TEACHERS’ COMPETENCE AND PROFESSIONAL DEVELOPMENT IN EARLY SCIENCE EDUCATION

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Abstract

There is common understanding that today’s global challenges (climate change, loss of biodiversity, limited availability of energy/resources, poverty, etc.) call for a scientifically literate society. Scientific literacy competence is acquired primarily through science instruction offered in institutions of the public education systems. Research in the field of developmental psychology has clearly demonstrated in the last decades that young children have a remarkable and frequently underestimated potential for domain-specific learning in science. Though, primary science teachers are reported to often lack of knowledge and confidence for science teaching.

Therefore, teachers’ professional competence and their professional development in early science education were under investigation in this thesis. The term early science education was used to refer to domain-specific education directed at children at the age from four to eight years, which, in Switzerland, relates to kindergarten and the first two grades of elementary school. This thesis builds on the assumption that high quality early science education depends upon knowledgeable and competent teachers and, more specifically, upon their acknowledgement of the constructivist nature of learning. Here, pedagogical content knowledge, understood as knowledge of how children learn and how learning can be facilitated, was of central interest. This thesis consists of three papers highlighting different aspects of professional development effectiveness: In the first paper, teachers’ pedagogical content knowledge was compared between kindergarten and lower grade elementary school teachers. In the second paper, the effects of teacher talk on children’s conceptual learning were examined. Finally, the effects of a professional development intervention on teachers’ competence and children’s learning were researched in the third paper.

The first paper concentrates on comparing kindergarten and lower grade elementary school teachers’ knowledge and beliefs about teaching and learning in early science education. Knowledge and beliefs relevant for facilitating effective science learning are theorized in pedagogical content knowledge. Differences in pedagogical content knowledge between kindergarten (KG) and lower grade elementary school teachers (LGES) were expected to be based upon group-specific professional socialization related to a differing work environment and professional education. Pedagogical content knowledge was assessed based on three aspects (classification of children’s statements, assessment of the importance of learning goals, and beliefs about teaching and learning). Further, teachers’ science-specific interest, self-concept of ability, and teaching time was measured. Data was gathered by means of a questionnaire in a sample of $N = 181$ teachers ($N_{KG} = 93; N_{LGES} = 88$). The results revealed no marked differences between KG- and LGES-teachers with respect to most of the analyzed measures of the pedagogical content knowledge: These groups of teachers did not differ in their classification of children’s statements, neither in their assessment of domain-specific learning goals, nor in their
science-specific interest and self-concept of ability. However, KG- and LGES-teachers differed with respect to their beliefs about teaching and learning in science: KG-teachers showed greater agreement with play-based beliefs, whereas LGES-teachers showed greater agreement with an understanding of learning as situated construction of knowledge. Surprisingly, KG-teachers reported devoting substantially more teaching time for science education compared to LGES-teachers. Regression analyses further revealed that the type of professional education teachers received (either in teacher training seminars, which ceased to exist or in universities of teacher education, currently in place) was related to teachers’ understanding of the constructivist nature of learning: Being educated at a university of teacher education (compared to being educated at a teacher training seminar) could explain higher agreements in understanding science learning as restructuring and co-constructing knowledge.

In the second paper addresses the relation between teacher talk and children’s conceptual learning in early science instruction. The role of teacher talk was examined in \( N = 32 \) kindergarten classes (\( N_{\text{teachers}} = 32, N_{\text{children}} = 468 \)). The teachers were videotaped during a regular kindergarten day at the beginning of a four-week instruction phase, while assisting a group of children working on learning materials about the topic floating and sinking. Teacher talk was coded as vocabulary specific to the content (content-specific vocabulary) and as talk having an underlying scaffolding function for children’s learning (scaffolding utterances) in an inter-rater agreement procedure. In a newly developed framework, teachers’ scaffolding utterances included the following types: (A) Clarification of phenomenon, task, and procedure, (B) Focus of attention, (C) Activation of prior knowledge, and (D) Challenging conceptual change. Children’s conceptual understanding about floating and sinking was measured in individual sessions in a pre-post-design. Latent regression modelling revealed that teachers’ content-specific language and their scaffolding utterances of type C (Activation of prior knowledge) could positively predict children’s learning outcomes, and their scaffolding utterances of type D (Challenging conceptual change) could do so negatively. The surprising negative effects of challenging conceptual change on children’s learning were analyzed in more depth in post-hoc analyses, which suggest that this scaffolding strategy has a situation-specific function.

The third paper examines the effects of a professional development intervention on teachers’ professional competence and on children’s learning in early science education. A sample of \( N = 50 \) kindergarten teachers (including \( N = 684 \) children) was randomly allocated to one of the following three groups: an experimental group attending one meeting as an introduction to learning materials and two meetings concentrating on effective teacher-child interactions, a control group participating only in the introduction to the learning materials, and a baseline group, where teachers did not participate in any professional development meeting. The teachers of both the experimental and the control group received the identical learning materials about the topic floating and sinking, which they implemented in their instruction directly after the first professional development meeting for the following four
weeks. The additional two meetings offered to the experimental group were designed according to the *Intentional Teaching* approach, which includes the aspects of knowing, seeing, doing, and reflecting about effective teacher-child interactions. Further, both interventions were designed to cohere to typical features named in literature of professional development effectiveness, i.e. content focus, active learning, coherence, and collective participation. Importantly, the interventions covered only a short duration (three meetings of a total of 12 contact hours for the experimental group and one meeting of four hours for the control group). The design of this study aimed at investigating whether programs of even short duration turns out to be effective. Data was gathered in a pre-post-design and included both dispositional (pedagogical content knowledge) and performance-related aspects of teachers’ professional competence (their talk during instruction) and children’s conceptual understanding of the topic floating and sinking. Results demonstrated that the intervention based on the *Intentional Teaching* approach (experimental group) led to partly substantial changes in teachers’ pedagogical content knowledge and instructional practices, but not with respect to children’s learning. The findings of these studies have important implications for early science education. In a general discussion, the most important findings will be summarized to derive directions about how to design meaningful and effective professional development in future.
Zusammenfassung


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Lernen der Kinder voraussagen konnte, während sich die Äußerungen mit impliziter Lernunterstützung im Typ D (Herausfordern von konzeptuellem Wandel) als negativer Prädiktor erwies. Der unerwartete negative Effekt der Äußerungen zur Herausforderung von konzeptuellem Wandel wurde in post-hoc Analysen tiefergehend untersucht, welche nahelegen, dass diese Art von Lehrpersonensprache situationsspezifisch wirkt.


Die Ergebnisse dieser Studien führen zu wichtigen Implikationen für die frühe naturwissenschaftliche Bildung. In einer übergreifenden Diskussion werden die wichtigsten Ergebnisse zusammengefasst, um
daraus Hinweise für die zukünftige Gestaltung bedeutsamer und wirksamer professioneller Weiterbildung abzuleiten.
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1 General Introduction

1.1 Early Science Education – What, Why, When, Who, and How?

In this thesis, teachers’ professional competence for early science instruction was under investigation. To begin with, it seems essential to address the following five questions:

1. What is meant by early science education?
2. Why should children be educated in the domain of science?
3. When should science education start?
4. Who should be an early science educator?
5. How should science be taught?

What? – Clarification of the Term Early Science Education

The term *early science education*, as used in the title of the thesis, is vague and therefore asks for clarification. In this thesis, this term refers to the education of children at institutions of early childhood and primary education in the domain of science. As a demarcation, learning in the familial context was not considered. More specifically this thesis focused teaching of children from four to eight years of age. In Switzerland, children at these ages generally attend one or two years in kindergarten and the first two grades of elementary school (see Figure 1.1). The terminology for the education of young children is diverse, varies by country or region and can therefore lead to considerable confusion. Especially in pre-primary education there are many different institutions and respective terms around (see Figure 1.1). Allowing for international comparability, the *International Standard Classification of Education ISCED-2011* nomenclature from UNESCO (2012) is being referred to for the clarification of the types of educational institutions in focus. This nomenclature operates with a three-digit code that characterizes different educational institutions according to their level (first digit) and further categories respectively sub-categories (second respectively third digit). At the first level, it is differentiated between early childhood education (from birth until entry into primary education) and primary education (starting at the age of around five to seven years). According to the ISCED-2011 nomenclature, Swiss kindergarten is to be classified as pre-primary

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1 Throughout this thesis, the term *science* refers to the natural sciences (in German: *Naturwissenschaften*), not to sciences in general.
education (code 020) and the first to grades of elementary school as part of primary education (code 100)\(^2\) (UNESCO, 2012).

**Figure 1.1.** Educational institutions referenced to the ISCED-2011 nomenclature.

### Why? – Science Education for Building Scientific Literacy

Building fundamental competences in reading, writing and mathematics is indisputably one of the key targets in primary education. However, besides literacy and numeracy competences in the domain science have increasingly gained recognition. Since the 1990s international studies of school achievement also assess student’s achievement in the domain of science: Here, the *Trends in International Mathematics and Science Study (TIMSS)* by the International Association for the Evaluation of Educational Achievement (IEA) and the *Programme for International Student Assessment (PISA)* by the Organization for Economic Co-operation and Development (OECD) are probably the two most prominent of these studies (Martin, Mullis, Foy, & Hooper, 2016; OECD, 2014). Although TIMSS and PISA target older students (4th to 8th graders respectively adolescents of 15 to 16 years of age) than those under investigation of this thesis (4 to 8 years), the establishment of these studies reflects the societal and political will for a scientifically literate society, which has influenced educational systems at all levels. *Scientific literacy* is a concept widely accepted to describe the ultimate purpose of any science education (Bybee, McCrae, & Laurie, 2009). According the PISA studies, scientific literacy refers to an individual’s:

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\(^2\) For a graph about the Swiss educational system including the ISCED-2011 codes, see https://www.bfs.admin.ch/bfs/de/home/statistiken/bildung-wissenschaft/bildungssystem.assetdetail.223674.html (retrieved on 6.6.2017)
“Scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues; Understanding of the characteristic features of science as a form of human knowledge and inquiry; Awareness of how science and technology shape our material, intellectual, and cultural environments; Willingness to engage in science-related issues and with the ideas of science, as a reflective citizen.” (OECD, 2006, p. 23).

Striving for a scientifically literate society could be interpreted as a response to global challenges such as climate change, energy and resource scarcity, environmental destruction, etc.

When? – Controversies About When to Begin Science Education

There is a strong consensus on the general importance of building scientific literacy through science education. However, there are fierce controversies about the question at what age children should ideally start being educated and instructed in science. Some seem to advocate ‘the sooner the better’, whereas others have at least caveats or are even worried about an early start in science education. The opponents describe a gradual change in the last decades in early education, where developmentally inappropriate academic contents and respective expectations from higher grades were moved to lower grades (Miller & Almon, 2009). They express worries about children being robbed of their self-initiated play, which is generally considered to be of great importance for children’s cognitive, emotional and social development. Increasing time and effort devoted to highly structured curricula, academic standards and respective testing at cost of learning through play is described as having led to a veritable “crisis in early education” (Miller & Almon, 2009, p. 16). Others advocate starting science instruction as early as in kindergarten/preschool age (Cabe Trundle, 2015; Eshach, 2011; Eshach & Fried, 2005; French, 2004; Ginsburg & Golbeck, 2004). According to Eshach and Fried (2005), arguments for an early exposure to science are based on the assertions that young children (i) naturally enjoy dealing with and thinking about natural phenomena, (ii) can develop positive attitudes towards science, (iii) can build basic conceptual understanding for later targeted complex scientific concepts, (iv) profit from the use of scientifically informed language for later conceptual learning, and (v) have the cognitive potential for scientific reasoning and the construction of scientific concepts. Proponents of an early start to science education do generally not disagree with the importance of play in early childhood education; instead, they describe children’s play as being essentially an activity closely related to the process of scientific inquiry:

“If you have ever watched young children at play, you know that they are innately curious about everything around them. They enjoy exploring and discovering, and they instinctively ask many questions – why, how, where, and when. They can be fearless in their experimentation because they are not afraid to “fail” to realize their ideas did not work out
the way they expected. They simply take what they learned, revise their thinking, ask new questions, and try again.” (Cabe Trundle, 2015, p. 1)

Widely accepted is the general importance of early childhood education for later learning and school success. For instance in the domain of mathematics, several longitudinal studies starting at kindergarten age demonstrated the importance of early mathematical precursor competences for mathematics achievement in elementary school: Individual differences in precursor competences, such as relational quantitative reasoning (Schalk, Saalbach, Grabner, & Stern, 2016), quantity to number word linkage (Krajewski & Schneider, 2009), spontaneous focusing on numerosity (Hannula, Lepola, & Lehtinen, 2010), counting ability (Aunola, Leskinen, & Nurmi, 2006), and the numerical magnitude comparison (De Smedt, Verschaffel, & Ghesquière, 2009), could explain individual differences later in elementary school mathematics achievement. For early science instruction, research about how early science education influences later learning is still rare (Greenfield et al., 2009). One of the few studies investigating longitudinal effects of early science experiences in kindergarten could not find strong predictors for children’s later science learning (Saçkes, Cabe Trundle, Bell, & O’Connell, 2011). Still, the authors hypothesized that limited time and insufficient instructional quality might explain their finding.

Who? - The Profile of an Ideal Early Science Teacher

The ideal early science teacher offers a stimulating learning environment that allows children to restructure and deepen their understanding of natural phenomena. Stimulating learning environments include providing meaningful learning materials on the one hand, and providing adequate learning support on the other hand (Eshach, Dor-Ziderman, & Arbel, 2011; Hardy, Jonen, Möller, & Stern, 2006; Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006; Leuchter, Saalbach, & Hardy, 2014; van de Pol, Volman, & Beishuizen, 2010; Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001). In this thesis, it is argued that the meaningfulness of learning materials and the adequacy of learning support should be evaluated taking into consideration the way in which children learn. In the domain of science, learning is often conceptualized as conceptual reconstruction, meaning that children integrate information about the world around them in a process of mental theory building (Carey, 1985; Chi, 2008; Gopnik, 2012; Vosniadou, 1994). This conceptualization of learning has its roots in the constructivist nature of learning: learning is understood as an individual process of cognition, which cannot be accomplished by another person. According this understanding of children’s learning, teachers have to dynamically adapt the material and the learning support to the changing knowledge structures of the individual learner. The importance of fitting instructional support to children’s cognition has been widely recognized in education research for a considerable time, illustrated by the concepts of the zone of proximal development or the scaffolding metaphor (Vygotsky, 1978; Wood, Bruner, & Ross, 1976). In turn this gives rise to substantial demands with
respects to the profile of an ideal science teacher: foremost, she should acknowledge the constructivist nature of learning and the associated importance of prior knowledge. A science teacher should grasp children’s rich base of prior knowledge about natural phenomena stemming from a multitude of prior experiences as a fruitful potential for further learning (Carey, 1985). At the same time, she should acknowledge that children may also have prior knowledge that sharply contrasts targeted concepts: it is well known in science instruction that misconceptions held by children may be very persistent, sometimes even into adulthood, despite repeated instructional offers for its reconstruction (Carey, 2000). Hence, a teacher needs to know about student’s understanding of specific science topics, including common misconceptions and about strategies to effectively deal with these situations. In theory on professional knowledge, this knowledge is referred to as pedagogical content knowledge, which is described as a combination of subject-matter content knowledge and generic pedagogical knowledge (Magnusson, Krajcik, & Borko, 1999; Shulman, 1987). An ideal science teacher has not only a profound base of pedagogical content knowledge, she is also capable and willing to activate and use this knowledge in respective situations in the classroom (Blömeke, Gustafsson, & Shavelson, 2015; Fröhlich-Gildhoff, Nentwig-Gesemann, & Pietsch, 2011). Finally, an ideal teacher has a solid self-concept of ability with respect to her own science competence and is confident when teaching science. A more detailed introduction to the concepts of professional knowledge and professional competence is provided in this chapter further below.

Contrasting the description above of the ideal science teacher, primary science teachers are often seen as being neither sufficiently knowledgeable nor confident to supply early science instruction effectively (Appleton, 2003, 2008). It is worthwhile to note that teachers in early childhood and primary education are in most cases generalists, as they either organize instruction under a holistic approach or teach many different subjects by themselves (UNESCO, 2012). In that sense, “the early science teacher” as such does not exist in practice. However, almost all teachers in the field of early childhood and primary education are confronted with children eager to learn about the fascinating natural phenomena on the one hand, and they also increasingly face the societal demand to educate children towards scientific literacy in the early years of schooling.

How? – Instructional Quality in Early Science Education

There is a considerable body of research on how to conceptualize instruction and examples of best practices in early science education (e.g., Eshach et al., 2011; French, 2004; Peterson & French, 2008). However, empirical research about the effectiveness of these conceptualizations and practices is rare (Greenfield et al., 2009). Of course, aspects of instructional quality in early science education seem to.

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3 The term she refers to both female and male teacher throughout this thesis. The feminine form has been used because teachers in early childhood and primary education are predominantly women.
be closely related to the profile of an ideal teacher as described above: A knowledgeable teacher ideally offers a high instructional quality through learning materials and learning support that reflect the constructivist nature of children’s conceptual learning. Criteria for further describing effective early science instruction may originate from different sources: for instance, from meta-studies about students’ learning achievement, it can be inferred that providing formative feedback or being clear about learning goals are important factors of effective instruction in general (Hattie, 2009). From research about studying effective pedagogy in early childhood education, teachers’ engagement in qualitative teacher child-interactions is frequently highlighted (Hamre et al., 2012; Siraj-Blatchford, Sylva, Muttock, Gilden, & Bell, 2002; Trawick-Smith & Dziurgot, 2011). Here, the term sustained shared thinking has gained considerable recognition as an important aspect of effective pedagogy, which describes the involvement of a teacher and a child in episodes of in-depth verbal interactions (Siraj-Blatchford et al., 2002). In conclusion, a current opinion of effective early science instruction should probably not fail to highlight the nature of children’s domain-specific conceptual learning and the associated importance of verbal interactions. The important role of verbal interaction in early education is also reflected in many approaches that integrate literacy and science (French, 2004; Haug & Ødegaard, 2014; Ødegaard, Haug, Mork, & Sørvik, 2014; Pearson, Moje, & Greenleaf, 2010). In this thesis, the role of language in science instruction is specifically examined in chapter 3.

