process of experimenting essential characteristics of cognitively activating science teaching: Learners think about how they can review a question, they consider whether their approach is suitable for this purpose and relate their results to the initial question. In addition, meta-studies show that action processes (such as experiments) are more effective if they are accompanied by cognitively activating instruction (Labudde & Möller, 2012; Minner et al., 2010). Accordingly, cognitive activation by teachers in experimental situations is important for such learning situations to be effective.

Aims and Research Questions

Based on this state of research, the aim of this study is to video-record and to investigate cognitive activation in experimental situations from kindergarten and primary school. The foundation for interest in the natural sciences and experimentation is probably laid at a young age and the cognitive activation of these situations in particular seems to have a high potential. Therefore, these experimental situations regarding cognitive activation should be systematically recorded and analyzed. Since there are only a few studies and rating systems for the analysis of cognitive activation in the elementary and primary spheres we aim to develop an objective, reliable and valid rating manual to record cognitive activation for these spheres. This is an important prerequisite for our analyses. Most of the existing manuals are for higher grades so it will be interesting if these specific pedagogical practices will also be shown in kindergarten and in primary school.

Experimental situations can be cognitively activating under certain conditions (Hartinger et al., 2013; Leisen, 2006; Lipowsky, 2015; Möller, 2009). Our approach for this study was to examine whether and how this behavior is also implemented by the teachers and educators in the videotaped experimental situations. Therefore, we used a mixed method approach with quantitative (RQ1, RQ2) and qualitative (RQ3) research questions:

RQ1: How do kindergarten educators and primary school teachers design experimental situations regarding cognitive activation?

RQ2: How do kindergarten educators and primary school teachers differ from each other concerning the design of experimental situations regarding cognitive activation?

RQ3: What are examples for higher cognitively activating and less cognitively activating experimental situations in kindergarten and primary school?

Method

Sample and Research Design

In the period of July 2017 to April 2018 we videotaped five lessons in primary schools as well as five lessons in kindergartens in Germany in which experiments were conducted. We analyzed the videotaped lessons of five kindergarten educators (four of them female) and five primary school teachers (three of them female) who participated in the study on a voluntary basis. The age of the primary school teachers ranged from 26 to 47 years (M=31.50, SD=10.34) and the years in the teaching profession ranged from 1 to 21 years (M=6.25, SD=9.85). The age of the five kindergarten educators ranged from 25 to 37 years (M=30.50, SD=5.20) and the years in the teaching profession ranged from 1 to 15 years (M=9.50, SD=6.46). The five primary school teachers stated they had attended a total of 63.75 hours of teacher training in the last two years, 3.25 hours of them in scientific topics. Kindergarten teachers stated they had attended a total of 26.25 hours of teacher training in the last two years, 1.67 hours of them in scientific topics. Only one primary school teacher studied a natural science subject (chemistry).

The average duration of the videos from the experimental situations in kindergarten was 45.04 minutes (SD=14.95) and the children were between 4 and 6 years old. The topics of the learning situations were ever twice electricity and swimming and sinking and once body parts. The average length of videos from primary schools was 63.84 minutes (SD=3.76). The experimental situations took place in third and fourth class. In four of the five lessons, the topic water was taught. Only in one lesson the topic electricity was taught (see Table 1). The lessons were videotaped with two cameras. One of the two cameras served as a teacher's camera, the second as an overview camera (Seidel, Prenzel, & Kobarg, 2005). The resulting videos were then integrated into the Video-graph program (Rimmele, 2003) and were transcribed.

Table 1. Duration and Topic of Recorded Videos (K= Kindergarten, P= Primary school)

video/ person	duration [min]	topic
K1	68.70	Electric circuit
K2	45.75	Electric circuit
K3	37.97	Swimming and sinking
K4	28.22	Body parts
K5	44.55	Swimming and sinking
P1	67.48	What dissolves in water?
P2	64.77	How to separate solutions/salt production
P3	57.45	Filter water/groundwater
P4	64.72	Why is groundwater cleaner than rainwater?
P5	64.78	Conductors and insulators: make the light bulb glow.