1.2 Teachers’ Professional Knowledge and Competence

In this thesis, early science education is viewed from the perspective of cognitive psychology. As stated above, children’s science learning is understood as a process of conceptual reconstruction, in which humans integrate information about the world around them (Carey, 1985; Chi, 2008; Vosniadou, 1994). This thesis postulates that effective teacher behavior in early science education is primarily based on a real understanding of how children learn. Effective teacher behavior in early science education roots, as hypothesized in this thesis, to a large extent in understanding of how children learn. This includes appreciating children’s cognitive resources and their limitations for learning as conceptual reconstruction on the one hand (see detailed information in chapter 3.1) and solid knowledge about the respective curricular topics on the other hand. Hence, the offering of effective science education depends on teachers having sufficient professional knowledge and competence.
Three Paradigms in Research on the Teacher Profession

What defines a successful teacher in (early science) instruction? From a historical perspective, the quest to define “the successful teacher” is often described according to the following three paradigms: the paradigm of teacher personality, the process-output-paradigm, and the expert paradigm. These three paradigms are briefly summarized based on Bromme (1997): According to the paradigm of teacher personality, the description of the successful teacher focused in the mid of the 19th century on relating effective instruction to individual teacher characteristics. Teacher characteristics were conceived as stable, sometimes almost innate, personality traits. According to this paradigm, effective instruction respectively the success of a teacher was not primarily understood in terms of student achievement, but rather in the sense of desirable, often only broadly defined, educational objectives. Bromme describes several weaknesses of this paradigm, for instance, that it remained unclear to what extent aspects of the teacher personality affected instruction under different conditions, such as differing instructional situations, contents or grades. Furthermore, the methods applied within this paradigm would not meet today’s standards in any way. Starting around the 1980s, the process-output-paradigm was associated to a more systematic search for identifying specific teacher skills related to effective instruction. The effect of specific teacher behavior was investigated on narrowly defined aspects of student achievement. Research in this paradigm was based on a methodological rigor, which was influenced by behaviorist thinking. The focus was on domain-general teaching skills, such as the number of teacher questions during instruction or the clarity of her explanations. Specific teacher measures were aggregated over several lessons and then associated to a measure of student achievement. Initially, it was assumed that teacher actions directly affect student learning. Increasingly, the view won recognition that the effects of specific teacher behavior depend on students’ situation-specific activities, interpretations and interactions on the one hand, and on the domain- or content-specific context on the other hand. Research moved from studying unidirectional effects of teacher actions on student learning towards studying reciprocal effects between teacher and student behavior. These changes gradually gave support to the expert paradigm. In this view, it became accepted that the teacher has only an indirect influence on students’ learning. The interpretation of the teachers’ role in the classroom changed from being the main source of knowledge to being responsible for the creation of effective learning environments and the provision of adaptive support. Accordingly a successful teacher would effectively stimulate and assist students’ individual...
knowledge construction. It is assumed that this adaptive role of teaching depends on a considerable amount of professional expertise.

This thesis can be placed both into the process-output and the expert paradigm. A recurrent theme will be that effective teacher behavior ultimately depends on a solid and well-structured knowledge base. The central role of knowledge for teacher professionalism is widely acknowledged in the literature with respect to different domains and educational levels (Ball, Thames, & Phelps, 2008; Grossman, 1990; Hill, Rowan, & Loewenberg Ball, 2005; Kleickmann et al., 2013; Kunter, Baumert, Blum, Klusmann, & Neubrand, 2013). Therefore, an introduction to the ontology and epistemology of teachers’ professional knowledge will be provided in the next section.

**Professional Knowledge**

In the field of educational research there exists a widely held opinion that separates teachers’ professional knowledge into three core dimensions: content knowledge, pedagogical content knowledge, and generic pedagogical knowledge (Baumert et al., 2010; Borko & Putnam, 1995; Krauss, Baumert, & Blum, 2008; Shulman, 1986, 1987). This thesis focuses on teachers’ content knowledge and foremost teachers’ pedagogical content knowledge. These knowledge dimensions are described in more detail in the next sections.

*Content knowledge* represents teachers’ deep understanding of the subject matter taught. According to Shulman (Shulman, 1986, 1987), a teacher must understand how knowledge is conceptually organized in the respective discipline and through which principles of inquiry knowledge is being developed. Understanding the structure of subject matter assumes that teachers are expected to understand “why a given topic is particularly central to a discipline whereas another may be somewhat peripheral” (Shulman, 1986, p. 9). This description of teachers’ content knowledge indicates that Shulman’s conceptualization of content knowledge goes clearly beyond merely accumulated factual knowledge. His conceptualization of content knowledge converges with Lederman and Lederman’s (2012) description of scientific knowledge, which consists of a body of knowledge (e.g., concepts, laws, theories, ideas, etc.), knowledge about typical processes/methods (processes/methods applied by scientists to develop the body of knowledge), and the nature of scientific knowledge (the characterization of knowledge directly related the processes/methods through which it was constructed). Besides these ontological categories of content knowledge, there are also considerations about the level of mastery a teacher should ideally have for teaching: Krauss et al. (2008) differentiated, in the domain of mathematics, between the following three notions respectively levels, first, “(1) the everyday mathematical knowledge that all adults should have, (2) the school-level mathematical knowledge that good school students have, and (3) the university-level mathematical knowledge [...]” (p. 876). In the COACTIV
studies, they situated teachers’ content knowledge between the second and third level of this categorization (Kunter, Baumert, et al., 2013).

Pedagogical content knowledge represents teachers’ understanding of how students’ knowledge construction respectively learning can be facilitated. Shulman (1987) described the pedagogical content knowledge as a “blending of knowledge and pedagogy” (p. 8) and as such, as being “uniquely the province of teachers” (p. 8). With reference to Shulman’s seminal work, Grossman (1990) describes four central components of pedagogical content knowledge: overarching conception of purposes for teaching subject matter, knowledge of students’ understanding, knowledge of instructional strategies, and knowledge of curriculum and curricular materials. For a comprehensive review on conceptualizations of pedagogical content knowledge, see Park and Oliver (2008). With respect to the domain of science, Magnusson et al. (1999) listed the components of teachers’ pedagogical content knowledge as follows: (a) ”orientations toward science teaching”, (b) ”knowledge and beliefs about science curriculum”, (c) ”knowledge and beliefs about students’ understanding of specific science topics”, (d) ”knowledge and beliefs about assessment in science”, and (e) ”knowledge and beliefs about instructional strategies for teaching science” (p. 96). References to Magnusson’s categorization will be used later in this thesis.

The above listed components of teachers’ pedagogical content knowledge from Magnusson et al. (1999) include both the terms knowledge and beliefs. The differentiation between these terms is primarily a question of the epistemic status of knowledge (Calderhead, 1996; Fenstermacher, 1994; Pajares, 1992): Knowledge is considered a truth, because there is a certain consensus among a wider group of persons about justifying and explaining it. In contrast, beliefs are considered a truth from an individual perspective. In that sense, knowledge has a higher epistemic status (i.e. more certain) compared to beliefs (i.e. less certain). Regardless of its epistemic status, knowledge and beliefs of teachers are both considered highly important for teaching, because they are understood to function as a filter in teachers’ perception and interpretation any job-related situation, which in turn influence teachers’ behavior (Blömeke et al., 2015; Borko & Putnam, 1995; Fröhlich-Gildhoff et al., 2011; Reusser, Pauli, & Elmer, 2011). For the same reason, teachers’ knowledge and beliefs are also seen as critical targets of change in professional development (Borko & Putnam, 1995). In this thesis, the term pedagogical content knowledge refers to those aspects of teachers’ knowledge and beliefs, which express how they understand and facilitate children’s learning in early science education.

8 The COACTIV project was conducted at the Max Planck Institute for Human Development and encompasses studies about the professional competence of teachers, cognitively activating instruction, and development of students’ mathematical literacy, for further information, see https://www.mpib-berlin.mpg.de/coactiv/en/index.php (retrieved on 12.6.17).

9 There is no consistent use of this term in German, often the terms fachspezifisch-pädagogisches Wissen or Fachdidaktisches Wissen are used.
Professional Competence

As described above, a successful teacher needs to have a considerable amount professional knowledge, including content knowledge and pedagogical content knowledge. In the last few years, the term competence has gained considerable recognition in the attempt to describe successful teachers, both in academia and in practice. At the same time, the term is often criticized for its vagueness and ambiguity. For instance, in the Anglophone areas, there are differences between the terms competence and competency, whereas the former term is more closely associated to the traits of a person (worker-orientation) and the latter refers usually to a person’s performance (work-orientation) (Chen & Chang, 2015). For a clarification of the term competence see Weinert (2001a) (in English) or Deiglmayer, Schalk, and Stern (2017) (in German). In German-speaking regions, the following competence definition from Weinert (2001b) is often cited:

Kompetenzen sind „die bei Individuen verfügbaren oder durch sie erlernbaren kognitiven Fähigkeiten und Fertigkeiten, um bestimmte Probleme zu lösen, sowie die damit verbundenen motivationalen, volitionalen und sozialen Bereitschaften und Fähigkeiten um die Problemlösungen in variablen Situationen erfolgreich und verantwortungsvoll nutzen zu können.” (Weinert, 2001b, pp. 27-28)

This definition of human competence is per se rather general, meaning that it is neither restricted to a specific profession nor to a specific educational level of a particular group of learners. Relating this definition to the teacher profession suggests that a successful teacher needs to have not only a considerable amount of knowledge, but she needs also to be capable and willing to make use of this knowledge in a real-world situation on the job. Typical job situations for teachers are characterized as being ill-defined, because knowledge about both the initial and the targeted state, relating to children’s learning, is uncertain (Stern, 2009). Accordingly, Kunter, Klusmann, et al. (2013) define professional competence “as the skills, knowledge, attitudes, and motivational variables that form the basis for mastery of specific situations” (p. 807).

Models of professional competence can be generally differentiated into at least the following two categories, i.e. models describing levels in the competence development and models describing structural components of competence. For instance, passing through the stages of a novice, advanced beginner, competent, proficient to an expert is an often cited theory of competence development (Berliner, 1988). With respect to the structure, Baumert and Kunter (2013) modeled professional competence as a multi-dimensional construct, including the components beliefs/values/goals, motivational orientations, self-regulation, and, at its core, professional knowledge.
Figure 1.2: Professional competence and professional knowledge. This graph is based on the COACTIVE model of professional competence from Baumert and Kunter (2013) and integrates the components of science-specific pedagogical content knowledge suggested by Magnusson et al. (1999).

Figure 1.2 depicts an adapted version of their model. Note, the mathematics-specific PCK-components were replaced in this figure by the respective science-specific components of Magnusson et al. (1999) to meet the targeted domain of this study. The original model was used by Kunter, Baumert, et al. (2013) to assess mathematics teachers’ professional competence in the COACTIV studies. Besides content knowledge, pedagogical content knowledge and generic pedagogical knowledge, they list two further domains of professional knowledge: organizational knowledge, which they explain as teachers’ understanding about the education system and the individual school institutions, and counseling knowledge, which refers to understanding how to effectively communicate with laypeople. Note further that in the model of Figure 1.2, teacher beliefs may be both considered as a domain-specific or a domain-general aspect of teachers’ professional competence. Problems about conceptualizing teacher beliefs are widely known and discussed in more detail in chapter 2.1 (Pajares, 1992). In this thesis, teacher beliefs were interpreted as belonging to science-specific pedagogical content knowledge as suggested by Magnusson, because they will be analyzed with a clear domain-specific focus (see in the respective methods sections).

Blömeke et al. (2015) provide a description of central positions and controversies about the conceptualization of professional competence. They describe a dichotomy between competence as disposition vs. competence as performance and provide considerations about how to overcome this dichotomy. They relate these differing positions about the conceptualization of competence to different respective origins: Competence as performance is described as an approach related to
industrial/organizational psychology. According to this approach, the rationale was originally to select candidates best suited for a specific job. Candidates have to complete a set of selected job tasks in order to make a prediction about their future job performance. In contrast, *competence as disposition* would originate from educational research. In this approach, the assessment of competence is focused on the identification of a person’s traits (knowledge, beliefs etc.), which are interpreted as a resource for further competence development. Here, the main idea is not to assess the job-person fit, but rather the opportunities to learn for competence development. In the attempt to resolve the dichotomy, Blömeke et al. (2015) propose that “competence ultimately refers to real-world performance, either as constituent of the construct or as a validity criterion” (p. 6). And further “instead of insisting on an unproductive dichotomy view of competence, in particular knowledge or performance, competence should be regarded as a process, a continuum with many steps in between” (p. 7).

With respect to the disposition vs. performance dichotomy described above, the model depicted in Figure 1.2 by Baumert and Kunter (2013) seems to be clearly on the disposition-side, because it addresses several traits rather than describing the situation of its application. According to the recommendation of Blömeke et al. (2015), trait-oriented approaches should “recognized the necessity to measure behaviorally” (p. 8). She recommends to model competence as a continuum from disposition, over situation-specific skills to performance. This idea is depicted in Figure 1.3, which integrates the entities of the model from Figure 1.2 as dispositional aspects of teachers’ professional competence.

![Figure 1.3. Professional competence as a continuum. Taken from Blömeke et al. (2015), adapted by the author of this thesis.](image)

The importance of integrating dispositional and performance-related aspects in the conceptualization of professional competence is widely recognized in research on the teacher professionalization in early childhood education (Fröhlich-Gildhoff et al., 2011; Mischo & Fröhlich-Gildhoff, 2011; Nentwig-Gesemann, Fröhlich-Gildhoff, & Pietsch, 2011). For instance, the model suggested by Fröhlich-Gildhoff et al. (2011) proposes teachers’ knowledge and orientations as influencing factors to the
planning of behavior and finally to situation-specific observable behavior. They characterize typical situations in early childhood education as being highly complex, interactive, and difficult to forecast. There were almost no studies found in pre-primary education that took a domain-specific look in the modeling of teachers’ professional competence. The only study suggesting a science-specific model of teachers’ professional competence for early science education was the thesis by Zimmermann (2011): She theorized a model for teachers’ professional competence for fostering children’s early science competence (“naturwissenschaftliche Frühförderkompetenz NFFK”). Zimmermann (2011) defined NFFK as the ability of educators to support children’s learning with respect to natural phenomena having specifically children’s own activities and their competence experiences in mind (p. 186). This model is based on the differentiation of the following four broad competence dimensions: (1) content-specific competence, action competence, competence of the self and metacognitive competence. These main competence dimensions further consist of a total of 15 sub-dimensions leading to an extremely broad and integrative perspective. Based on this model, she offered several professional development interventions to investigate developments in teacher competence. Unlike this thesis, the effects of these interventions on teachers’ competence was assessed only based on teachers’ self-reports and not according to actual behavior during instruction. Furthermore, competence was not related to a performance measure of children’s learning.

1.3 Framework for Measuring Professional Development Effectiveness

Teacher professionalization primarily aims at strengthening teachers’ professional competence including facets such as knowledge, beliefs or motivation. This thesis builds on the assertion that teacher success should always be related to instructional quality and students’ learning achievements, because the primary role of a teacher is to support children’s competence development. Therefore, the three papers of this thesis will be situated in a framework of professional development effectiveness (depicted in Figure 1.4), which integrates these aspects. Note, more detailed information about this framework is provided in chapter 4.1.
The framework of professional development effectiveness in Figure 1.4 originates from Desimone (2009) and includes a differentiation of dispositional and performance-related aspects of teachers’ professional competence from Blömeke et al. (2015). According to this framework, an effective professional development intervention should be designed at the basis of a set of core features (explained in more detail in chapter 4.1), which should enable teachers to increase their knowledge or alter their beliefs respectively, which in turn should increase the quality of their instructional practices and finally lead to improved student learning. Professional development interventions are often caused by the pressure of school reform, through which teachers are expected to learn about new practices and activities. Here, teachers’ existing knowledge and beliefs (pedagogical content knowledge) are considered important, because they influence how teachers implement recommended practices and activities (Borko & Putnam, 1995). Desimone (2009) recommends using this model in all empirical causal studies of professional development to increase the validity of comparisons and conclusions among studies of professional development effectiveness. Recent research about the effectiveness of professional development programs were frequently based on this basic model, respectively on adapted versions of it (e.g., Hamre et al., 2012; Kleickmann, Tröbst, Jonen, Vehmeyer, & Möller, 2016; Scheerens & Blömeke, 2016).

1.4 Introduction to the Project

This thesis was developed as part of a project funded by the Swiss National Science Foundation (SNF). The project was administered under the number 100014_134812 and was titled Professional Competencies of Teachers in Early Science Instruction (Professionelle Kompetenzen von Lehrpersonen der Eingangsstufe im Bereich des naturwissenschaftlichen Unterrichts). The SNF funding covered 48 months and started in January 2012. The project proposal was submitted to the SNF in 2011 by Prof. Miriam Leuchter, currently professor at the University of Koblenz-Landau,
Germany, and Prof. Henrik Saalbach, co-examiner of this thesis and currently professor at the University of Leipzig, Germany. Subsequently, Miriam Leuchter had to withdraw from the project because of a call for a professorship in Germany. She remained a close collaborator in the project. Prof. Annette Tettenborn, currently head of Institute of Pedagogical Professionalism and School Culture (IPS) at University of Teacher Education Lucerne (PH Luzern), Switzerland, replaced Miriam Leuchter and figured together with Henrik Saalbach as project leaders. The project was carried out in cooperation between the PH Luzern and the ETH Zurich.

1.5 Aims and Abstracts of the Three Papers of This Thesis

The overarching aim of this thesis was to better understand the state and the development of teachers’ competence and their role for effective early science education. This thesis consists of the three papers highlighting different aspects teacher professionalization. To this aim, the three papers were localized into the framework for studying professional development effectiveness as introduced in chapter 1.3 (see Figure 1.5).

![Figure 1.5. Localization of the three papers of this thesis within the conceptual framework for studying professional development effectiveness following Desimone (2009).](image)

In the first paper teachers’ knowledge and beliefs were investigated as dispositional aspects of their professional competence. The main question was to identify and describe differences between kindergarten and elementary school teachers with respect to their science-specific pedagogical content knowledge and beliefs. In the second paper, kindergarten teachers’ instructional practices were the focus. The main question was to investigate whether specific types of teacher talk can foster children’s science learning. Finally, the third paper focused on the question whether a specific and short professional development intervention leads to changes in kindergarten teachers’ pedagogical content knowledge, their instructional practice and finally in children’s conceptual knowledge. In this last paper, the effectiveness of professional development was investigated integrating all aspects of the
model in Figure 1.5. In the following these three papers are briefly summarized in form of abstracts (not including references).

Paper 1: Kindergarten and Lower Grade Elementary School Teachers’ Pedagogical Content Knowledge in Science

There are many arguments supporting science instruction in the early years of schooling. Effective science instruction is thought to depend on knowledgeable and competent teachers, who can adaptively support children’s conceptual learning. Problems reported for primary science education include teachers’ lack of domain-specific pedagogical content knowledge, low associated confidence in teaching and partially inadequate conceptions about learning. Pedagogical content knowledge, beliefs, interest and self-concept of ability are considered important facets of teachers’ professional competence. In this study, these aspects of professional competence were investigated by means of a questionnaire with a sample of \( N = 181 \) in-service kindergarten and first and second grade elementary school teachers with respect to early science teaching and learning. The aim was to test whether differences with respect to these facets can be identified between kindergarten (KG) and lower grade elementary (LGES) school teachers. LGES-teachers were expected to have a higher pedagogical content knowledge, a differing belief system, and a higher self-concept of ability related to facilitating early science instruction. Expected differences between these groups of teachers were justified as being a product of differing long-term socialization processes with respect to their working environment (teaching at KG vs. LGES) and their type of professional education (teacher training seminar vs. university of teacher education). Measures included three aspects of pedagogical content knowledge (classification of children’s statements, the assessment of learning goals, beliefs about teaching and learning), interest, self-concept of ability, and self-reported teaching time in science. The result showed that KG- and LGES-teachers differ only in a few of the analyzed measures of their pedagogical content knowledge: No significant differences were found with respect to their classification of children’s statements, nor in their assessment of the importance of domain-specific learning goals and nor in their interest and self-concept of ability in science. However, differences were identified with respect to teachers’ belief system: KG-teachers agreed higher on the belief scales ‘Hands-on activity’ and ‘Play’ compared to LGES-teachers. Surprisingly, KG-teachers claimed to offer substantially more time in science instruction compared to LGES-teachers. Interestingly, teachers educated at universities of teacher education (compared to those educated at teacher training seminars) were associated with higher rates of agreement with respect to the belief scales representing the constructivist nature of learning. These results are discussed with respect to fostering instructional quality in early science education.

Key words: early science instruction and learning, professional competence, pedagogical content knowledge, beliefs
Paper 2: Early Science Learning: The Effects of Teacher Talk

Developmental research has shown that children have enormous cognitive resources for science learning. This study examined whether this potential can be effectively exploited by teacher talk. The influence of teacher talk on children’s science learning was investigated in $N = 32$ kindergarten classes during working with inquiry-based learning materials about the topic ‘floating and sinking’. Videotaped instruction and individual testing sessions were the main sources of information. Teacher talk was conceptualized in this study as the provision of vocabulary specific to the content (content-specific language) on the one hand, and utterances having underlying scaffolding intentions (scaffolding utterances). In a newly established framework, it was differentiated between the following four types of scaffolding utterances: (A) Clarification of phenomenon, task, and procedure, (B) Focus of attention, (C) Activation of prior knowledge, and (D) Challenging conceptual change. Latent regression modelling revealed that children indeed profited from teachers’ content-specific language. The analysis concerning the effects of teachers’ scaffolding utterances revealed both positive and negative effects on children’s learning. In accordance with the expectation teacher talk with the function of activating prior knowledge (type C) was positively related to children’s learning. Contrasting the expectations, teacher talk with the function of challenging conceptual change (type D) was negatively related to children’s learning. It seems that content-specific language, as a relatively straightforward way to conceptualize teacher talk, better supports children’s conceptual understanding in early science instruction compared to more elaborated forms of teacher talk. Implications for theory and professional education are discussed.

Key words: early science instruction, teacher talk, content-specific language, scaffolding

Paper 3: The Effects of a Short-Term Intervention in Early Science Professional Development on Teachers’ Pedagogical Content Knowledge, Instructional Practices, and Children’s Conceptual Learning

There is some consensus on the general characteristics of effective professional development (PD) programs for teachers: Desimone (2009) for instance, has described five core features: content focus, active learning, coherence, duration, and collective participation. With respect to the core feature of duration, it seems not surprising that a targeted change in teachers’ professional knowledge, beliefs, and practice is more likely to occur in PD interventions with extensive time spans respectively high number of instructional hours compared to shorter courses. However, in practice, the typical formats of PD interventions are generally rather short. A typical format often covers only around six to twelve hours of contact time, either as a one-time intervention, or over a time span of several weeks. In this study, the effectiveness of PD programs for kindergarten teachers in early science instruction were investigated in such a limited format. It follows the question to what extent PD programs, of even short durations, have effects on teachers’ pedagogical content knowledge, on their instructional
behavior and, on children’s learning outcomes. Besides the conscious violation of the core feature of duration, all other features of effective PD were adequately recognized: The intervention focused on the topic of floating and sinking and the respective subject matter content and associated challenges in children’s conceptual learning (content focus); the intervention offered opportunities for teachers to actively observe and discuss expert behavior during the analysis of video examples (active learning); the intervention was designed to allow teachers to calibrate their own beliefs about effective teacher-child interaction with current scientific knowledge (coherence); and finally, the intervention was designed for a local group of Kindergarten teachers, which should enable the exchange of experiences among each other (collective participation). Following an experimental design, \( N = 50 \) kindergarten teachers randomly assigned to one of the following three groups: (1) Teachers of the experimental group received an half-day introduction into learning materials and two additional half-day meetings based on the Intentional Teaching approach (Hamre et al., 2012) that highlights the importance of effective teacher-child interactions. (2) Teachers of the control group received only the introduction into the learning materials. Both groups implemented the learning materials directly after the introductory session in their classes over a period of four weeks. (3) Teachers of the baseline group did neither participate in the course nor in any further meeting, nor did they work with the learning materials. Measures were taken in a pre-post- design and included teachers’ pedagogical content knowledge, their talk during instruction, and children’s conceptual understanding of the topic floating and sinking. Results demonstrated that even a short-duration PD intervention can lead to substantial changes in teachers’ knowledge, beliefs and instructional behavior. However, children’s learning gain could not be traced back as a direct consequence of the professional development intervention, rather as a consequence of the way in which the learning material is structured. Consequences for professional development in early science instruction will be discussed.

Key words: professional development effectiveness, teacher talk, pedagogical content knowledge, beliefs

1.6 Notes About the Structure, Originality, and the Publication of This Thesis

This thesis comprises of three papers (as outlined above), which are going to be submitted as single articles in journals after submitting the thesis. For the reader of this thesis, it is important to note that the paper-based structure leads to some redundant information among these papers, at least with respect to some parts of the respective theoretical and methodological sections. Further, I hereby confirm that I am the sole author of this thesis. Information from others was cited to the best of my ability. Excepted are those parts, which I have corrected or revised based on the feedback from my supervisor (Elsbeth Stern) respectively my co-supervisor (Henrik Saalbach). For the planned publication in journals, I will be named as the lead author in all these three papers. The first paper is
planned to be co-authored by Henrik Saalbach, Miriam Leuchter, and Annette Tettenborn, and the second and third paper additionally by Anneliese Elmer, who was engaged in the coding of the video material. After submitting the thesis, a review will be done that includes all the mentioned co-authors. This strategy was chosen in agreement with both my supervisor and co-supervisor to meet the criteria of thesis originality on the one hand and to be able to stick to the time plan for finalizing the thesis on the other hand.

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1.8 References


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2 Kindergarten and Lower Grade Elementary School Teachers’ Pedagogical Content Knowledge in Science

2.1 Introduction

Current science curricula emphasize the importance of starting with science education as early as in preschool age (Eshach, 2006, 2011; French, 2004). Children should have opportunities to learn about natural phenomena in order to be able to participate in a scientifically literate society (Bybee, 2006; OECD, 2013). Science instruction in early years ideally offers children opportunities to understand basic science concepts that facilitate the understanding of more complex concepts later in school (Cabe Trundle & Saçkes, 2012; Eshach & Fried, 2005; Plummer & Krajcik, 2010). In Switzerland, a new curriculum is currently being implemented that targets, for the first time, children’s continuous competence development in science from the entry in kindergarten (children at the age of four) till the end of mandatory public school (children at the age of fifteen) (D-EDK, 2017). Numerous developmental studies have underpinned the opinion that even young children have a great potential for domain-specific learning in science (Baillargeon, 1994; Carey, 1985; Gopnik, 2012; Koerber, Sodian, Thoermer, & Nett, 2005; Mandler, 2008; Metz, 1995).

Learning in science means that children reconstruct their knowledge in a process of conceptual change (Carey, 2000; Chi, 2008; Vosniadou, 1994). This process is demanding because targeted formal science conceptions often stand in contrast with previously held naive conceptions stemming from everyday experiences. Teaching in science is, therefore, likewise a demanding endeavor. Teachers have an important role in stimulating children’s thinking and assisting their knowledge construction via the provision of adequate learning environments and verbal support (Hardy, Jonen, Möller, & Stern, 2006; Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006). Having these challenges of science learning and instruction in mind, it is clear that effective science teaching is considered to depend on a substantial amount of pedagogical content knowledge, as suggested by models of professional knowledge (Magnusson, Krajcik, & Borko, 1999). Teachers need to be aware of the constructivist nature of children’s learning to efficiently support children’s process of conceptual reconstruction. However, studies about teachers in primary science education revealed that they often lack the necessary professional knowledge and, in consequence, do not feel confident in science teaching (Appleton, 2003, 2008).

12 According to this curriculum, science instruction is offered as a part of an integrative subject called Nature-Human-Society (in German: Natur-Mensch-Gesellschaft).
This study investigated differences between kindergarten and lower grade\textsuperscript{13} elementary school teachers with respect to their science-specific pedagogical content knowledge. In Switzerland, Kindergarten and elementary school are part of the public school for children at the age from four to eight years. There are only few studies overtaking taking a domain-specific focus for the analysis of instruction at these early years of education (Greenfield et al., 2009). It will be hypothesized that kindergarten and lower grade elementary school teachers differ in their pedagogical content knowledge because of a different professional socialization in their past, including differences in their work environment respectively their type of professional education.

**Pedagogical Content Knowledge and Beliefs: Theoretical Aspects, Definitions, Origins, and Change**

Teachers’ knowledge and beliefs are important components of teacher cognitions (Baumert et al., 2010; Calderhead, 1996; Magnusson et al., 1999; Shulman, 1987). Teachers’ decision taking is considered to depend on a system of beliefs and knowledge, which in turn influences various aspects of instructional quality and children’s learning (Calderhead, 1996; Hartinger, Kleickmann, & Hawelka, 2006; Jones & Carter, 2007; Kleickmann, 2008; Staub & Stern, 2002). The differentiation between teachers’ knowledge and belief is primarily a question of the epistemic status of knowledge (Calderhead, 1996; Fenstermacher, 1994; Pajares, 1992): Knowledge is considered a truth, because there is a certain consensus among a wider group of persons about justifying and explaining it. In contrast, beliefs are considered a truth from an individual perspective. In that sense, knowledge has a higher epistemic status (i.e. more certain) compared to beliefs (i.e. less certain). Teachers’ beliefs about teaching and learning can, but not necessarily must be, consistent with the state-of-the-art of theoretical knowledge. Regardless of its epistemic status, knowledge and beliefs are considered to function as a filter in teachers’ perception and interpretation of specific job situations and finally influencing the planning and performance of respective behavior (Blömeke, Gustafsson, & Shavelson, 2015; Fröhlich-Gildhoff, Nenttwig-Gesemann, & Pietsch, 2011; Reusser, Pauli, & Elmer, 2011). Through this process, knowledge and beliefs are considered to influence teacher behavior in classroom, and in turn instructional quality and finally students’ learning.

The ontology of teachers’ knowledge is theorized in models of teachers’ professional knowledge. In reference to the seminal work of Shulman (1987), content knowledge, pedagogical content knowledge, and generic pedagogical knowledge are generally the listed knowledge components (Baumert et al., 2010; Borko & Putnam, 1995; Shulman, 1987). Pedagogical content knowledge is seen as a knowledge component uniquely important for teachers (Shulman, 1987). The idea is that teachers

\textsuperscript{13} In this study, lower grade refer to the first and second grade of elementary school. In Switzerland, children at the age of around six to seven years are attending these grades.
having a thorough pedagogical content knowledge would provide better instruction, including adequately adapted support for children’s learning. There is a broad consensus on the conceptualization about the above-listed components of teachers’ professional knowledge (Baumert et al., 2010; Calderhead, 1996; Magnusson et al., 1999; Shulman, 1987).

However there is a lack of consensus on how to conceptualize teacher beliefs (Pajares, 1992). The extensive amount of similar terms, such as orientations, attitudes, personal theories, views, conceptions, cognitions, etc., illustrates the ambiguity within the belief concept. Calderhead (1996) proposed a differentiation according to the categories of (a) “beliefs about the learners and learning”, (b) “beliefs about teaching”, (c) “beliefs about the subject”, (d) “beliefs about learning to teach” and (e) “beliefs about self and teaching role” (pp. 719-720). In research about teacher cognitions, beliefs are often evaluated at the reference of a view of an ideal or alternative state that contrasts reality (Calderhead, 1996). With respect to early instruction, teacher beliefs about teaching and learning are often mapped on current debates such as “child-centered vs. more didactic, basics skills approaches” (Stipek & Byler, 1997), “laissez-faire/loosely structured classroom vs. didactic/highly structured classroom” (Miller & Almon, 2009) or its “developmental appropriateness” (Buchanan, Burts, Bidner, White, & Charlesworth, 1998; Charlesworth et al., 1993). This study aims to map selected beliefs (see below) on the scientific understanding of efficient teaching and learning in early science instruction. Of course, the “scientific understanding” of efficient teaching and learning is not carved in stone, but rather itself subject to developments in theory building. Some beliefs are more in line with a state-of-the-art of understanding of teaching and learning, while others stand rather in conflict to it.

In this study, teacher knowledge and beliefs are conceptualized from a domain-specific perspective. Magnusson et al. (1999) have theorized five components of the science-specific pedagogical content knowledge, i.e. (a) ”orientations toward science teaching”, (b) ”knowledge and beliefs about science curriculum”, (c) ”knowledge and beliefs about students’ understanding of specific science topics”, (d) ”knowledge and beliefs about assessment in science”, and (e) ”knowledge and beliefs about instructional strategies for teaching science” (p. 96). In this study, the assessment of teachers’ pedagogical content knowledge was based on Magnusson’s components (a), (b) and (c) (see methods section).

In-service teachers’ pedagogical content knowledge and beliefs may by deeply rooted in their biography both as a student and as a learner (Friedrichsen et al., 2009; Neuweg, 2002; Stern, 2009). Relating to this wide temporal scope, teacher beliefs are often characterized as being relatively stable (Reusser et al., 2011). A fast change of teachers’ beliefs is rather unlikely because beliefs themselves restrict how teachers perceive and interpret new situations (as mentioned above). According to a framework from Friedrichsen et al. (2009), beliefs respectively knowledge about science teaching originate from prior science learning experiences as a student, from teacher education programs, and from teaching experiences. The role of prior experiences as a student play a major role in the teacher
Teachers’ Competence and Professional Development in Early Science Education

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profession: Unlike in other professions, teachers can draw on a large base of knowledge associated to many years of their own schooling (Stern, 2009). Knowledge and beliefs stemming from own school experiences can both function as a fruitful ground but also as a barrier for new teacher learning. Consequently, institutions of teacher professional education play by definition an important role in offering formal programs targeting the development and strengthening of teachers’ knowledge and beliefs related to competent teaching. Finally, changes in teacher cognitions may occur on the job also, both formally in programs of professional development and informally while teaching. Knowledge and beliefs may also be shaped not only by teaching experiences, but also based on the job environment including exchanges with professional peers at the school. Such processes are referred to as professional respectively organizational socialization, where profession- respectively organization-specific norms and ideologies are internalized (Kelchtermans & Ballet, 2002; Murray & Male, 2005).

**Typical Teacher Beliefs About Teaching and Learning in Science**

Teacher beliefs about teaching and learning are often evaluated from the background of a constructivist understanding of learning, and more specifically with respect to theories about conceptual change (more detailed information about the nature of children’s learning is provided in chapter 3.1) (De Corte, 2011; Kleickmann, 2008; Staub & Stern, 2002). Theories about learning as conceptual change already have a long tradition: Posner, et al.’s (1982) conceptual change model, Vosniadou’s (1994) naive framework theory, Chi’ et al.’s (1994) ontological categories and Pintrich, et al.’s (1993) interaction of the motivational perspective were some of the milestones in this area (for a review of these theories, see Murphy & Mason, 2006). In the following, the constructivist understanding of learning in science is described under the aspects of restructuring, co-constructing and situated construction of knowledge. These and later terms printed in italics refer to the labels of the beliefs scales used in this study (see methods section).

Restructuring knowledge. Learning could be defined as restructuring the own knowledge base, which is per se a self-active and autonomous process (Stern, 2005). Humans constantly evaluate their internal knowledge structures against new information from their surroundings (Chi, 2008; Vosniadou, 1994). Evaluating internal knowledge structures against new observations resembles closely to the concept of theory building in science, where hypotheses are tested against data (Gopnik, 2012). Already young children can build on an extensive intuitive knowledge base about natural phenomena stemming from a multitude of experiences in their everyday life (Carey, 1985). Disequilibria between prior knowledge and information from new experiences stimulate individuals to restructure their existing knowledge base (Posner et al., 1982; Vosniadou, 2008). This process of conceptual restructuring generally needs considerable time and effort, because it often means to getting rid of deeply rooted prior conceptions (Posner et al., 1982; Vosniadou, 2008). According to such a conceptualization of learning, instruction should aim to support children in their construction of knowledge structures, which are in line with the
later understanding of scientific conceptions. Scientific conceptions are targeted, because they are more reliably and universally applicable to new situations/problems compared to naive prior conceptions.