Rating Manual

In order to analyze the videos for evidence of cognitive activation, a rating manual was newly developed from biology, mathematics and physics instruction for high school as well as for primary school (Förtsch, Werner, Dorfner, von Kotzebue, & Neuhaus, 2018; Ewerhardy, 2010; Lotz, Lipowsky, & Faust, 2013; Möller, 2016; Rakoczy & Pauli, 2006; Vehmeyer, 2009; Vogelsang & Reinhold, 2013). The newly developed cognitive activation rating manual consisted of 23 items, which were grouped in three main categories with each two or three subcategories (see Table 2).

Table 2. Categories and Subcategories of the Construct Cognitive Activation

Categories	Subcategories
A Challenging questions	A1 Challenging phenomena at the beginning
	A2 The questioning of the students is supported
	A3 The teacher asks cognitive activating questions
B Prior knowledge / ideas, in-depth learning opportunities and cognitive conflicts	B1 The prior knowledge and the ideas of the learners are explored
	B2 In-depth learning opportunities
	B3 Cognitive conflicts are generated
C Instructional dialogue	C1 Discuss ideas together
	C2 Discussion of errors

These subcategories address different facets of cognitively activating instruction as described in current literature. Every item describes a specific pedagogical practice that a teacher could undertake to cognitively activate their students. The theoretical backgrounds of every construct as well as examples for every item are given in the rating manual.

As a first step, we piloted the rating manual with a different sample of four primary school lessons with the topic “swimming and sinking” from the platform *ViU: Early Science* in order to verify if cognitive activation could be measured objectively using our adapted rating manual activation in experimental situations of kindergarten and in primary school. Next, all videos were coded by two independent raters who were trained for this task. The raters were research assistants with teacher training in the natural sciences. Before the items were rated the overall impression of each of the eight subcategories were rated. Each item and the overall impression are rated using a four-point Likert scale (1=does not apply 2=rather not apply, 3=rather apply, 4=apply). Each rating refers to the entire learning situation, i.e. the video, as an analysis unit. Due to some discrepancies between the raters during the piloting some items were changed. As the ICC values showed substantial inter-rater agreement, we assumed that we were able to measure cognitive activation objectively and rated all ten videos of the study. For the analysis, each video of the lessons was viewed twice. In the first round the overall impression and in the second viewing the items were rated. Because of the small sample, all ten videos (100%) were coded by two independent raters. The Intra-class correlation (ICC) was calculated to determine the observer's conformity. ICC values of .70 are counted as good reliability (Döring & Bortz, 2016). The rating manual showed a good reliability (Cronbach´s Alpha=.87). The categories (A) Challenging questions and (B) Prior knowledge / ideas; in-depth learning opportunities and cognitive conflicts showed also good reliability only the category (C) Instructional dialogue a lower reliability (see Table 3).

Table 3. Interrater Reliability of the Construct and the Categories

	N (items)	ICC	Cronbach's Alpha
Total	23	.80	.870
A) Challenging questions/ Demands	8	.71	.776
B) Prior knowledge/ideas; in-depth learning opportunities and cognitive conflicts	7	.80	.753
C) Instructional dialogue	6	.75	.528

In a further step we calculated the correlation between the mean of the individual items and the overall impression of each subcategory in order to assess the construct validity of the rating system (see Table 4). These correlations mostly show significant values with a high to medium correlation (Cleff, 2015). Subcategory A2 (The questioning of the students is supported) and C1 (Discuss ideas together) did not find any significant correlation. The Cronbach's alpha values of A1: Challenging questions and B2: Deeper learning opportunities are above .80, which can be considered satisfactory (Döring & Bortz, 2016). All other values are below this limit, which may be due to the width of the construct. Similar to a knowledge test, it is difficult to test reliability here (Lienert & Raatz, 1998). Although Cronbach's alpha values between .50 and .60 are most of the times considered poor or low, we have included subscales with a value of at least .50 in the analysis. We have made this decision on the one hand in order to take into account the broadness and diversity of the construct cognitive activation. On the other hand, in knowledge tests Cronbach's alpha values up to .60 are even described as acceptable, since the subject areas are more heterogeneous because they are more multi-faceted than in clearly definable personality traits (Hossiep & Schulte, 2008).