Co-constructing knowledge. The reconstruction of knowledge is per se a self-active cognitive process, which cannot be accomplished by another person. Human learning is, at the same time, a social endeavor: The fundamental role of social interaction in the development of human cognition was theorized in the influential work from Vygotsky (1978). Drawing on this sociocultural perspective, learners should have the opportunity to make their current conceptions explicit in order to share and discuss them with peers and teachers (John-Steiner & Mahn, 1996). The importance of argumentation, dialogue, and interaction in learning is often condensed in the term co-construction, which is highlighted both in a domain-general (Burbules & Bruce, 2001; Rojas-Drummond, Torreblanca, Pedraza, Vélez, & Guzmán, 2013), and a science-specific perspective on learning (Chi, Roy, & Hausmann, 2008; Erduran & Jiménez-Aleixandre, 2007; Mercer, Dawes, & Staaarman, 2009; Mercer & Howe, 2012; Newton, Driver, & Osborne, 1999).

Situated construction of knowledge. Another aspect the constructivist nature of learning highlights the importance of situating learning into meaningful contexts (Brown, Collins, & Duguid, 1989; Wortham, 2001). This means that children are placed in real-world situations, which demand a transfer of formal knowledge to these situations. The transfer of acquired knowledge to new situations is often difficult for learners. This relates to the problem of inert knowledge14, which describes the phenomenon that students often fail to apply knowledge learned in formal contexts for problem solving, although they are able to explicate it (Renkl, Mandl, & Gruber, 1996). Situated construction of knowledge points to the importance of children having sufficient opportunities in science instruction for applying their knowledge in meaningful, diverse, and complex contexts.

Hands-on activity. Besides the above-mentioned aspects of the constructivist nature of learning, pre-service- and in-service primary teachers often hold beliefs about the importance of hands-on activities in science learning (e.g., King, Shumow, & Lietz, 2001; Lavonen, Johanna, Koponen, & Kurki-Suonio, 2004). The definitions, roles and effects of hands-on science respectively hands-on activities in science instruction have already been debated for many decades, often controversially (for a brief overview, see Klahr, Triona, & Williams, 2007). Flick (1993) provides an overview of meanings of hands-on science: Hands-on science respectively hands-on science activities refers to a widely used instructional strategy, where students are actively engaged in manipulating materials. According to Flick, these situations can be defined as hands-on activities, if students are cognitively engaged in a sense that the manipulation of physical objects is directed at the understanding of a part of their natural environment. Furthermore, he points out the importance of making the students accountable with

14 In German: träges Wissen
respect to their observations, inferences and conclusions. Hands-on activities were not only debated in research but found their way also into practice through a multitude of activity-based teaching materials. The beliefs held by in-service teachers about hands-on science do, however, often not accord with the original idea outlined by Flick (1993). Many science teachers seem to be attracted simply by the idea of children handling science materials (referred to as “hands-on”), without addressing the link to associated cognitive processes. The problem of the missing connection between children’s activities and their thinking is widely known under the heading “hands-on, minds-off”, which is seen as a severe misunderstanding of the original idea of hands-on science (“hands-on, minds-on”). In this context, Mayer (2004) used the term “constructivist teaching fallacy” to point to the misinterpretation that constructivism-based instruction should primarily require behaviorally active learners. These misunderstandings are even more articulated, if teachers’ beliefs reflect the importance of leaving children during their hands-on activities merely alone in the sense of laissez-faire. Research has clearly shown that unguided hands-on approaches are not effective in terms of children’s learning (Butts, Hofman, & Anderson, 1993). A contemporary understanding of effective science learning highlights the importance of instructional support and guidance during hands-on activities (Kirschner, Sweller, & Clark, 2006; Möller, 2006). For instance, guided inquiry-based approaches in science instruction pose a promising approach to make children’s hands-on meaningful and effective, because these activities are related to testing a hypothesis of interest about a natural phenomenon.

Play. Play has been considered an important context for learning in early childhood education for an extended period of time (Fleer, 2009; Miller & Almon, 2009; Saracho & Spodek, 1995; Wannack, 2004). There are numerous definitions, typologies, and theories about play and its relevance for educative purpose (for an historical and theoretical overview, see Saracho & Spodek, 1995). For early conceptual learning, play-based contexts can be considered as appropriate, as long as they have the potential to stimulate children’s deliberate thinking about the natural phenomenon at hand (Fleer, 2009). At the same time, it seems unlikely that children let go of deeply rooted misconceptions without some degree of guidance and scaffolding from the teacher in the context of free play activities.

Transmission of knowledge. Finally, transmission describes an frequently-studied teacher belief that conceptualizes learning as a transfer of knowledge from the teacher to the learner (Staub & Stern, 2002). According to this belief, students pick up knowledge directly from teachers’ speech in the literal sense of transmission: Knowledge is transmitted into children. Such a belief is clearly not in line with a state-of-the-art understanding effective science instruction, because it contradicts the constructivist nature of learning.

In conclusion, teacher beliefs about teaching and learning in science as (1) restructuring, (2) co-constructing, and (3) situated construction of knowledge can be considered as being consistent with a state-of-the-art understanding of the constructivist nature of science learning. The beliefs highlighting (4) the importance of hands-on activities, especially in combination with laissez-faire orientation,
contrasted with this understanding. Teacher beliefs about the importance of play (5) were considered being important for effective science instruction, as long as play-based contexts stimulate children for conceptual learning. Finally, the transmission belief (6) was seen to largely disagree with a state-of-the-art understanding of effective science instruction and learning.

**Conditions For Science Instruction and Learning in Institutions of Early Education**

Theoretical considerations suggest that effective science instruction and learning depends, among other factors, on sufficient opportunities for science learning experiences (Cabe Trundle & Saçkes, 2012; Piasta, Logan, Pelatti, Capps, & Petrill, 2015), on adequate learning materials (Hardy et al., 2006; Leuchter, Saalbach, & Hardy, 2014; Tu, 2006), and on teachers having sufficient knowledge, skills and confidence to scaffold children’s learning (Appleton, 2003, 2007, 2008; Magnusson et al., 1999). Studies analyzing how children spend their time during a regular pre-school day revealed that only a relatively small share of time is devoted to science learning activities compared to other realms such as language/literacy, social studies, art or motor-related activities (Early et al., 2010). In a study conducted at kindergarten, 75.8% of the teachers reported spending less than 30 minutes for science instruction per day (Saçkes, Cabe Trundle, Bell, & O'Connell, 2011). Furthermore, the availability of science materials and equipment is often not given in institutions of early childhood education (Tu, 2006). This reported lack of teaching time and learning materials suggest that children do not receive sufficient learning opportunities in early science instruction. It could be shown that sufficient science learning opportunities are important for children’s effective learning (Piasta et al., 2015). Early years teachers’ lack of science-specific content and pedagogical content knowledge further impairs the conditions for science learning (Appleton, 2003, 2008). Kindergarten teachers were reported as having rather limited science-specific content and pedagogical content knowledge, which, for instance, prevents them from adequately addressing science-related questions from children (Kallery & Psillos, 2001). All these aspects together must lead to the conclusion that the current situation for early science instruction and learning is rather difficult.

**Kindergarten and Lower Grade Elementary School in Switzerland**

The year(s) in kindergarten and the first grades of elementary school are associated with major changes for the children; they must get accustomed to new attachment figures and peers, they should make great leaps towards autonomy, formal learning, adequate social behavior, etc. With the entrance into kindergarten the attachment figures are not primarily caregivers anymore but teachers, who are in place to support children’s knowledge and competence development. In Switzerland, the education of four to eight year old children has gained considerable attention, which can be inferred from the respective journals (4-8 Fachzeitschrift für Kindergarten und Unterstufe), books (Guldimann & Hauser, 2005; Tietze, Rossbach, & Grenner, 2005), or curricular development (D-EDK, 2017).
A detailed characterization of the Swiss kindergarten and lower grade elementary school respectively the associated groups of teachers is provided by Wannack’s (2004) book titled “Kindergarten and Elementary school between Approximation and Demarcation”\textsuperscript{15}. Her work will be described in detail next, because it directly relates to the aims of this study (i.e. investigating commonalities and differences between kindergarten and lower grade elementary school teachers).

Wannack (2004) described and compared the vocational field\textsuperscript{16} and job profile\textsuperscript{17} of kindergarten and the lower grade elementary school teachers of the canton of Berne in depth. The research design included a standardized teacher questionnaire ($N = 996$), a qualitative analysis of curricula, and a qualitative analysis of semi-structured children interviews (children of four classes). In reference to the ecological perspective of the American psychologist Urie Bronfenbrenner, she pointed out that human behavior would depend on the subjective interpretation of the environment. In the context of her study, she inferred that social, structural and spatial aspects of teachers’ vocational field would be important to understand teachers’ behavior in the classroom. In her analysis of teachers’ vocational field, she differentiated between a micro-level (the class of kindergarten, respectively elementary school), a meso-level (the institution of kindergarten, respectively elementary school), and a macro-level (the embeddedness of the institution in society). And within each of these levels, she described the kindergarten and elementary school with respect to personal, structural, and spatial characteristics. At the macro-level, she identified differing functions of the kindergarten and the elementary school, which have historically evolved: Both kindergarten and elementary school were characterized to serve the function of “qualification” and “social integration”, with only the elementary school carrying out the additional function of “selection” (selecting children for an academic/non-academic path towards the end of elementary school) (p. 173). At the meso- and macro-level, she identified a trend of integrating the kindergarten into the organizational unit of the school. At the micro-level, her results showed substantial commonalities between kindergarten and elementary school teachers. For instance, both groups of teachers reported to have to deal with the challenge of heterogeneous groups of children. On the other hand, kindergarten and elementary schools substantially differed with respect to the spatial arrangement in the classrooms and with respect to the availability of learning and play materials. With respect to the teachers’ job profile, Wannack analyzed aspect such as professional education, employment, professional development, and career opportunities. Substantial differences were identified between the kindergarten and elementary school teachers with respect to:

- Professional education: The professional education of kindergarten teachers would normally focus on a narrower age group (i.e. children at the age of four and five years), while

\textsuperscript{15} This title was translated by the author of this thesis. The original book title is “Kindergarten und Grundschule zwischen Annäherung und Abgrenzung”.

\textsuperscript{16} In German: Berufsfeld

\textsuperscript{17} In German: Berufsbild
professional education of elementary school teachers would focus on a wider age group (i.e. for teaching children from the age of six to twelve years) (more information about the professional education is provided further below).

- Lesson planning: Kindergarten teachers lesson planning was reported as being more strongly child-oriented compared to the lesson planning of the elementary school teachers, which was more focused on teaching and learning materials.

- Importance of play: Kindergarten teachers found it more typical for themselves to offer unguided play and learning activities compared to guided play and learning activities, whereas the opposite was reported from elementary school teachers.

Wannack (2004) interpreted these differences in the context of group-specific processes of professional socialization. In her conclusion, she stipulated “the rationale of development” as being typical for kindergarten teachers and the “the rationale of learning” as being typical for elementary school teachers (p. 173). She described the rationale of development in kindergarten teachers’ stronger affinity to child-orientation and in the central role of unguided play; and the rationale of learning by elementary school teachers’ stronger affinity for domain-specific curricular topics and more guided approaches of instruction.

Professional Education of Kindergarten and Lower Grade Elementary school Teachers in Switzerland

In Switzerland, the education of kindergarten and elementary school teachers went through several far-reaching reforms and changes over the last decades (Leuchter & Wannack, 2010). The most fundamental change was the shift in teacher education from the secondary level to the tertiary level of education at the turn of this century (Criblez & Hofstetter, 2002). Through this shift, institutions formerly known as teacher training seminars were replaced by universities of teacher education.

This shift is often referred to by the term tertiarization. It has taken place with the rationale of teacher professionalization and was understood as an answer to the increasing complexity of demands associated to the teacher profession (Merkli et al., 1998; Reusser, 1996). The question whether teacher education should be lifted from a secondary to a tertiary level of education was already discussed in the 1970s (Leuchter & Wannack, 2010). These discussions resulted, for the time being, not in the tertiarization of teacher education, but in the prolongation of the existing vocational education at teacher training seminars, from four to five years at elementary school seminars and from two to three

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18 In the ISCED-2011-nomenclature, i.e. a shift from the “upper secondary level” to the “bachelor” at tertiary level of education.
19 In German: Lehrpersonenseminare
20 In German: Pädagogische Hochschulen
21 In German: Tertiarisierung
years at kindergarten seminars (Leuchter & Wannack, 2010). In the 1990s, the question of tertiarization was brought up again in the context of the development of universities of applied sciences. These discussions included whether teacher education should be institutionalized at regular universities or at new types of universities of applied sciences (Reusser, 1996). At the turn of this century, these deliberations resulted in the formation of universities of teacher education, which can be conceived as universities of applied sciences having a specific focus of teacher professionalization. Programs of these institutions combine a vocational and academic education, which gives the graduates both a nation-wide legitimation for teaching (teaching diploma) and accessibility to a further academic career (bachelor degree). The tertiarization of kindergarten and elementary school education described above happened not without controversial debates, both in politics and society. Especially the requirement of a general qualification for university entrance (in the German-speaking part of Switzerland called Matura) for prospective kindergarten teachers was a controversially discussed topic (Leuchter & Wannack, 2010). The tertiarization of teacher education was also accompanied by an increasing recognition for and development of subject-specific pedagogies (Heitzmann & Pauli, 2015). To date, at universities of teacher education, prospective kindergarten and elementary school teacher devote a substantial share of study time in subject-specific pedagogies.

Structural differences in the professional education between kindergarten and elementary school teachers clearly diminished after the tertiarization: Before the 1970s, kindergarten and elementary school teacher education was offered at different institutions of upper secondary education (kindergarten teacher training seminars vs. elementary school teacher training seminars) and comprised also a different duration of training (three vs. four years) (Leuchter & Wannack, 2010). Currently, the education for public school teachers is organized at the tertiary level at the same institution, i.e. at the UTE, and comprises the same study time (three years). With respect to the study programs of prospective kindergarten and elementary school teachers, the UTE have taken different routes; there are some institutions offering a study program that fully integrates programs for kindergarten and elementary school teachers, others offer (at least to some extent) specific programs for either kindergarten/lower elementary school teachers and elementary school teachers (Sörensen Criblez & Wannack, 2006).

2.2 The Present Study

This study investigated the science-specific pedagogical content knowledge of 181 in-service teachers, consisting of 93 kindergarten teachers and 88 first and second grade elementary school teachers. In this study, kindergarten (henceforth abbreviated with KG) and the lower grade elementary school

22 In German: Fachhochschulen
23 In German: Fachdidaktiken
Teachers’ pedagogical content knowledge and beliefs are considered important components of teacher professional knowledge and teacher professional competence (Blömeke et al., 2015; Shulman, 1987). Studies analyzing teachers’ knowledge and beliefs in pre-primary and primary science education are rare. Most relevant studies focus on some of these aspects in general, rather than from a domain-specific perspective (e.g., Stipek & Byler, 1997; Wannack, 2004). A science-specific focus was chosen because research in developmental psychology has demonstrated that already young children have a substantial potential for domain-specific learning. At the same time, elementary school teachers were reported to lack of sufficient pedagogical content knowledge and often hold beliefs partly contrasting a state-of-the-art understanding of the nature of science learning. The first aim was to investigate whether KG-teachers differ from LGES-teachers with respect to their science-specific pedagogical content knowledge. After controlling for these differences, a second aim was to investigate whether the type of professional education (teacher training seminar, henceforth abbreviated with TTS vs. university of teacher education, henceforth abbreviated with UTE) can further explain differences in their pedagogical content knowledge and beliefs. The general hypothesis was that teachers’ knowledge and beliefs have been developed in as a function of their socio-cultural environment during their career in their workplace (as KG teacher, respectively as a LGES teacher) respectively during their professional education (TTS vs. UTE). Data was gathered by means of a questionnaire. Teachers’ pedagogical content knowledge was measured by three aspects, including classifying children’s statements about the topic floating and sinking, assessing domain-specific learning goals, and rating items about conceptualizations of learning and instruction in science. This study was conducted according the following research question:

1) To what extent do teachers of the grade KG and LGES differ in their science-specific pedagogical content knowledge, including their (1.1) classification of children’s statements, (1.2) assessment of the importance of learning goals, and (1.3) beliefs about teaching and learning?

Hypotheses:

- Classification of children’s statements: The correct classification of children’s statements about floating and sinking (for details, see methods section) was assumed to depend on an understanding of the physics of floating and sinking and the appreciation of the importance of children’s prior knowledge for learning. LGES-teachers were expected to perform better in this task because teachers of upper grades are generally more confronted with domain-specific knowledge than teachers of lower grades. This can be illustrated by respective curricula in public school: Domain-specific knowledge is more highlighted in curricula of higher grades compared to curricula of lower grades (D-EDK, 2017). Further, LGES-teachers were characterized as being closer to formal learning and guided approaches of instruction compared to KG-teachers who generally lay
more stress on informal and unguided approaches (Wannack, 2004). Therefore, knowledge about a systematic understanding of floating and sinking is expected to be more acknowledged by LGES-teachers.

- Assessment of the importance of learning goals: It was expected that LGES-teachers assign a higher importance to domain-specific learning goals and a lower importance to domain-general learning goals in the respective comparisons with KG-teachers. The justification for these hypotheses was the same as for teachers’ classification of children’s statements (see above).

- Beliefs about teaching and learning: In the theoretical section, three beliefs (i.e. ‘Restructuring knowledge’, ‘Co-constructing knowledge’, and ‘Situated construction of knowledge’) were described as being in line with a state-of-the-art understanding of effective science learning, which based on the constructivist nature of learning. For these beliefs, no directed hypothesis was formulated, because no tangible information was available from previous studies. The beliefs ‘Hands-on activities’ and ‘Play’ are expected to be more accepted by KG-teachers compared to LGES-teachers, since these beliefs are often considered as typical aspects of kindergarten pedagogy (Miller & Almon, 2009; Saracho & Spodek, 1995; Wannack, 2004).

2) To what extent do teachers of the grade KG and LGES differ in their (3.1) interest and (3.2) self-concept of ability towards science?

Hypotheses:

- Studies about early science teachers revealed that they often do not have a solid base of content and pedagogical content knowledge, nor of great confidence with respect to science teaching (Appleton, 2003, 2007). The problem of lacking knowledge and confidence for teaching science seems to be more accentuated at lower grades. Therefore, it was expected that both the interest and self-concept of ability towards science is higher in LGES-teachers compared to KG-teachers.

3) To what extent do teachers of the grades KG and LGES differ in their self-reported teaching time in science?