Table 4. Correlations and Cronbach's Alpha Values

	A1	A2	A3	B1	B2	B3	C1	C2
Overall impression	.80**	.62	.80**	.76*	.86**	.84**	.55	.65*
Cronbach's Alpha	.87	0	.61	.57	.81	.61	.46	.53

$^{**}p < .01$; $^{*}p < .05$

Analysis

Concerning our first research question, we were interested in how teachers design experimental situations regarding our construct of cognitive activation. Therefore, we analysed the descriptive data of all eight subcategories. To answer our second research question, we examined all three categories as well as the six left subcategories and calculated t-tests using SPSS to analyse if the differences between the two groups are significant. In the qualitative segment of this study, to answer our third research question, we aimed to highlight one typical successful or one less successful example of each of the six left subcategories. Therefore, we analysed all ten recorded lessons with videos and transcripts.

Results

Descriptive Statistics

In order to answer our first research question, we have first of all calculated the descriptive statistics for each subscale of the construct cognitive activation (see Table 5). For the sake of completeness, the values of subscales A2 and C1 are also presented here, although the Cronbach's alpha values were too low.

Table 5. Descriptive Statistics of the Subcategories of Cognitive Activation

Subcategories	Example item	N (items)	M	SD	Min	Max
A Challenging questions						
A1 Challenging phenomena at the beginning	The teacher introduces challenging or fascinating problems/tasks at the beginning of the lesson.	4	2.93	0.73	1.5	4.0
A2 The questioning of the students is supported	The teacher offers the students time and opportunities to ask their own questions.	2	2.25	0.43	1.5	3.0
A3 The teacher asks cognitive activating questions	The questions asked by the teacher require more than just yes/no answers and do not just ask for memorized knowledge. The questions cannot be answered spontaneously and make the learners think.	2	2.60	0.74	1.5	3.5
B Prior knowledge/ideas, in-depth learning opportunities and cognitive conflicts						
B1 The prior knowledge and the ideas of the learners are explored	The teacher asks for the assumptions or encourages the kids to express their suspicions	3	2.57	0.52	1.67	3.33
B2 In-depth learning opportunities	The teacher tries to understand the thinking of the learners by asking how they came up with specific answers and/or by asking to justify their answers.	3	2.47	0.55	1.67	3.33
B3 Cognitive conflicts are generated	The teacher confronts the learner with facts, observations or phenomena that contradict learners' expectations and/or alert learners to inconsistencies.	2	1.75	0.54	1.0	3.00
C Instructional dialogue						
C1 Discuss ideas together	The teacher encourages the exchange among the learners by asking them to relate their contributions to each other and/or to discuss their own assumptions/explanations.	3	1.63	0.46	1.0	2.67
C2 Discussing errors	The teacher picks up mistakes of the learners and uses them in the further course of the lesson.	3	1.40	0.31	1.0	2.0

It is striking that the subcategory A1 (Challenging phenomena at the beginning) is best fulfilled with a mean of 2.93 by kindergarten educators and primary school teachers. At a similar intermediate level, cognitive activating questions are asked A3 (M=2.60) as well as the prior knowledge explored B1 and in-depth learning opportunities offered B2 (M=2.47). A little less often, the kids are supported in asking their own questions A2 (M=2.25). In contrast, cognitive conflicts are rarely generated B3 (M=1.75) and hardly any ideas are discussed together C1 (M=1.63). It is also noticeable that hardly any student errors are discussed in class C2 (M=1.40).

Differences between Primary School Teachers and Kindergarten Educators

So far, the results from the video analysis for the primary school teachers and kindergarten educators were considered together. In the following, to answer our second research question, differences between the two groups are shown. Due to the very low Cronbach’s alpha values as well as the lacking significant correlation to the overall impression the two subscales “The questioning of the students is supported” (A2) and “Discuss ideas together” (C1) are not included in the overview in Figure 1 and are no longer taken into account in the further presentation of the results.