- In general, teachers in early education were reported to offer opportunities for science learning rather rarely (Early et al., 2010; Kallery & Psillos, 2001; Sâkes et al., 2011; Tu, 2006). Furthermore, the studies of Appleton (Appleton, 2003, 2007, 2008) would make it plausible that the phenomenon of “science avoidance” as especially pronounced in teachers of lower grades. Along the same lines, the fact that children have less overall teaching time may also be relevant. The total amount of teaching time generally rises with the higher grades in public school. Further, KG teachers were reported to have more freedom in how to organize instruction compared to LGES-teachers (Wannack, 2004). If science avoidance practices were to be equally present in both
groups, then less science teaching time would be expected at the KG-level. All these considerations lead to the hypotheses of lower science teaching time at KG.

4) Can the type of teachers’ professional education (TTS vs. UTE) explain (4.1) teachers’ science-specific pedagogical content knowledge, (4.2) their interest and self-concept of ability towards science, and (4.3) their self-reported teaching time in science, after controlling for their working experience and teaching grade (KG vs. LGES)?

Hypotheses:

- Teachers’ science-specific pedagogical content knowledge: It was expected that the tertiarization of teacher education (shift from TTS to UTE at the turn of this century) enabled teachers to build a stronger base of pedagogical content knowledge for science teaching, because this seems connected to the aim of professionalization including a strengthening of subject-specific pedagogies (Heitzmann & Pauli, 2015). The UTE, as educational institutions of the tertiary level, should base their study programs on academic knowledge. Therefore, teachers educated at UTE were expected to have (i) a higher performance in their classification of children’s statements, (ii) a higher rating of the importance of domain-specific learning goals, and (iii) a higher agreement with respect to beliefs representing the constructivist nature of learning (i.e. ‘Restructuring knowledge’, ‘Co-constructing knowledge’, and ‘Situated construction of knowledge’). No specific differences were expected for the other belief scales.

- Interest and self-concept of ability towards science: The newly established UTE have a higher focus on subject-specific pedagogies compared to TTS (Heitzmann & Pauli, 2015). More study-time in subject-specific pedagogies should ideally lead to a higher level of content and pedagogical content knowledge, which is considered to be related to the associated self-concept of ability and interest (Appleton, 2003, 2007, 2008). Therefore, UTE-teachers were expected to display a higher interest and self-concept of ability in science than TTS-teachers.

- Self-reported teaching time in science: No differences related to the type of professional education were expected for teachers’ self-reported teaching time in science.

2.3 Methods

Sample

This study included a sample of 181 in-service teachers. Detailed information about the sample is presented in Table 2.1. The sample used in this study resulted after selecting those teachers relevant for the comparison of kindergarten and lower grade elementary school teachers (see research question 1): Twenty-two teachers were excluded because they either did not solely teach only at one
teaching grade (KG vs. LGES) or did not solely attend one type of professional education (TTS vs. UTE). On average, these teachers were 39.5 years old (SD = 11.6) and had 15.0 years (SD = 9.7) of teaching experience. Female teacher clearly dominated the sample (97%), which is typical for Swiss teachers at these grades (Wannack, 2004).

Table 2.1

Participants Characteristics by Groups

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total Used</th>
<th>Groups According Teaching Grade</th>
<th>Groups According Type of Professional Education</th>
<th>Excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>KG</td>
<td>LGES</td>
<td>TTS</td>
</tr>
<tr>
<td>Teachers</td>
<td>203</td>
<td>93</td>
<td>88</td>
<td>146</td>
</tr>
<tr>
<td>Gender: Female (%)</td>
<td>97</td>
<td>97</td>
<td>100</td>
<td>97</td>
</tr>
<tr>
<td>Age (M [SD])</td>
<td>39.3 (11.6)</td>
<td>39.3 (11.7)</td>
<td>39.3 (11.5)</td>
<td>42.6 (11.9)</td>
</tr>
<tr>
<td>Teaching experience, years (M [SD])</td>
<td>14.9 (9.6)</td>
<td>14.3 (9.7)</td>
<td>14.3 (9.2)</td>
<td>17.7 (10.2)</td>
</tr>
<tr>
<td>Teaching Grade (%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>KG</td>
<td>48</td>
<td>51</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>LGES</td>
<td>43</td>
<td>49</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Combination or other (%)</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Type of Professional Education (%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Seminar (%)</td>
<td>76</td>
<td>81</td>
<td>81</td>
<td>81</td>
</tr>
<tr>
<td>UTE (%)</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Combination or other (%)</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note. Total Used is the sample used in this study, which resulted after sorting out the teachers described in the column ‘Excluded’. KG = kindergarten, LGES = elementary school grade 1 and 2, UTE = university of teacher education, TTS = teacher training seminar.

Measures

Data was gathered by means of a questionnaire. The associated measures will be explained in detail in this section. The full list of the respective original items (in German) is provided in the Appendix A.

The measurement of teachers’ pedagogical content knowledge and beliefs comprised of the following three aspects: (i) classification of children’s statements, (ii) assessment of the importance of learning goals, (iii) beliefs about teaching and learning. Table 2.2 should clarify their reference to the components of the pedagogical content knowledge for science teaching as suggest by Magnusson et al. (1999).
Table 2.2

Implemented Measures About Teachers’ Pedagogical Content Knowledge and Its References to the Model of Magnusson

<table>
<thead>
<tr>
<th>Measures of This Study</th>
<th>Components of Pedagogical Content Knowledge for Science Teaching According Magnusson et al. (1999, p. 97)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification of children’s statements</td>
<td>(c) knowledge and beliefs about students’ understanding of specific science topics</td>
</tr>
<tr>
<td>Assessment of the importance of learning goals</td>
<td>(b) knowledge and beliefs about science curriculum</td>
</tr>
<tr>
<td>Beliefs about teaching and learning</td>
<td>(a) orientations toward science teaching; (c) knowledge and beliefs about students’ understanding of specific science topics</td>
</tr>
</tbody>
</table>

**Classification of children’s statements.** The participants had to assess 19 children’s statements about the topic of floating and sinking (see Table 2.4 and Appendix A). Floating and sinking is a typical curricular topic in early science education, which is often chosen in associated research (Butts et al., 1993; Hardy et al., 2006; Hsin & Wu, 2011). The children statements, example items are provided in Table 2.4, had to be qualified either as being a “misconception” or as being “correct, respectively in line with conceptions targeted later in school”. This instrument was newly developed for this study, based on the KiNT materials developed by the group around Kornelia Möller. The number of correct classifications was divided by total classifications to attain a performance score.

**Assessment of the importance of learning goals.** Teachers’ knowledge and beliefs about curricular goals are seen as an important component of teacher knowledge (Magnusson et al., 1999; Shulman, 1987). The two applied constructs differentiate between domain-specific vs. domain-general learning goals with the topic of natural phenomena around the farm respectively farming, which is also a typical curricular topic in primary education. The participating teachers were asked to rate these items on a five-point Likert scale from 1 (not important at all) to 5 (very important) (see Table 2.4 and Appendix A).

**Beliefs about teaching and learning.** Teacher beliefs about teaching and learning in science were measured by six scales consisting of a total of 31 items (see Table 2.4 and Appendix A). These items had to be rated on a five-point Likert scale from 1 (not important at all) to 5 (very important). The scales included those conceptualizations of science learning and instruction, which were introduced in the theoretical section. All items (with one exception, see below) were taken from an existing item pool from (Kleickmann, 2008), who has analyzed teacher beliefs in a sample of \( N = 46 \) in-service elementary school teachers (grades three and four) in Germany. These items were slightly adapted for this study. The above-mentioned exception concerns the scale “Play” and the associated items, which

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was newly developed to specifically address the play-based pedagogy, which is typical for early childhood education (Wannack, 2004). The structure of this instrument was analyzed in an exploratory factor analysis, which is provided in Appendix B. This factor analysis revealed a structure, which was largely identical to the structure found by Kleickmann (2008, pp. 144-145). Originally Kleickmann had stipulated a dimensionality of teachers’ beliefs system consisting of nine factors (see Table 2.3, first column). Empirically he could identify only five components, because the items of the scales EIG/DIS (see again the first column of Table 2.3 for the meaning of these abbreviations), those of CON/SCH, ANW/MOT and LAI/PRA loaded on the same respective component. Interestingly, the structural analysis with the sample of Swiss KG and LGES-teachers led to nearly the identical structure (compare again with Appendix B): The participants did not differentiate between CON/SCH, EIG/DIS and LAI/PRA. The only difference was that items of ANW and MOT indeed loaded on different components. These results from the structural analysis and further theoretical considerations (see above, in theoretical section of this study) led to a new framing and respective labeling of the scales, i.e. the items of CON/SCH representing the scale ‘Restructuring knowledge’, the items of EIG/DIS the scale ‘Co-constructing knowledge’, the items of TRA ‘Transmission of knowledge’, the items of LAI/PRA the scale ‘Hands-on activity’, and the items of ANW the scale ‘Situated construction of knowledge’. The MOT-items were not used in this study, because they were considered not equally relevant to the purpose of this study. Instead, the above-mentioned scale of ‘Play’ was included.

Table 2.3

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Entwicklung eigener Deutungen (EIG)</td>
<td>EIG/DIS (component 1)</td>
<td>CON/SCH (component 1)</td>
<td>Restructuring knowledge</td>
</tr>
<tr>
<td>Diskussion von Schülvorstellungen (DIS)</td>
<td>CON/SCH (component 2)</td>
<td>EIG/DIS (component 2)</td>
<td>Co-constructing knowledge</td>
</tr>
<tr>
<td>Schüler mit Vorstellungen über Naturphänomene (SCH)</td>
<td>TRA (component 3)</td>
<td>TRA (component 3)</td>
<td>Transmission of knowledge</td>
</tr>
<tr>
<td>Conceptual Change (CON)</td>
<td>ANW/MOT (component 4)</td>
<td>LAI/PRA (component 4)</td>
<td>Hands-on activity</td>
</tr>
<tr>
<td>Transmission (TRA)</td>
<td>LAI/PRA (component 5)</td>
<td>ANW (component 5)</td>
<td>Situated construction of knowledge</td>
</tr>
<tr>
<td>Anwendungsbezogenes Lernen (ANW)</td>
<td></td>
<td>Play (component 6)</td>
<td>Play</td>
</tr>
<tr>
<td>Motiviertes Lernen (MOT)</td>
<td></td>
<td>MOT (component 7)</td>
<td>not used</td>
</tr>
<tr>
<td>Praktizismus (PRA)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laisser-faire (LAI)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
For the belief scales, the reliability analysis revealed Cronbach’s alpha values between .67 to .80 (see Table 2.4). These values are slightly below those reported by Kleickmann (2008, p. 148).

Table 2.4
Measures, Example Items, and Internal Consistency Estimates of Teachers’ Pedagogical Content Knowledge

<table>
<thead>
<tr>
<th>Construct</th>
<th>Example items</th>
<th>N of items</th>
<th>Cronbach’s alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification of children’s statements</td>
<td>“This button has four small holes. It is certainly going to sink.” (misconception)</td>
<td>19</td>
<td>NAa</td>
</tr>
<tr>
<td></td>
<td>“Heavy things sometimes float too. Then, these things are rather big and need a lot of space in water.” (correct, respectively in line with conceptions targeted later)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessment of the importance of learning goals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domain-specific learning goals</td>
<td>Being able to justify the relevance of weather and climate (for instance drought, thunder) for a farm.</td>
<td>7</td>
<td>.67</td>
</tr>
<tr>
<td>Domain-general learning goals</td>
<td>Being able to ask a question to an unfamiliar person in comprehensible and understandable way.</td>
<td>7</td>
<td>.69</td>
</tr>
<tr>
<td>Beliefs about teaching and learning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restructuring knowledge</td>
<td>Children may already have persisting concepts that may make learning a demanding process.</td>
<td>7</td>
<td>.80</td>
</tr>
<tr>
<td>Co-constructing knowledge</td>
<td>Children should be encouraged to share their ideas even if their concepts about a science phenomenon are wrong.</td>
<td>7</td>
<td>.73</td>
</tr>
<tr>
<td>Situated construction of knowledge</td>
<td>Every-day problems are the starting point for science learning.</td>
<td>4</td>
<td>.67</td>
</tr>
<tr>
<td>Hands-on activity</td>
<td>In science, it is enough if children are having hands-on experiences.</td>
<td>5</td>
<td>.70</td>
</tr>
<tr>
<td>Play</td>
<td>In free play children discover important principles about natural phenomena.</td>
<td>3</td>
<td>.74</td>
</tr>
<tr>
<td>Transmission of knowledge</td>
<td>Teachers should transfer important domain-specific knowledge before children are allowed to make their own experiences in science.</td>
<td>5</td>
<td>.72</td>
</tr>
</tbody>
</table>

Note. Internal consistency estimates were calculated with the total sample (N = 203).

a This measure consists of dichotomous variables; therefore Cronbach’s alpha is not reported (Sijtsma, 2008).

Teachers’ interest in science. Teachers’ interest in science was measured by five items (see Table 2.5 and Appendix A). The participating teachers were asked to rate five items on a five-point Likert scale from 1 (fully incorrect) to 5 (fully correct).

Teachers’ self-concept of ability in science. Teachers’ self-concept of ability in science was measured by two items (see Table 2.5 and Appendix A). The participating teachers were asked to rate these items on the same five-point Likert scale from 1 (fully incorrect) to 5 (fully correct).

Self-reported teaching time in science. Teachers’ teaching time in science was measured with two items (see Table 2.5 and Appendix A). The participating teachers were asked to rate these items on the following five-point Likert scale: 1 (less than ½ hour a week), 2 (1/2 to 1 hour a week), 3 (1 to 2
hours a week), 4 (2 to 5 hours a week), and 5 (more than five hours a week). Note that in public school, teaching time according to different school subjects is prescribed by the state authority. Nevertheless, teachers generally have great freedom about allocating instruction time to respective curricular contents. The problem science avoidance is well known in early science education (Appleton, 2003, 2008). Therefore, it was meaningful to include a measure about the devoted time of science instruction.

Table 2.5

<table>
<thead>
<tr>
<th>Construct</th>
<th>Example items</th>
<th>N of items</th>
<th>Cronbach’s alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest in science</td>
<td>I deal with physical contents also in my leisure time.</td>
<td>5</td>
<td>.75</td>
</tr>
<tr>
<td>Self-concept of ability in science</td>
<td>I have a good understanding of physical phenomena.</td>
<td>2</td>
<td>.74</td>
</tr>
<tr>
<td>Self-reported teaching time in science</td>
<td>How many hours a week do children in your class work about phenomena of life sciences on average?</td>
<td>2</td>
<td>.77</td>
</tr>
</tbody>
</table>

Note. Internal consistency measures were calculated with the total sample (N=203).

Missing data

Missing data ranged, depending to the respective variables, from 0.0% to 0.5%. Averaged over all variables, 0.2% of the data was missing.

Analysis

The analysis was done by the R software. With respect to the first question, differences between the groups of interest, KG- vs. LGES-teachers, were calculated by independent t-tests (Field, Miles, & Field, 2012). The Welch’s test was applied, which does not make the assumption of homogeneity of variances. Effect sizes were calculated with the CohensD-function of the lsr-package using the method = “pooled”, which is applied for the comparison of independent samples. The Cohen’s d values were evaluated as being small (.20), medium (.50), and large (.80) according to Cohen (1992).

In this analysis, a special attention must be attributed to the multiple comparisons problem. This problem describes an increased probability of detecting an effect in the data with increasing number of tests that is not present in reality. In terms of statistical hypothesis testing, this problem describes the

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25 R is a free open-source software environment for statistical computing and graphics, which is available under https://www.r-project.org/ (retrieved 25.5. 2017)

26 There are further terms used in literature relating to the problem of multiple comparisons, such as familywise error rate, alpha inflation, etc.
inflation of Type I error rates (i.e. incorrect rejection of a true null hypothesis). The *Bonferroni* and the *Holm-Bonferroni* correction procedures are widely used methods for addressing this problem by reducing the Type I error rates. Important to note, reducing Type I error rates necessarily leads to an increase of Type II error rates (i.e. the probability of retaining a false null hypothesis = failure to detect an effect that is present). Hence, there is a trade-off between correcting for the Type I error and the loss of statistical power (Field et al., 2012). The Bonferroni correction procedure is a very conservative correction method, in which the commonly used significance criterion \((\alpha = 0.05)\) is divided by the number of tests \(k\), leading to the formula \(p_{\text{crit}} = \alpha/k\) (Field et al., 2012). The Holm-Bonferroni correction procedure is a somewhat less conservative method, in which the significance criterion is adapted in a sequential procedure (Holm, 1979). In this procedure, the comparisons are listed according to the calculated \(p\)-values, then the \(p\)-values are indexed from the highest to the lowest \(p\)-value with \(j = 1, 2, ..., k\), then the corrected significance level is calculated by the formula \(p_{\text{crit}} = \alpha/j\). The idea behind this procedure is that only the remaining number of test \(j\) (instead of the total number of tests \(k\)) is considered for correction (Field et al., 2012).

In this study, the multiple comparisons problem seem to be most serious with respect to the teacher beliefs, because this construct consists of the largest number of subscales (six), which, individually tested, would lead to a highly inflated Type I error. Therefore, it was decided to apply a correction procedure for these scales specifically. The Holm-Bonferroni correction procedure (not the Bonferroni procedure) was chosen, because it seems to best balance the trade-off between Type I and Type II error rates (for further argumentation, see Aickin & Gensler, 1996). Furthermore, a multivariate analysis of variance (MANOVA) was calculated in advance, in which all six belief scales were combined. Putting all beliefs into one test has its theoretical relevance, since beliefs are often considered to belong to a larger belief system (Calderhead, 1996). Differences with respect to the other variables were assessed on regular (non-corrected) \(t\)-tests.

With respect to the second research question, regression analyses were conducted with the *lm*-function from the *stats*-package in R. Multiple R-squared values were reported to provide information about the model fit. R square values tell how much of the variance in the dependent variable is being explained by the inserted predictors (independent variables) (Field et al., 2012).


2.4 Results

Descriptive statistics of to the total used sample and of the groups according the teaching grade (KG vs. LGES) and according the type of professional education (TTS vs. UTE) are provided in Table 2.6.