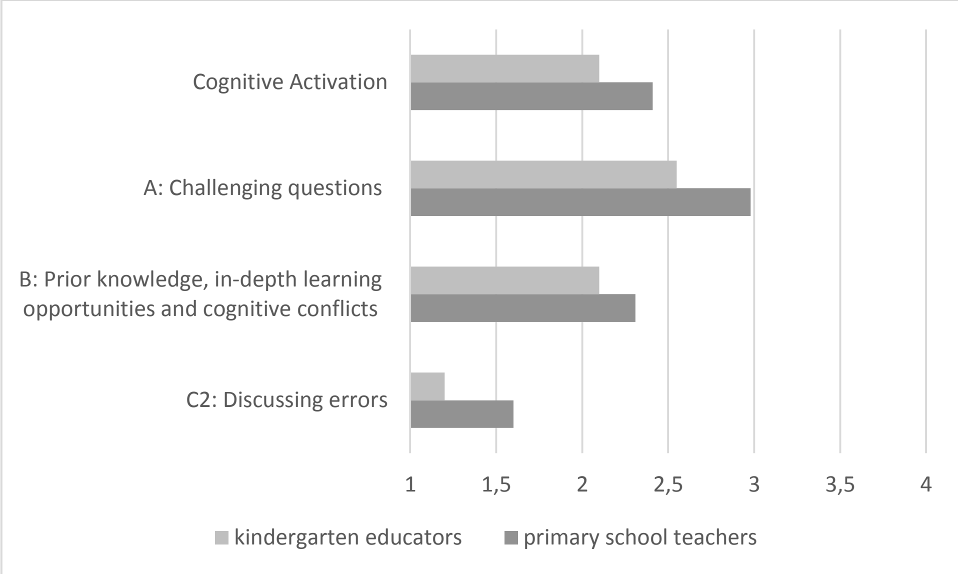

Figure 1. Comparison of the Mean Values

At first glance on the bar chart it is noticeable that primary school teachers are more likely to use cognitive-activating measures than the kindergarten educators. This is evident both in the whole construct of cognitive activation (M_P=2.41, SD=0.35 and M_K=2.10, SD=0.13) as well as in all three categories. However, there is no significant difference for the whole construct between primary school teachers and kindergarten educators (t(5.17)=-1.89; p=0.12). When analyzing the three categories of both groups the children were most frequently cognitively activated by challenging questions (A, M_K=2.55, SD=0.40; M_P=2.98, SD=0.61). The analysis of the subcategories showed that challenging questions at the beginning (A1) were the best implemented subcategory in primary school (A1, M_P=3.35, SD=0.45) but much rarer implemented in kindergarten (A1, M_K=2.50, SD=0.73). The differences between primary school teachers and kindergarten educators were almost significant in the subcategory A1 (t(8)=-2.21, p =0.06). While challenging questions at the beginning was most frequently implemented by the primary school teachers, kindergarten educators most frequently implemented cognitively activating questions (A3, M_K=2.60, SD=0.82). Primary teachers had the same mean score in this subcategory (A3, M_P=2.60, SD=0.82).

Compared to category A, category B: Activating of prior knowledge, in-depth learning opportunities and cognitive conflicts took place less often (B, M_P=2.31, SD=0.45; M_K=2.10, SD=0.06). No significant differences (t(8)=-1.05; p=0.33) between primary school teachers and kindergarten educators were found. The analysis of the subcategories has shown that both activated their students relatively often through exploring their prior knowledge (B1, M_P=2.40, SD=0.65; M_K=2.40, SD=0.74) or in-depth learning (B2, M_P=2.73, SD=0.55; M_K=2.20, SD=0.45). Cognitive conflicts were rarely provoked by both (B3, M_P=1.80, SD=0.76; M_K=1.70, SD=0.27). Discussing errors was hardly found in the videos of the kindergarten and the primary school (C2, M_K=1.20, SD=0.18; M_P=1.60, SD=0.28). For both groups it was the subcategory with the lowest mean score. However, primary school teacher discussed errors significant more often (t(8)=-2.26; p=0.03). To sum up, the differences in the means are quite similar for category A and C and less for B (A: 0.43; B: 0.21; C: 0.4, see Figure 1). The order in which the categories of cognitive activation of primary school teachers and kindergarten educators are used is the same. To further analyze the differences between these two groups, we took a closer look at the subcategories. For all subcategories, primary school teachers were able to produce more or the same number of cognitive activating teaching situations. It turns out that there are hardly any differences in A3, low differences in B3, stronger differences in B1 and B2 and big differences in A1 and C2. The two groups of people show for category A (challenging questions) and B (prior knowledge, in-depth learning opportunities and cognitive conflicts) no significant differences while for C2 (discussing errors) the differences are significant.

Higher Cognitively Activating and Less Cognitively Activating Examples in Experimental Situations

In order to answer our third research question and therefore to gain a deeper insight into the individual subcategories of the videotaped cognitive activation in the experimental situations, quotes for successful and less successful examples are presented and discussed below. For each subcategory either a successful or a less successful is described.

Subcategory A1: Challenging Phenomena at the Beginning

Subcategory A1 covers the extent to which the teacher begins the lesson with questions, problems or phenomena that are exciting, fascinating or inexplicable to the learner, thus challenge him or her to think. This can be done, for example, by the teacher describing a problem at the beginning with the help of an experiment and using this as a motivating starting point for the teaching topic. A further option is that the teacher allows the learner to set their own questions at the beginning of the lesson. It also aims to record the extent to which challenging questions and problems that have been raised are followed up in the course of the lesson (e.g. Ewerhardy, 2010).

For the according subcategory A1 the entry into teaching by the primary school teacher P4 is a successful example. At the beginning of the lesson of P4, the children should describe the aggregate states of water as repetition on the earlier instructions. This happens in partner work and together with the teacher at the blackboard. In particular, the transition between the states of aggregation and the difference between evaporation and vaporization are discussed. Then the teacher hangs two pictures of two girls on the blackboard and asks the students who they see in the pictures. The students know who the two girls are. This is followed by a listening exercise. The students hear a story in which one of these two girls thinks they should rather drink groundwater, because it is cleaner than rainwater. Afterwards the teacher summarizes the story with the students at the blackboard:

> P4: *That's right. Now I have to swap the two again quickly and then I'll show you what they said. Poly pop said: No, let it go, you cannot drink it, the water is too dirty. And what did Luna reply to that? Chris.*
> Chris: *Can you wash water?*
> P4: *Exactly, what do you say, can you wash water?*
> Chris: *No.*
> P4: *And what does Poly Pop say and what kind of tip does she give to Luna, Mandy?*
> Mandy: *She could drink groundwater.*
> P4: *Mhm, just take groundwater. Huh? So, Luna has only question marks on her face. Huh? Should I drink groundwater? What kind of question could she face? Steven.*
> Steven: *If she does not know what groundwater is, what is groundwater?*
> P4: *What is groundwater? This is a good question. Maybe she already knows, Poly Pop has already explained a lot. Dylan.*
> Dylan: *Maybe, where is groundwater?*
> P4: *Where is groundwater? Also, a good question. Do you already know where groundwater is, Megan?*
> Megan: *Hmm, under the ground.*
> P4: *Ok. Caren.*
> Caren: *Why is groundwater cleaner than the normal water in the gutter?*
> P4: *Mhm. Jamie.*
> Jamie: *Where does the groundwater come from?*
> P4: *Mhm.*
> Charly: *How am I supposed to get that out?*

In the further course of the lesson, the children carry out experiments on the topic of filtering water. They try to reconstruct the soil layers of the earth with cups and different materials such as stones, sand and gravel and filter muddy water through these cups. They want to find out if groundwater is cleaner than rainwater. Before the experiments begin, the children make assumptions about the question of the lesson: Why is groundwater cleaner than rainwater? The teacher goes through the class while the children carry out the experiments independently in group work with instructions on worksheets and supports the children if necessary. This introduction has been successful in terms of cognitive activation because it raises a challenging problem that is followed up in the course of the lesson and worked towards a solution. The problem is a challenging learning opportunity that makes students think and reflect.