Table 2.6

Means and Standard Deviations for all Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Total used</th>
<th>Groups According Teaching Grade</th>
<th>Groups According Type of Professional Education</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>KG</td>
<td>LGES</td>
</tr>
<tr>
<td>n</td>
<td>181</td>
<td>93</td>
<td>88</td>
</tr>
<tr>
<td>Classification of children’s statements</td>
<td>61.2 (16.7)</td>
<td>60.3 (17.2)</td>
<td>62.1 (16.1)</td>
</tr>
<tr>
<td>Assessment of the importance of learning goals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domain-specific learning goals</td>
<td>3.74 (0.55)</td>
<td>3.78 (0.59)</td>
<td>3.69 (0.50)</td>
</tr>
<tr>
<td>Domain-general learning goals</td>
<td>3.87 (0.55)</td>
<td>3.77 (0.55)</td>
<td>3.97 (0.53)</td>
</tr>
<tr>
<td>Beliefs about teaching and learning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restructuring knowledge</td>
<td>2.93 (0.62)</td>
<td>2.95 (0.65)</td>
<td>2.90 (0.60)</td>
</tr>
<tr>
<td>Co-constructing knowledge</td>
<td>3.94 (0.54)</td>
<td>3.98 (0.56)</td>
<td>3.90 (0.52)</td>
</tr>
<tr>
<td>Situated construction of knowledge</td>
<td>3.62 (0.77)</td>
<td>3.46 (0.80)</td>
<td>3.78 (0.70)</td>
</tr>
<tr>
<td>Hands-on activity</td>
<td>3.34 (0.58)</td>
<td>3.45 (0.58)</td>
<td>3.23 (0.58)</td>
</tr>
<tr>
<td>Play</td>
<td>4.24 (0.66)</td>
<td>4.41 (0.54)</td>
<td>4.06 (0.72)</td>
</tr>
<tr>
<td>Transmission of knowledge</td>
<td>2.79 (0.67)</td>
<td>2.80 (0.65)</td>
<td>2.79 (0.68)</td>
</tr>
<tr>
<td>Interest in science</td>
<td>4.06 (0.57)</td>
<td>4.10 (0.60)</td>
<td>4.01 (0.55)</td>
</tr>
<tr>
<td>Teachers’ self-concept of ability in science</td>
<td>3.75 (0.69)</td>
<td>3.74 (0.68)</td>
<td>3.76 (0.71)</td>
</tr>
<tr>
<td>Self-reported teaching time in science</td>
<td>2.86 (1.05)</td>
<td>3.27 (1.03)</td>
<td>2.42 (0.87)</td>
</tr>
</tbody>
</table>

Note. KG = kindergarten, LGES = lower grade elementary school, UTE = university of teacher education, TTS = teacher training seminar. Coding: Classification of children’s statements, performance from 0 to 100; Assessment of the importance of learning goals, Likert scale from 1 (not important at all) to 5 (very important); Beliefs about teaching and learning, Likert scale from 1 (not important at all) to 5 (very important); Interest in science, Likert scale from 1 (fully incorrect) to 5 (fully correct); Self-concept of ability in science, Likert scale from 1 (fully incorrect) to 5 (fully correct); Self-reported teaching time in science, Likert scale, 1 (less than ½ hour a week), 2 (1/2 to 1 hour a week), 3 (1 to 2 hours a week), 4 (2 to 5 hours a week), and 5 (more than five hours a week).

Question 1: Differences Between KG- and LGES-Teachers With Respect to Their Science-Specific Pedagogical Content Knowledge

LGES-teachers scored higher in the classification of children’s statements (M = 62.1, SD = 16.1), than KG-teachers (M = 60.3, SD = 17.2), see Figure 2.1. This difference was not significant \( t(177.9) = -0.72, p > .05 \); it did represent a small effect, Cohen’s \( d = .11 \).

With respect to the assessment of learning goals, LGES-teachers assigned a lower importance to domain-specific learning goals (M = 3.69, SD = 0.50), than KG-teachers (M = 3.78, SD = 0.59), see Figure 2.2. This difference was not significant \( t(176.6) = 1.16, p > .05 \); it did represent a small effect, Cohen’s \( d = .17 \). LGES-teachers assigned a higher importance to domain-general learning goals.
(M = 3.97, SD = 0.53), than KG-teachers (M = 3.77, SD = 0.55), see again Figure 2.2. This difference was significant \( t(179) = -2.58, p < .05 \), and represented a medium effect, Cohen’s \( d = .38 \).

**Figure 2.1.** Classification of children’s statements according teaching grade. KG = kindergarten; LGES = lower grade elementary school. Error bars represent the 95% confidence intervals.

**Figure 2.2.** Teachers’ assessment of learning goals according teaching grade. KG = kindergarten; LGES = lower grade elementary school. Likert scale from 1 (not important at all) to 5 (very important). Error bars represent the 95% confidence intervals.

Group-specific differences in teachers’ pedagogical content beliefs about teaching and learning were assessed comprehensively by means of MANOVA and separately by means of individual with Holm-Bonferroni corrected \( t \)-tests (see methods section):

The MANOVA revealed that there was a significant effect of group membership (KG vs. LGES) on teachers’ beliefs (combining all six belief scales), \( F(6, 174) = 4.60, p < .001 \).

In the individual \( t \)-tests, significant differences were observed in two out of the six scales (compare with Table 2.7 and Figure 2.3): KG-teachers agreed more with the belief ‘Play’ and less with the belief ‘Situated construction of knowledge’ compared to LGES-teachers.
Table 2.7
Comparison of Teachers’ Beliefs According to Teaching Grade

<table>
<thead>
<tr>
<th>Belief scale</th>
<th>M [SD]</th>
<th>t-statistics</th>
<th>Holm-Bonferroni</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KG</td>
<td>LGES</td>
<td>---</td>
</tr>
<tr>
<td>Play</td>
<td>4.41 (0.54)</td>
<td>4.06 (0.72)</td>
<td>$t(162.2) = 3.62, p = 0.0004, Cohen’s $d = 0.54$</td>
</tr>
<tr>
<td>Situated construction of knowledge</td>
<td>3.46 (0.80)</td>
<td>3.78 (0.70)</td>
<td>$t(178.9) = 0.95, p = 0.0048, Cohen’s $d = 0.42$</td>
</tr>
<tr>
<td>Hands-on activity</td>
<td>3.45 (0.58)</td>
<td>3.23 (0.58)</td>
<td>$t(178.4) = 2.46, p = 0.0148, Cohen’s $d = 0.37$</td>
</tr>
<tr>
<td>Co-constructing knowledge</td>
<td>3.98 (0.56)</td>
<td>3.90 (0.52)</td>
<td>$t(178.9) = 0.95, p = 0.3459, Cohen’s $d = 0.14$</td>
</tr>
<tr>
<td>Restructuring knowledge</td>
<td>2.95 (0.65)</td>
<td>2.90 (0.60)</td>
<td>$t(179.0) = 0.50, p = 0.6182, Cohen’s $d = 0.07$</td>
</tr>
<tr>
<td>Transmission of knowledge</td>
<td>2.80 (0.65)</td>
<td>2.79 (0.68)</td>
<td>$t(177.2) = 0.06, p = 0.9487, Cohen’s $d = 0.01$</td>
</tr>
</tbody>
</table>

Note. KG = kindergarten; LGES = lower grade elementary school; $p_{crit}$ = critical values for $p$ based on the Holm-Bonferroni correction.

* indicates that a comparison is significant

Figure 2.3. Teachers’ beliefs about teaching and learning according teaching grade. KG = kindergarten; LGES = lower grade elementary school. Likert scale from 1 (not important at all) to 5 (very important). Error bars represent the 95% confidence intervals.

In conclusion to the first research question, the hypothesized differences between KG- and LGES-teachers with respect to their science-specific pedagogical content knowledge was only partly supported by the analyses conducted above: No significant differences between these groups were found for their classification of children’s statements and nor for their assessment of domain-specific learning goals. In contrast to the formulated hypothesis, LGES-teachers assessed domain-general learning goals more positively compared to KG-teachers. However, with respect to the teacher beliefs,
KG- and LGES-teachers differed significantly in their belief system in general, and more specifically with respect to the beliefs of situated construction of knowledge and play.

**Question 2: Differences Between KG- and LGES-Teachers With Respect to Their Interest and Self-Concept of Ability Towards Science**

In contrast to the formulated hypotheses, no significant differences were found between KG- and LGES-teachers with respect to both their interest and their self-concept of ability in science; see Figure 2.4, respectively Figure 2.5.

LGES-teachers reported a lower interest ($M = 4.01$, $SD = 0.55$), than KG-teachers ($M = 4.10$, $SD = 0.60$). This difference was not significant $t(177.8) = 0.96$, $p > .05$, Cohen’s $d = 0.14$.

LGES-teachers reported a higher self-concept of ability ($M = 3.76$, $SD = 0.71$), than KG-teachers ($M = 3.74$, $SD = 0.68$). This difference was not significant $t(176.6) = -0.11$, $p > .05$, Cohen’s $d = 0.02$.

In conclusion to the second research question, the hypothesized higher interest and self-concept of ability in science of LGES-teachers (compared to KG-teachers) could not being supported.
Question 3: Differences Between KG- and LGES-Teachers With Respect to Their Self-Reported Teaching Time in Science

KG-teachers reported devoting more teaching time in science (M = 3.27, SD = 1.03), than LGES-teachers (M = 2.42, SD = 0.87), see Figure 2.6. This difference was significant t(176.7) = 6.02, p < .001; it did represent a large effect, Cohen’s d = 0.89. This finding is opposed to the formulated hypothesis.

![Figure 2.6. Self-reported teaching time in science according teaching grade. KG = kindergarten; LGES = lower grade elementary school. Likert scale: 1 (less than ½ hour a week), 2 (1/2 to 1 hour a week), 3 (1 to 2 hours a week), 4 (2 to 5 hours a week), and 5 (more than five hours a week). Error bars represent the 95% confidence intervals.]

Question 4: Type of Professional Education as Predictor for These Differences

The question whether the type of professional education can further explain the dependent variables of question 1 to 3 was examined by several regression analyses. The type of professional education (TTS vs. UTE) was inserted as third predictor, after controlling for teachers’ teaching experience and their teaching grade. The following tables report these regression analyses using unstandardized regression coefficients. In the example for the dependent variable of teachers’ classification of children’s statements, it can be read as follows: An additional year of teaching experience leads to a decrease of 0.16 points in the performance of teachers’ classification of children’s statements (in its original scale). The predictors of teaching grade and professional education indicate the shift from being a KG-to a LGES-teacher, and the shift from being educated at the TTS to UTE respectively.

Table 2.8 provides the information about the three regression analyses for teachers’ classification of children’s statements and their assessment of domain-specific and domain-general learning goals respectively. With respect to teachers’ classification of children’s statements, neither of the predictors were significant predictors. In consequence, this model accounted for only 1% of the variability in the dependent variable. Non-significant predictors were also detected for teachers’ assessment of domain-specific learning goals. The assessment of domain-general learning goals was significantly predicted
by teaching experience and the type of teaching grade, but not by the type of professional education. This result is consistent with the found significant difference between the respective means of KG- and LGES-teachers.

Table 2.8
Regression Analyses on Teachers’ Classification of Children’s Statements and Their Assessment of the Importance of Learning Goals

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Classification of children’s statements</th>
<th>Assessment of learning goals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Domain-specific learning goals</td>
</tr>
<tr>
<td>Intercept</td>
<td>62.53*** (3.23)</td>
<td>3.84*** (0.11)</td>
</tr>
<tr>
<td>Teaching experience</td>
<td>-0.16 (0.16)</td>
<td>&lt;-0.01 (0.01)</td>
</tr>
<tr>
<td>Teaching Grade (0=KG, 1=LGES)</td>
<td>2.02 (2.50)</td>
<td>-0.09 (0.08)</td>
</tr>
<tr>
<td>Professional Education (0=TTS, 1=UTE)</td>
<td>0.41 (3.82)</td>
<td>-0.04 (0.13)</td>
</tr>
<tr>
<td>R²</td>
<td>.01</td>
<td>.01</td>
</tr>
</tbody>
</table>

Note. Unstandardized regression coefficients; standard errors in parentheses. KG = kindergarten; LGES = lower grade elementary school, UTE = university of teacher education, TTS = teacher training seminar. Coding: Classification of children’s statements, performance from 0 to 100; Assessment of the importance of learning goals, Likert scale from 1 (not important at all) to 5 (very important).
***p < .001, **p < .01, *p < .05

The regression analyses for teachers’ beliefs about teaching and learning are presented in Table 2.9. Note that the type of teaching grade was a significant predictor for the three scales ‘Situated construction’, ‘Hands-on activity’ and ‘Play’, which is largely consisted with the conducted mean comparisons above. These three scales were not explained additionally by the type of professional education. Interestingly, the other scales (restructuring, co-construction and transmission) were not significantly predicted by the teaching grade, but indeed by the type of professional education (0.38, .40, and -0.14 respectively). Note that these models explained between 5 and 14% of the variance in the respective dependent variables.
Table 2.9
Regression Analyses on Teachers’ Beliefs About Teaching and Learning

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Restructuring knowledge</th>
<th>Co-constructing knowledge</th>
<th>Situated construction of knowledge</th>
<th>Hands-on activity</th>
<th>Play</th>
<th>Transmission of knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.04*** (0.11)</td>
<td>3.65*** (0.10)</td>
<td>3.31*** (0.14)</td>
<td>3.45*** (0.11)</td>
<td>4.44*** (0.12)</td>
<td>2.99*** (0.13)</td>
</tr>
<tr>
<td>Teaching experience</td>
<td>-0.01 (0.01)</td>
<td>0.02*** (&lt;0.01)</td>
<td>0.01 (0.01)</td>
<td>&lt;0.01 (0.01)</td>
<td>&lt;0.01 (0.01)</td>
<td>-0.01 (0.01)</td>
</tr>
<tr>
<td>Teaching Grade (0=KG, 1=LGES)</td>
<td>-0.03 (0.09)</td>
<td>-0.10 (0.08)</td>
<td>0.31** (0.11)</td>
<td>-0.21* (0.09)</td>
<td>-0.34*** (0.10)</td>
<td>&lt;0.01 (0.10)</td>
</tr>
<tr>
<td>Professional Education (0=TTS, 1=UTE)</td>
<td>0.38** (0.13)</td>
<td>0.40*** (0.12)</td>
<td>0.28 (0.17)</td>
<td>-0.14 (0.13)</td>
<td>-0.13 (0.15)</td>
<td>-0.41** (0.15)</td>
</tr>
</tbody>
</table>

R² .14 .09 .06 .05 .07 .04

Note. Unstandardized regression coefficients; standard errors in parentheses. KG = kindergarten; LGES = lower grade elementary school; UTE = university of teacher education, TTS = teacher training seminar. Coding: Beliefs about teaching and learning, Likert scale from 1 (not important at all) to 5 (very important).
***p < .001, **p < .01, *p < .05

Finally, Table 2.10 presents the regression analyses for teachers’ interest, self-concept of ability and self-reported teaching time in science. In accordance to the mean comparisons above, teaching grade was only for the self-reported teaching time a significant predictor. In these models, the type of professional education could not further predict the respective dependent variables on a significant level.

Table 2.10
Regression Analyses on Teachers’ Interest, Self-Concept of Ability, and Their Self-Reported Teaching Time in Science

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Teachers’ interest in science</th>
<th>Teachers’ self-concept of ability in science</th>
<th>Self-reported teaching time in science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.95*** (0.11)</td>
<td>3.48*** (0.13)</td>
<td>3.33*** (0.19)</td>
</tr>
<tr>
<td>Teaching experience</td>
<td>0.01 (0.01)</td>
<td>0.02** (0.01)</td>
<td>-0.01 (0.01)</td>
</tr>
<tr>
<td>Teaching Grade (0=KG, 1=LGES)</td>
<td>-0.10 (0.09)</td>
<td>-0.02 (0.10)</td>
<td>-0.85*** (0.14)</td>
</tr>
<tr>
<td>Professional Education (0=TTS, 1=UTE)</td>
<td>0.03 (0.13)</td>
<td>-0.03 (0.15)</td>
<td>0.12 (0.22)</td>
</tr>
</tbody>
</table>

R² .03 .08 .17

Note. Unstandardized regression coefficients; standard errors in parentheses. KG = kindergarten; LGES = lower grade elementary school; UTE = university of teacher education, TTS = teacher training seminar. Coding: Interest in science, Likert scale from 1 (fully incorrect) to 5 (fully correct); Teachers’ self-concept of ability in science, Likert scale from 1 (fully incorrect) to 5 (fully correct); Self-reported teaching time in science, Likert scale, 1 (less than ½ hour a week), 2 (½ to 1 hour a week), 3 (1 to 2 hours a week), 4 (2 to 5 hours a week), and 5 (more than five hours a week).
***p < .001, **p < .01, *p < .05
In conclusion to the fourth research question, the hypothesized higher performance in the classification of children’s statements and the higher assessment of domain-specific learning goals of UTE-teachers (in comparison to teachers educated at TTS) could not be supported by the data. Interestingly, the hypothesis of UTE-teachers’ higher agreement in scales representing the constructivist nature of learning could be supported for ‘restructuring knowledge’ and ‘co-constructing knowledge’, but not for ‘situated construction of knowledge’. There was also no support for the hypotheses that UTE-teachers were associated to a higher interest respectively self-concept of ability in science.

2.5 Discussion

The main aim of this study was to investigate kindergarten (KG) and lower grade elementary school teachers’ (LGES) pedagogical content knowledge relevant for early science education. Science education in early years is an under-researched field (Greenfield et al., 2009). Studies looking at the early education through domain-specific lenses are rare. However, a domain-specific perspective for early childhood education seems important because of the reassessment of children’s cognitive potential for domain-specific learning in developmental psychology during the last decades on the one hand, and the identified unfavorable conditions for early science education in the field (teachers’ lack of pedagogical content knowledge; few opportunities for science learning, etc.).

The research questions were formulated to specifically address commonalities and differences between kindergarten and lower grade elementary school teachers. Hypotheses were formulated from the background of group-specific professional socialization (Kelchtermans & Ballet, 2002; Murray & Male, 2005; Wannack, 2004). With respect to the first three questions, group-specific differences in teachers’ cognitions (knowledge, beliefs, etc.) were considered to have developed as a result of a differing work place environment (with its own characteristics including social, structural, and spatial aspects). With respect to the fourth research question, it was hypothesized that teachers’ type of professional education would further (after controlling for KG vs. LGES) explain differences in the analyzed aspects of teacher cognitions.