Subcategory A3: The Teacher Asks Cognitive Activating Questions

This subcategory is intended to record the extent to which teachers use challenging questions to make learners think and reflect. The focus of the assessment is on the teacher's instructions. These questions require cognitively demanding activities such as comparing or analyzing different solutions and ideas (Förtsch et al., 2018). A negative example of this subcategory can be seen in the lesson of K3. At the beginning of the learning situation, the educator asks which of the children was in a swimming course and in which they swam in. Next, K3 wants to know if the kids had any help with swimming:

K3: *But now I have a question, Sven. How did you swim in the water at swimming school? Did you have any help, or did you just jump in?*
Sven: *No.*
K3: *No, did you have any help?*
Sven*: No.*

Then, they start to test whether different objects swim or sink. However, the question of the educator is not dealt with further. Thus, it is a yes-or-no-question that does not require cognitively demanding activity from the children.

Subcategory B1: The Prior Knowledge and the Ideas of the Learners are Explored

Subcategory B1 covers the extent to which the teacher explores the prior knowledge and ideas of learners. Prior knowledge here includes pre-concepts, i.e. ideas that children bring with them into the classroom. For example, by asking specific questions about learners' and assumptions about a problem presented, it is possible to find out the students' ideas (Ewerhardy, 2010; Rakoczy & Pauli, 2006). An example in which the prior knowledge and the ideas of the pupils were often tried to explore comes from P3 on the topic of water filtration/groundwater. Here, many shorter questions are asked to activate and find out the prior knowledge. Here are three examples:

P3: *Maybe you already know something about water? Do you remember our mind maps, which we often do, what could be written about water?*
P3: *You used the term filter. What does filter actually mean?*
P3: *We recently had it on the topic of snow, winter and ice. Think about it, I think they even called it that. Which can be problematic also for the groundwater it was said.*

Subcategory B2: In-Depth Learning Opportunities

The aim of subcategory B2 is to record the extent to which the teacher endeavors to understand the learner's way of thinking. In addition, it is recorded whether and how the teacher tries to find out what the learners have understood in the course of the lesson. The teacher should encourage reflection on own experiences and references to things and situations (Lotz et al., 2013; Möller, 2016). A good example of this shows P4. The description of the lesson can be found on in the example of subcategory A1. At the end of the lesson, P4 wants to summarize with the children what they have found out in the experiments:

P4: Now we want to think about everything and talk about it again, ok? What did you have to do first? Cali.
Cali: First of all, you had to fill the water into the cup, then you had to put stones, sticks and earth into it.
P4: I see. And what did we get then? Julia.
Julia: Dirty water.
P4: All dirty water, iih. Who said to me, Tim said to me, iih the water is very dirty. Yeah, well, what did you do then? Tim.
Tim: So, then you put in those plastic cups with holes first, so at the bottom stones, in the middle sand and at the top humus and then we have the dirty water.
P4: Stop. Thanks, for now. Sand, uh, humus, sand and stones. Why just like that?

By asking, the teacher makes sure that the children have understood why they set up the cups in this order (readjusting the layers of soil), or whether they have simply run the experiments as a cookbook.

Subcategory B3: Cognitive Conflicts are Generated

The subcategory B3 determines whether the teacher tries to make clear to the students' possible discrepancies in their own ideas. For this purpose, the teacher can draw the students' attention to disagreements within their ideas, for example through provocative theses or by contrasting contradictory ideas of different students. These measures serve to create dissatisfaction with the existing ideas among the learners (Ewerhardy, 2010; Vehmeyer, 2009). A successful example can be found in the lesson of P1: At the end of the experimental unit (topic: which substances dissolve in water?), the collected results were summarized together on the blackboard. For this purpose, the teacher painted three containers on the blackboard, where they depict the dissolution process in water at particle level: Salt and water, oil and water and in the last container oil, water and soap. Then a student arranges water particles, oil particles and soap particles. The teacher then orders these again, but deliberately wrongly:

P1: I'll order it.
Jenny: That's not possible P1.
P1: What does not fit? Not happy, Jenny? Very well, explain why.

The teacher deliberately misplaced the particles on the blackboard to test the students to see if they understood. This deliberate mistake is a good way to confront the students with a cognitive conflict, that is a contradiction with what they have just learned.

Subcategory C2: Discussion Errors

The subcategory C2 covers the handling of errors or erroneous ideas in a way that promotes learning. This is done, among other things, by teaching learners that detours are important to reach the goal, including by picking up on learners' mistakes and continuing to work with them (Ewerhardy, 2010). An example in need of improvement can be found in the lesson of primary school teacher P2. At the beginning of the lesson P2 asks for the prior knowledge of the children. Here a student starts telling about positive and negative particles:

Tom: There are negative particles, atoms.
P2: Mhm, mhm.
Tom: They only connect to negative particles.
P2: Again, again.
Tom: No. No.
P2: Negative?
Tom: Negative?
P2: No.
Tom: None at all?
P2: No, negative to...
Tom: ...positive.
P2: Positive, exactly, mhm.

Tom obviously did not understand why positive and negative particles combine and why negative particles repel each other. However, this error is not dealt with further, but it is only clarified by repeated inquires that positive and negative particles combine.

Discussion

In our study, we analyzed the cognitive activation in experimental situations from kindergarten and primary school. For this purpose, we newly developed a rating manual based on current literature and manuals, which are often for secondary school and were used in mathematics and physic instruction. Therefore, we adapted it for experimental situations from kindergarten and primary school. Herewith we could measure the construct cognitive activation objectively and as whole construct also reliable. However, in some cases, only a low reliability of the categories and subcategories was shown. One possible reason for this may have been the small number of items. However, in order to cover the construct of cognitive activation in its breadth of content, we have also included scales with lower Cronbach's alpha values in the analyses. By directly observing the instruction, we assumed that we could validly measure the construct of cognitive activation (Waldis, Grob, Pauli, & Reusser, 2010). Furthermore, Praetorius, Lenske and Helmke (2012) showed that ratings of trained raters who use indicators and examples to justify their decisions could be even more valid. Since, on the one hand, our raters were trained on another video sample and, on the other hand, our rating manual is based on current literature, we assume that we validly measured cognitive activation in our videotaped instructions (Förtsch et al., 2017).

Our first research question was to find out how kindergarten educators and primary school teachers design experimental situations regarding cognitive activation. The results showed that in the investigated experimental situations, only a few cognitively activating measures were implemented by the teachers or the educators. However, cognitive-stimulating education is likely to be positively associated with student learning and it is therefore desirable to implement it (e.g. Kunter & Voss, 2011). At the same time, however, these findings are consistent with other studies showing that the potential for learning opportunities in which learners are cognitively activated is not exhausted (Förtsch et al., 2017; Seidel, 2014). However, intervention studies indicate that the goal of providing cognitively stimulating learning situations could well be realized (Seidel, 2014). We analyzed cognitively activating measures in the three categories. It is noticeable that the category Challenging questions (A) was used most frequently. The category Prior knowledge/ideas, in-depth learning opportunities and cognitive conflicts (B) was the second most widely used, but cognitive conflicts were rarely attempted to generate. The category Instructional dialogue (C) was by far the rarest in the videos. Both mistakes and ideas were hardly discussed together. However, dealing with children's mistakes is important because they can learn from such situations (Oser & Spychiger, 2005). In addition, it should be noted that in the analyzed learning situations often no or only very few errors occurred. In these cases, there were no mistakes that teachers or educators should have responded to. Here, in addition to the four-point Likert scale, the grading system would offer a grading with non-existent, in order to be able to look more closely at the error situations. On the other hand, the small number of errors could also be an indicator that the learners were cognitively challenged rather little and therefore made fewer mistakes. This would also be in line with the findings of the study that generally rather few cognitive activating measures were used.