The results of this study showed that the hypotheses about differences between KG- and LGES-teachers with respect to their pedagogical content knowledge (Question 1) must be rejected for the majority of the analyzed measures: These groups of teachers didn’t differ in their classification on children’s statements about floating and sinking, nor in their assessment of the importance of domain-specific learning goals. Hence, KG- and LGES-teacher do not seem to have developed extremely different bodies of science pedagogical content knowledge, despite being socialized in the respective environments. However, with respect to teachers’ beliefs about teaching and learning in science, distinct differences between these groups were detected for two out of the six of the analyzed scales. In accordance to the hypotheses, KG-teachers agreed higher on the scale ‘Play’. These results fit the
characterization of early childhood education highlighting the importance on the pedagogy of play (Miller & Almon, 2009; Saracho & Spodek, 1995; Wannack, 2004). The data did not support the hypotheses about differences between KG- and LGES teachers with respect to their interest and their self-concept of ability in science (Question 2). Overall, the revealed commonalities between KG- and LGES-teachers with respect to their pedagogical content knowledge and beliefs could be explained by the trend of incorporating kindergarten into the public school related to the tertiarization of teacher education in Switzerland (Criblez & Hofstetter, 2002; Wannack, 2004): This trend might have equalized some of the formerly present differences in teachers’ working environment.

The comparison of self-reported teaching time between KG- and LGES-teachers (Question 3) revealed an unexpected result: KG-teacher reported spending significantly more teaching time in science compared to LGES-teachers. This finding is remarkable because it contrasts with research stating that only a small share of time is allocated for science education in early education (Early et al., 2010; Sačkes et al., 2011). More time devoted to science in kindergarten is even more remarkable, if one considers the smaller total amount of instruction time compared to elementary school. It seems, that KG-teachers offer, be it consciously or not, more science-related opportunities for learning than LGES-teachers. A possible explanation can be pointed out that LGES-teacher might feel a higher pressure at elementary school to devote more instruction time to other fields, such as mathematics or language, at cost of the science instruction time. Children’s mathematics and language competence might be perceived as being more relevant for later learning. This would fit into the characterization of elementary schools as institutions, which, compared to kindergarten, additionally fulfill the function of selection, besides the functions qualification and social integration (Wannack, 2004).

Finally, the fourth research question asked whether teachers’ type of professional education further explained the level in teachers’ pedagogical content knowledge, beliefs, etc., after controlling for their working experience and the teaching grade (KG vs. LGES). It was expected that being educated at UTE (compared to TTS) is associated with the development of a more thorough pedagogical content knowledge. The results showed that the type of professional education could only partly explain teachers’ pedagogical content knowledge: On the one hand, the type of professional education could neither explain teachers’ classification of children’s statements, nor their assessment of domain-specific learning goals, and nor teachers’ interest, self-concept of ability and self-reported teaching time. These results are surprising if one considers the goals of professionalization in teacher education, which is to equip teachers with a solid base of research-based professional knowledge and competence (Criblez & Hofstetter, 2002). On the other hand, the type of professional education was indeed a significant predictor of teachers’ beliefs: Teachers educated at UTE were associated to increased agreements with respect to the beliefs ‘restructuring knowledge’ and ‘co-constructing knowledge’ and to decreased agreements with respect to the belief of ‘transmission of knowledge’. As outlined in the theoretical
section, the directions of these changes are to be evaluated as beneficial, since they cohere to a state-of-the-art understanding of science learning.

The limitations of this study are related to the difficulty in how meaningfully to assess teachers’ pedagogical content knowledge in the early years of education (for teacher beliefs, see Pajares, 1992). In this study, teachers’ pedagogical content knowledge was assessed in their classification of children statements and domain-specific/domain-general learning goals within very specific curricular topics (floating and sinking and farms/farming respectively). It remains open whether the results would be consistent, if different curricular topics would have been chosen as a context for measuring teachers’ pedagogical content knowledge. Even though there is strong consensus on the theoretical importance of teachers’ pedagogical content knowledge (for details, see chapter 1.2), it remains a challenge to clearly determine facets for a meaningful measurement (Stern, 2009). This problem of determining teachers’ pedagogical content knowledge might be especially articulated in early science education, where subject-specific boundaries do not yet exist in the curricula. Teachers’ pedagogical beliefs were framed from a domain-specific perspective, because the associated items covered science-specific conceptions about teaching and learning. However, it is not fully clear to what extent these scales indeed represent domain-specific or a domain-general view about learning. This problem has already been discussed by Kleickmann (2008) and can be illustrated in models of professional competence, where beliefs can conceptualized both as being a component of domain-specific pedagogical content knowledge or as a domain-general aspect (see Figure 1.2, chapter 1.2).

What are the implications of this study for the conditions of children’s science learning in kindergarten and the lower grade elementary school? Effective science learning in primary education is considered to depend on sufficient specific learning opportunities (Cabe Trundle & Saçkses, 2012), adequate learning materials (Hardy et al., 2006; Leuchter et al., 2014; Tu, 2006) and, last but not least, knowledgeable and confident teachers (Appleton, 2003, 2007, 2008; Magnusson et al., 1999). With respect to science instruction, knowledgeable teachers should be able to grasp the challenges associated with the constructivist nature of learning and, in consequence, to provide support adapted to children’s needs (Eshach, Dor-Ziderman, & Arbel, 2011; van de Pol, Volman, & Beishuizen, 2010). The expressed apprehension that children at lower grades would be assisted by less knowledgeable and less confident teachers could, fortunately, not be supported by the data. In contrast, children’ at kindergarten seem to have more time compared to their companions at elementary school for learning and thinking about natural phenomena.

What are the implications of this study for the professional education at UTE? The good news is that these result support the claim that being educated at UTE seems to strengthen teachers’ understanding of the constructivist nature of learning. As explicated in the theoretical section, an understanding of the constructivist nature of learning can clearly be considered as a meaningful target for the alteration of teacher beliefs about science learning (Duit & Treagust, 1998, 2003; Hartinger et al., 2006).
bad news is that being educated at UTE was not a predictor of the other analyzed aspects of teachers’ pedagogical content knowledge, and neither seems to affect teachers’ interest and self-concept of ability in science. In the theoretical section, knowledge and beliefs were described as being equally important for teachers (because both are considered to affect their behavior in classroom), but as having a different epistemic status (Fenstermacher, 1994). At universities of teacher education, knowledge construction should target knowledge construction of a high epistemic status, in other words, knowledge, which is both well-referenced in recent literature and tangible for students. Universities of teacher education have to reflect about whether their students have enough opportunities to build such domain-specific content and pedagogical content knowledge for early science education (Cabe Trundle & Saçkes, 2012). For the study programs at universities of teacher education, it seems important that students can build awareness about their subjective theories about science learning, including their negative attitudes, misunderstandings and misconceptions (Garbett, 2003). The explication of how to understand effective science instruction seems essential in order to build teachers’ professional knowledge and associated interest and confidence.
2.6 References


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3 Early Science Learning: The Effects of Teacher Talk

3.1 Introduction

Language is of utmost importance for the child’s cognitive development including the development of scientific skills and concepts (Haug & Ødegaard, 2014; Henrichs & Leseman, 2014; Saalbach, Grabner, & Stern, 2013; Saalbach, Leuchter, & Stern, 2010; Tomasello, 1999). Tomasello (1999) lists three main dimensions in the way language influences children’s cognitive development: First, language affects children’s development through parents, teachers, or other adults providing instructions and explanations; second, language directs children’s attention; and third, language prompts children to change perspectives. Language can thus be seen as the basis for the organization of children’s cognitive activities and the construction of higher knowledge structures encompassing science knowledge (Saalbach et al., 2013). This study examines the role of language in early science learning. In particular, teacher talk was investigated as a scaffold for children’s cognitive processes underlying science learning.

The Possibilities and Boundaries of Young Children's Science Learning

Science learning can be understood as conceptual change, whereby humans integrate information about the world around them in a process of mental theory building (Carey, 1985; Chi, 2008; Vosniadou, 1994). Intuitive beliefs having validity limited to specific experiences of everyday life are to be reconstructed into conceptual knowledge having wider validity needed for further learning. Evidence from the last decades of research on children’s early cognitive development has led to a profound revision of young children’s cognitive resources for science learning (Carey, 1985; Metz, 1995). It could convincingly be demonstrated that young children are biologically prepared to learn science (Baillargeon, 1994; Carey, 1985; Cohen & Cashon, 2007; Gopnik, 2012; Mandler, 2008; Metz, 1995). At preschool and early elementary school age children have surprisingly well-developed abilities for scientific reasoning in conditions of child-oriented tasks and appropriate learning support (Koerber, Sodian, Thoermer, & Nett, 2005; Sodian, Zaichik, & Carey, 1991; Tytler & Peterson, 2003; Zimmerman, 2007). Already infants acquire a substantial amount of knowledge about their surrounding natural world in a process of intuitive theory building (Baillargeon, 1994; Carey, 1985; Cohen & Cashon, 2007; Gopnik, 2012; Mandler, 2008). Young children constantly evaluate their internal knowledge structures against what they observe in the world around them. In that sense, children’s learning resembles closely theory building in science, where hypotheses are tested against data (Gopnik, 2012). Young children are able to construct abstract and coherent representations of the world around them. For instance in the domain of physics, it could be shown that infants at the age of
only four months have already built intuitive knowledge about permanency and solidity of physical objects (Baillargeon, 1987; Spelke, Breinlinger, Macomber, & Jacobson, 1992). Besides the simple mechanics of solid bounded objects (naive physics) researchers have also extensively studied children’s intuitive knowledge bases in other areas, such as the behaviors of psychological agents (naive psychology) or the actions and organization of living things (naive biology) (Akerson, Weiland, & Fouad, 2015; Hadzigeorgiou, 2015; Saçkes, 2015). Relating to these fields of research, there is a growing consensus that science education should start as early as in preschool age (Eshach, 2011; Eshach & Fried, 2005; French, 2004). Early science education should exploit children’s cognitive potentials to prepare them for further science learning towards the goal of scientific literacy (Bybee, McCrae, & Laurie, 2009; French, 2004; OECD, 2013).

Despite children’s cognitive resources for science learning, there are also limitations which require special attention. Young children, in general, have less prior knowledge and less developed self-regulation skills than older children and adults (Center on the Developing Child at Harvard University, 2011; Morrison, Ponitz, & McClelland, 2010; Ruff & Lawson, 1990; Saalbach et al., 2013). Self-regulation refers to cognitive processes such as attention, working memory, and inhibitory control that enable children to follow an instruction, to stay attentive, to complete tasks, and work independently. Although, children’s self-regulation typically develops rapidly during the preschool years, there is substantial individual variation (Gunzenhauser & von Suchodoletz, 2015). These limitations not only affect the acquisition of complex concept knowledge but also children’s capability to organize and reflect about their own learning.

Given these cognitive resources and limitations, young children’s potential for science learning in early science education might be best exploited, if (1) children’s domain-specific prior knowledge is taken into account, and (2) if domain-specific learning support is provided at the appropriate level.

**Effects of Teacher Talk on Children’s (Science) Learning in Early Childhood and Primary Education**

Teacher talk is seen as an important factor in children’s language development. In particular, research on children’s language acquisition has revealed that the quantity and complexity of teacher (and adult) talk positively relates to children’s development of language and literacy skills (Dickinson & Porche, 2011; Foy & Mann, 2003; Huttenlocher, 1998; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Huttenlocher, Vasilyeva, Cyberman, & Levine, 2002). For example, Huttenlocher et al. (2002) found that individual differences in children’s mastery of multiclause sentences was associated to the proportion of multiclause sentences in parental talk. At preschool, they further found that those children showed a greater syntactic growth over a year where teachers talk was more syntactically

27 Note, the term teacher refers in this paragraph also to other pedagogic personnel (for instance, caregivers).
complex. Further, teacher talk is an important component of the teacher-child interaction, which has been identified as one of the most important aspects for high-quality early childhood respectively preschool education (e.g., Curby et al., 2009; Hamre, Downer, Jamil, & Pianta, 2012; Hopf, 2011; Siraj-Blatchford, Sylva, Muttock, Gilden, & Bell, 2002). Mascareño, Snow, Deunk, and Bosker (2016) analyzed the complexity of teacher-child verbal interaction patterns in Chilean kindergartens. They coded teacher-child discourses for function (initiation, response, and follow-up), type (e.g., open vs. closed questions), and complexity (literal vs. inferential initiations). They found positive relations between the proportion of inferential teacher-child talk and children’s vocabulary and symbolic understanding.

Research examining the relations between teacher talk and children’s learning in domains other than language, such as mathematics and science, is rare. In one of the few studies, Klibanoff, Levine, Huttenlocher, Vasilyeva, and Hedges (2006) examined the development of preschool children’s mathematical knowledge in relation to the amount of mathematical input in teacher talk over the period of one year. Teacher talk was coded according to different types of mathematically relevant input types, such as aspects of cardinality, equivalence, ordering, etc. They found that the amount of math input in teachers’ talk was significantly related to the growth of children’s mathematical knowledge at preschool. Interestingly, domain-general variables, such as syntax input, classroom quality, and socio-economic status, were not associated with these gains in mathematics knowledge. The importance of domain-specific teacher talk for children’s domain-specific learning has also been shown by Leuchter and Saalbach (2014). They found a relation between the content-specific accuracy in teacher talk and preschool children’s conceptual learning in early science instruction: Children learned less when teachers’ utterances contained scientifically erroneous statements.

In the context of elementary school science, a study by Hardy, Jonen, Möller, and Stern (2006) found that children’s conceptual understanding of floating and sinking can be optimized by providing instructional support. They defined instructional support in the sequencing of the activities on the one hand and in teachers’ provision of cognitively structuring statements on the other hand. However, the design of this study did not permit differentiation as to whether the sequencing of the instructional content or the structuring statements of the teacher led to the additional learning gain. Within the same content-area, Rappolt-Schlichtmann, Tenenbaum, Koepke, and Fischer (2007) investigated the effects of teachers’ support through modeling reasoning about why objects sink or float. They found that teachers’ support affected the complexity of children’s answers, but not their predictions about the objects buoyancy. In kindergarten science instruction, Eshach, Dor-Ziderman, and Arbel (2011) identified and described scaffolding strategies from a small sample of kindergarten teachers when conducting science activities. In an inductive procedure, they established a scaffolding scheme that differentiates between an affective and a cognitive domain. In the cognitive domain, they name scaffolding strategies according to the categories “Clarification and goal orientation”, “Task
reduction”, “Diagnosis and Calibration”, “Encouraging higher-order thinking language” and “Withdrawal techniques” (p. 556). Unfortunately, the study from Eshach et al. (2011) does neither inform about how frequently these scaffolding strategies were observed, nor about possible relations between these types of teacher input and children’s learning.

Previous research thus suggests that teacher talk can be conceptualized in two ways: First, as verbal input for incidental language and content learning (Dickinson & Porche, 2011; Foy & Mann, 2003; Huttenlocher, 1998; Huttenlocher et al., 2002; Klibanoff et al., 2006; Mascareño et al., 2016). From this perspective, the underlying rationale is that a higher amount and a more complex verbal input generates a richer learning environment which in turn increases the chance of children’s knowledge acquisition. According to this understanding, the role of the teacher is to contribute a rich (content-specific) language environment without directly addressing specific aspects of children’s learning (such as misconceptions, prior experiences, etc.). In this study, the term content-specific language (CSL) is used to refer to this kind of teacher talk. For teachers’ content-specific language, the general hypothesis is that children enhance their science learning (i.e. the construction of conceptual knowledge) from specific vocabulary in teachers’ talk. Following this idea, the exposure to content-specific vocabulary would stimulate the construction of appropriate representations of the phenomenon at hand. This would imply that children are able to form coherent conceptual knowledge simply based on being exposed to a set of content-specific vocabulary. Second, teacher talk can be conceptualized as verbal input intentionally directed at domain-specific learning (Eshach et al., 2011; Hardy et al., 2006; Rappolt-Schlichtmann et al., 2007). Teacher talk in this sense relates to the scaffolding metaphor, which was originally coined by describing a tutoring situation, where a more knowledgeable person enables a novice to succeed in a task, which would be otherwise out of reach (Vygotsky, 1978; Wood, Bruner, & Ross, 1976). In the last decades, the notion of scaffolding has become increasingly prominent in research on science instruction. Many different approaches to scaffolding have emerged addressing a variety of aspects of science instruction, such as the design of learning environments, the description of effective classroom communication, or conceptual learning (Eshach et al., 2011; Hogan & Pressley, 1997; Sandoval & Reiser, 2004). A review of empirical evidence on scaffolding for science education is provided by Lin et al. (2012). This review revealed that the scaffolding is most often studied at high-school level. Recent studies confirm the efficacy of scaffolding not only for learning and teaching in tutoring situations but also in group and even whole-class settings (Curby et al., 2009). In this study, the scaffolding function of teacher talk is referred to using the term scaffolding utterance. Here, the general hypothesis is that children enhance their science learning from teacher talk having underlying scaffolding functions, such as stimulating prior knowledge, asking open-ended questions or stimulating cognitive conflicts.
Framework for Analyzing Teacher Talk as a Scaffold for Science Learning

In a general framework for scaffolding, van de Pol, Volman, and Beishuizen (2010) distinguish between scaffolding *means* (‘how is scaffolding taking place’) scaffolding *intentions* (‘what is scaffolded’). For example, students’ metacognitive activities, cognitive activities, or emotion regulation (intentions) can be scaffolded by means of feedback, hints, instruction, explaining, modeling, or questioning. They further characterize scaffolding in teacher-student interactions by the inter-related aspects of ‘contingency’ and ‘transfer of responsibility’. The first aspect refers to the adaptation of teachers’ support to students’ actual needs, the second aspect to the incremental withdrawal of teachers’ support. Both aspects are described to account for the dynamic nature of the scaffolding process. It is not surprising that this dynamic and complex nature of defining scaffolding is associated to challenges respectively problems with respect to its measurement (Davis & Miyake, 2004; Granott, 2005; van de Pol et al., 2010). In the present study, this framework for the analysis of scaffolding served as a general idea, but does not fulfill the exact purpose, since it is clearly domain-general in nature.