In the next step, to answer our second research question, we analyzed how the actions of kindergarten educators and primary school teachers differ during experimental situations regarding cognitive activation. In all areas examined, the primary school teachers showed the same number or more cognitive activating measures. While we found little difference in some subcategories, such as A3 (cognitive activating questions), the differences were clear for others, especially for A1 (challenging phenomena at the beginning) and C2 (discussing errors). The rarest subcategory was found in both C2. While kindergarten educators have most often asked cognitive activation questions (A3), primary school teachers have confronted their students with challenging phenomena at the beginning (A1). The comparatively lower values of the educators could have been due to the different training. Training as an educator at a technical college is broader than, as the study of the primary school teaching profession (Verbeek, 2016). Accordingly, it is understandable that educators may acquire less technical and didactic knowledge in science than primary teachers. The training of educators focuses on other areas (KMK, 2018). In kindergarten, the basis for further learning is laid (Grasedieck, 2010). Still, cognitively demanding learning situations are possible both in kindergarten and primary school (Grasedieck, 2010; Möller, 2016). Nevertheless, it does not come as a surprise that there are different requirements for experimental situations in the kindergarten than for lessons in third and fourth grade and thus also for the respective teachers. Educators should support the children more to pursue their own ideas and rather not act as a knowledge facilitator (Zimmermann, 2013). All in all, learning in kindergarten must be more playful in order to be effective (e.g. Leuchter & Möller, 2014).

Our third research question was to identify typical examples for higher cognitively activating and less cognitively activating experimental situations in kindergarten and primary school. Therefore, we presented for each subcategory one successful or one less successful example in order to illustrate what lies behind the categories. These examples can be used to train (preservice) kindergarten educators and primary school teachers concrete ways how to cognitively activate during experimental situations. In addition, the videos could be used in training courses, since the use of videos in the training of teachers has great potential (Krammer & Reusser, 2005). These materials can be used to encourage educators and teachers to overthink their own instruction (Förtsch et al., 2017). Through this assistance, the key features of cognitive activation in the classroom could be better implemented.

Conclusions

Limitations

The rating manual is designed to a typical course of instruction and is therefore not necessarily suitable for the course in a kindergarten. In kindergarten the day is not divided into lessons but is more open. Individual activities, such as experiments, can extend over longer phases. Due to the relatively small sample, our study is not representative of German kindergarten educators and primary school teachers. Furthermore, we analyzed only a particular group of pre-selected educators and teachers as they participated voluntarily in the study. Additionally, we videotaped only each one experimental situation, consequently our results should not be generalized but could only serve as valuable hints (Praetorius, Pauli, Reusser, Rakoczy, & Klieme, 2014). Since it is a partly newly developed coding manual, it should be validated by experts in the field of science didactics for kindergartens and primary schools in the next step. Since the content in the experimental situations are heterogeneous (see Table 1), as well as the background and teaching experience of the educators and teachers, the results of this study should be viewed with some reservation. Nevertheless, the results show first tendencies in dealing with cognitive activation in experimental situations from the primary and elementary level. These results could provide significant ideas for teacher trainers as well as in-service and future teachers to refine their practice in terms of cognitive activation.

Implications

Due to the moderate use of cognitively activating measures in the videotaped experimental situations, it can be assumed that teachers and educators are not sufficiently prepared for the task of offering demanding scientific learning situations. In order to implement demanding scientific learning situations in primary and elementary education, the cognitively stimulating measures of primary school teachers and educators must be improved. The acquisition of this knowledge should already be more strongly and obligatorily integrated within the framework of studies or training. A further possibility to support the in-service teachers and educators is to offer further training (KMK, 2014). The examination of our sample showed that at present only a small proportion of further training in the natural sciences is provided. Teachers often do not focus on the subject or on scientific topics. Here it would help to implement compulsory further training in scientific topics. Involving universities more in the organization of further training courses could also help to meet the demand for challenging material lessons and challenging learning situations in kindergartens now and in the future (GDSU, 2013). The results of this study can give some important hints over the topics which should be implemented in the (further) trainings. Furthermore, the examples and the rating manual can be used to guide educators and teachers to reflect on their own teaching.

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