Reiser (2004) suggests two mechanisms of teachers’ scaffolding talk in science learning: *structuring* and *problematizing*. According Reiser (2004)* structuring* targets the reduction of complexity by providing structural information, such as clarifying the goal, decomposing complex tasks, and focusing effort and monitoring. Hardy et al. (2006) used this kind of teacher scaffolding talk. *Problematizing* challenges students’ thinking about the problem and domain, in general, by prompting explanations, cognitive conflicts, or disagreements. While structuring is thought to reduce complexity, problematizing, in a way, increases the complexity and, through that, the cognitive demand for the learner. Therefore, structuring and problematizing can to some extent be seen as contrasting mechanisms of scaffolding. Reiser’s proposal of a dual mechanism for scaffolding of science learning has been similarly applied in other studies: Furtak, Seidel, Iverson, and Briggs (2012), for example, introduced a framework for inquiry-based science teaching that distinguishes the degree of guidance (cf. to the mechanism of structuring) on the one hand and cognitive features (cf. to the mechanism of problematizing) on the other hand. Steffensky, Gold, Holdynski, and Möller (2015) used the terms structuring (identical term) and cognitive activation (cf. to the mechanism of problematizing) to describe facets of teachers’ professional vision of learning support. These studies point out that teacher talk serves either the structuring function or the problematizing function. These two broad functions will be developed in further detail below.

The structuring mechanism targets, in the first instance, supporting children’s understanding of the task, including the learning goal associated to the phenomenon at hand. Meta-analyses revealed that being clear and transparent about learning goals is an important determinant of instructional quality (e.g., Hattie, 2009). This kind of teacher talk could be illustrated by repeating task descriptions, explaining part of the phenomenon or giving guidance about the next step in the procedure of the task.
Kirschner, Sweller, and Clark (2006) highlight that the provision of structure and guidance would especially be important for novices, who do not have a very large amount of prior knowledge yet. A second instance of the structuring mechanism is teacher talk, which directs children’s attention to the relevant aspects of the phenomenon to be investigated. The possibility and importance of directing children’s attention via verbal prompts is extensively researched in the field of infants’ cognitive development (e.g., Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998; Daum, Ulber, & Gredebäck, 2013; Senju & Csibra, 2008). Beneficial effects of this kind of teacher talk can be explained by the cognitive load theory suggesting that instructional support facilitates children’s learning through directing children’s cognitive resources towards the most important aspects (Chandler & Sweller, 1991; Sweller, 1994; Sweller, van Merrienboer, & Paas, 1998). From a developmental perspective, self-regulation is a realm of drastic changes around the preschool age as mentioned above (Center on the Developing Child at Harvard University, 2011). Therefore, children’s learning at this age may especially benefit from prompts directing their attention.

The problematizing mechanism includes, in the first instance, prompts directed to the activation of children’s prior knowledge. Prior knowledge activation is per se seen as a necessary pre-condition for any conceptual learning (Carey, 1985; Posner, Strike, Hewson, & Gertzog, 1982; Vosniadou, 1994). Questioning is a strategy tightly related to the activation of prior knowledge. Several studies highlight the role of questioning for (science) learning (Chappell, Craft, Burnard, & Cremin, 2008; Chin, 2006; Kawalkar & Vijapurkar, 2013; Saalbach & Schalk, 2011). For instance, Saalbach and Schalk (2011) could demonstrate that asking question can support children’s ability to categorize items according to a taxonomical logic, rather than according to mere perceptual features. They concluded that questions perform a crucial function in the activation of children’s prior knowledge. A second instance of the problematizing mechanism include prompting children to explain, compare, reason or resolve discrepancies with respect to the phenomenon at hand. These four sub-facets will be explained in the following: (i) Prompting self-explanations has been identified as an important source for conceptual learning in different domains (Berthold, Eysink, & Renkl, 2009; Chi, De Leeuw, Chiu, & Lavancher, 1994; Rittle-Johnson, 2006; VanLehn, Jones, & Chi, 1992). For instance, Chi et al. (1994) demonstrated that prompting students for self-explanations positively affects their conceptual understanding about humans circulatory system. They described self-explanations as a constructive activity, whereby the learner builds awareness about the consistency between newly acquired knowledge and his or her existing mental knowledge structures (Chi et al., 1994). (ii) There is a broad agreement that comparison is a fundamental mechanism for conceptual learning (for an overview, see Gentner, 2010; Holyoak, 2005; Rittle-Johnson & Star, 2011). The general idea of comparison is that children learn from the juxtaposition of two elements, because their similarities and differences become highlighted. In this process, the learner processes the learning material in depth and is more likely to reason about the abstract underlying conception. The positive effect of comparison on
children’s learning is well-understood in different fields (for a recent meta-study, see Alfieri, Nokes-Malach, & Schunn, 2013), such as language development (Gentner, Loewenstein, & Hung, 2007; Gentner & Namy, 1999), propositional logic (Schalk, Saalbach, & Stern, 2016), mathematics (Ziegler & Stern, 2014, 2016) or science (Haglund, 2012; Kurtz, Miao, & Gentner, 2001). For instance, Gentner and Namy (1999) demonstrated that children of the age of four years are capable of identifying a common abstract conceptual characteristic of two perceptually different objects after being prompted for a comparison. Conversely, it could be shown that contrasted comparisons of perceptually similar but conceptually different learning material in mathematics lead to increased conceptual understanding in elementary school mathematics (Ziegler & Stern, 2014, 2016).

(iii) Prompts, then, could be directed to stimulate children’s scientific reasoning. In science education, reasoning is discussed within the concept scientific inquiry (for models of the process of scientific inquiry, see Bybee, 2006; Chen & Klahr, 1999; Klahr, 2000; Zimmerman, 2000, 2007). Hereby, teacher talk should stimulate children to evaluate evidence, i.e. the comparison between hypotheses and experimental observations (Klahr, 2000; Klahr & Dunbar, 1988). Understanding the control of variables strategy (CVS) is as an important aspect of scientific reasoning. CVS is a domain-general processing strategy that refers to the production, respectively the understanding of unconfounded experiments. Chen and Klahr (1999) demonstrated with children aged from seven to ten that direct instruction on CVS improved children’s understanding of CVS and domain-specific learning.

(iv) Invoking cognitive conflicts is seen as a further typical instructional strategy to foster conceptual learning (Limón, 2001; Posner et al., 1982). Hereby, new data or contradictory information is presented to produce a mental disequilibrium with previously held conceptions. The associated dissatisfaction was already posited as a precondition for conceptual learning in early theories about conceptual change (Posner et al., 1982). On the other hand, a known problem of prompting cognitive conflicts is that the learner must have the ability to reach a state of a meaningful conflict, which might be constrained by limited prior knowledge (Dreyfus, Jungwirth, & Eliovitch, 1990). Therefore, the prompt for cognitive conflict may not necessarily support conceptual learning in a beneficial way.

The review presented above led to the following framework for analyzing teacher talk according to different types of scaffolding intentions:

(A) Clarification of phenomenon, task, and procedure: Clarify goals and the associated procedures for investigating a natural phenomenon

(B) Focus of attention: Sharpen the focus of attention to specific properties of the phenomenon

(C) Activation of prior knowledge: Activate children’s intuitive knowledge to motivate the formulation of hypotheses about the phenomenon

(D) Challenging conceptual change: Support children’s knowledge construction via prompting explanations, comparisons, reasoning, cognitive conflict
The following notes should further clarify the above presented framework: The formulated categories and descriptions relate to the question of ‘what to scaffold’ (i.e. the scaffolding intentions), and not to the question of ‘how to scaffold’ (i.e. the scaffolding means). For instance, teachers’ utterances of type B express the intention to sharpen children’s focus of attention towards the targeted properties of the phenomenon at hand, regardless through which verbal means (be it a question, a modeling, a hint, etc.) this is achieved. This should steer the analysis of teacher talk towards its potential influence on children’s learning (and away from a purely literal analysis). In this study, children’s learning was conceived as a process of conceptual reconstruction from naive conceptions towards more elaborated conceptions within the topic ‘floating and sinking’ (see methods section for detailed information). It is important to recognize that the types (A) and (B) are closely related to the mechanism of structuring (and the need to address preschoolers’ cognitive limitations) and categories (C) and (D) to the mechanism of problematizing (and the need to address preschoolers’ cognitive resources). Teacher talk of all four types was hypothesized to be positively related to children’s conceptual learning (see hypotheses further below). A hierarchical nature of this framework is presumed in the sense that structuring is a precondition of problematizing, and within structuring, that being clear about the phenomenon, task and procedure (A) is a precondition for the focus of attention (B), and finally within problematizing, activation of prior knowledge (C) is a precondition for challenging conceptual change (D). The strength in the framework presented above lies, it will be argued, in its direct references to theories about learning as conceptual reconstruction, whereas both scaffolding mechanisms of structuring and problematizing are integrated, and in its domain-specific orientation.

3.2 The Present Study

There is a considerable body of research about the curricular development and examples of best practice in early science instruction (e.g., Eshach et al., 2011; French, 2004; Peterson & French, 2008). However only very few studies have analyzed the effectiveness of these developments and practices (Greenfield et al., 2009). The present study examined the effect of teacher talk on children’s conceptual learning in early science instruction. To this aim $N = 32$ kindergarten teacher were videotaped while tutoring a group of children about the topic floating and sinking. Videos of 40 minutes length were recorded at the beginning of a four weeks phase covering inquiry-based instruction about the topic of floating and sinking. These videos and respective transcripts served as information sources to code and quantify teacher talk as content-specific language on the one hand and as scaffolding utterances on the other hand. The coding was established through an inter-rater agreement procedure. Teachers’ content-specific language was analyzed for the occurrence of vocabulary specific to the topic floating and sinking. Teachers’ scaffolding utterances were coded according the logic of the newly established framework (see the respective theoretical and methodological sections), which interprets teacher talk according to different types of scaffolding.
intentions: (A) Clarification of phenomenon, task, and procedure, (B) Focus of attention, (C) Activation of prior knowledge and (D) Challenging conceptual change (examples are provided in the methods section). Children’s performance was assessed employing a repeated measures-design (pre-test and post-test) in individual testing sessions covering four tasks about conceptual knowledge within the topic floating and sinking.

To my knowledge, this is the first study that tries to empirically link specific types of teacher talk to children’s conceptual learning in early science instruction. The research was guided by the following two research questions and associated hypotheses:

1. How frequently do kindergarten teachers provide talk in the form of (i) content-specific language and (ii) scaffolding utterances?

It was assumed that the provision of teacher talk for domain-specific learning relies on a solid basis of domain-specific professional knowledge, such as pedagogical content knowledge and content knowledge (Baumert et al., 2010; Fröhlich-Gildhoff, Nentwig-Gesemann, & Pietsch, 2011; Shulman, 1987). A low frequency in content-specific language was expected, because early science teachers were often reported to lack a solid science content knowledge and pedagogical content knowledge and often feel insecure in science teaching (Appleton, 2003, 2008). The same argumentation was also applied to formulating expectations about the frequency of different types of scaffolding utterances. Here, it was hypothesized that structuring (A, B) occurs more often than problematizing (C, D), then, within structuring, type A (Clarification of phenomenon, task, and procedure) occurs more often than type B (Focus of Attention), and finally within problematizing, type C (Activation of prior knowledge) occurs more often than type D (Challenging conceptual change). Such hypothesized observations would be in line with studies in pre-school institutions, which have shown that more elaborate forms of teacher-child interactions, such as sustained shared thinking, could only rarely be observed (Siraj-Blatchford et al., 2002).

2. To what extent can teacher talk in the form of (i) content-specific language and (ii) scaffolding utterances explain children’s conceptual learning?

Given the importance of language input for children’s cognitive development and domain-specific learning, as reviewed above, it was hypothesized that the frequency of teacher talk, both in the facet of content-specific language and all types of scaffolding utterances, positively relates to children’s learning performance.
3.3 Methods

Sample

A total of 32 kindergarten teachers and the associated classes with 468 children from the region of Lucerne, Switzerland, participated in this study. On average, these teachers were 39.0 years old (SD = 11.1 years) and had teaching experience of 14.6 years (SD = 8.9 years). All teachers are female. The children were, on average, 5.0 years old (SD = 0.7 years). The proportion of females was 49.1%.

In Switzerland, kindergarten is a compulsory part of the public educational system. Children generally attend kindergarten between the ages of four to six years. According to the *International Standard Classification of Education ISCED* from the (UNESCO, 2012), Swiss kindergarten is to be classified between pre-primary education and the beginning of primary education. For an in-depth description of Swiss kindergarten, see Wannack (2004).

Procedure

*Overview.* The participating teachers registered for a professional development course about early science instruction. They were asked to fill in a questionnaire ahead of the training course. Teachers’ personal background information (age, working experience, etc.) was measured by this questionnaire. The half-day professional development course consisted of an introduction into inquiry-based learning materials about the topic ‘floating and sinking’ (see below for detailed information). All participants received a set of learning materials directly at the beginning of this training course. The teachers were then requested to implement this learning material with their classes for the subsequent four weeks, immediately after this introductory course. The teachers were recorded for 40 minutes on video during the first week of the implementation phase, while assisting the activities of a group of children during the “free play” time. The *free play* time is a typical phase in a kindergarten day, where the children of a class are engaged in small groups at different workstations. Teacher talk was assessed based on this video material and the associated transcripts. Further, children’s conceptual knowledge about ‘floating and sinking’ was measured in individual sessions in a pre-post-design.

*Learning Materials.* For this study, the learning materials about ‘floating and sinking’ from Leuchter, Saalbach, and Hardy (2014) were further refined. These learning materials intend that children are supported in their construction of an early *conception of matter*. In natural sciences, especially in physics and chemistry, conceptions of matter have been and still of fundamental importance (e.g., periodic table, atomic theory, etc.). Specifically, these learning materials intend that children’s construct the *concept of material kind*, which represents, according Dickinson (1987), a conception of matter that is meaningful and comprehensible for young children. He further described this concept as
a child-oriented understanding for organizing knowledge about characteristic qualities and behaviors of materials. In the tasks associated to the learning materials of this study, the kinds of materials (such as iron, clay, wood, polystyrene, etc.) function as a predictor for the objects’ buoyancy. Knowledge about buoyancy is considered important for the later development of conceptions, such as conceptual density, displacement of water, or Archimedes’ principle, etc. Although the concept of density generally, for instance, cannot be understood by very young children, they have intuitive ideas based on experiences about the buoyancy when playing with objects in water (Hadzigeorgiou, 2015; Kohn, 1993). The learning materials were structured in a way that should children enable to construct knowledge from contrasting their hypotheses with actual observations in a process of scientific inquiry (see Bybee, 2006). A group of two to six children worked at two different workstations; the station ‘office’ for the generation and reflection of hypotheses about the buoyancy of the objects; and the station ‘lab’ for observing the real buoyancy of these objects, including a bin filled with water. The children should make observations about the buoyancy of a specifically selected set of objects to reason about relations between the patterns of their observations and the physical properties of the presented objects. The learning materials were presented both as real objects and as pictorial representations on worksheets in both workstations. The worksheets consisted of three columns; a column of pictures of the objects, a column to express the hypothesis about the buoyancy and a column for reporting the observed buoyancy of the respective objects (see Figure 3.1 for an example work sheet). On each worksheet objects were specifically chosen and presented with the intention of challenging commonly prevailing misconceptions about the physics of buoyancy. In the example work sheet, children should be prompted to rethink the two misconceptions “Everything with a hole sinks” and “Small things sink and large things float”. These learning materials were intended to stimulate children’s conceptual restructuring about floating and sinking of objects, from one dimensional attributes (such as the shape, the volume, the weight of objects) towards the identification of the kinds of materials as a property of objects that inherently integrate aspects of weight and volume (such iron, clay, wood, polystyrene, etc.) (Leuchter et al., 2014).
Assessment of children’s conceptual knowledge. Children’s learning was examined looking at their development of the concept of material kind. This concept is considered as an important step in children’s learning process (see above). Children’s conceptual knowledge was measured before and after the intervention with respect to the four tasks labeled as (i) Classification, (ii) Justification, (iii) Allocation, and (iv) Labeling. Children’s knowledge was assessed in one-to-one sessions in a quiet place in the respective kindergarten during a regular kindergarten day. Each testing session lasted for approximately 10 minutes. In the first task, the children had to classify 16 objects according to their predicted buoyancy. The children could express their buoyancy prediction either verbally or with gestures. The predictions were coded as correct/false with respect to the real buoyancy of the respective objects. The variable CLASS (abbrev. for score in the classification task) reflects the relative proportion of correct predictions. In the second task, the children were asked to justify these 16 buoyancy predictions verbally. Children’s statements were coded according to its coherence with the concept of material kind (see section “learning materials”). Statements related to this concept (example “it floats, because it is iron”) were rated as fully correct (1 point), statements consisting of a single dimension such as weight, form, etc. (example “it floats, because it is not heavy”) were rated as partly correct (0.5 points), statements as “I don’t know” were rated as incorrect (0 points). The variable JUST (abbrev. for score in the justification task) reflects the proportion of correct justifications with respect to the coherence to the concept of material kind. In the third task, the children had to match six pairs of objects according to the kinds of materials. For instance, a wooden toothpick had to be matched to a larger wood piece. The variable ALLOC (abbrev. for score in the allocation task) reflects the proportion of correct allocations to total allocations. Finally, the fourth task
consisted of labeling these six objects according to the material kind. The variable \textit{LABEL} (abbrev. for score in the labeling task) reflects the proportion of correct labeling to total labeling. The internal consistency of these score variables were evaluated according to Bühner (2011) as follows, for \textit{CLASS} for t1 .34 (low) and for t2 .53 (low), for \textit{JUST} for t1 .90 (high) and for t2 .93 (high), for \textit{ALLOC} for t1 .63 (low) and for t2 .67 (low), and for \textit{LABEL} for t1 .52 (low) and for t2 .62 (low). These partly low internal consistency estimates are not surprising, because formal conceptual learning in science is just about to start at kindergarten age. With respect to the classification task, it must be assumed that some of children’s classification of the objects buoyancy was, especially in the pre-test, a mere guess and therefore not a reliable representation of a knowledge structure (see Leuchter & Saalbach, 2014). Nevertheless, the constant improvement of the internal consistency estimates between the pre and the post measurement indicated that conceptual reconstruction was indeed taken place. In the modeling, the four dependent variables (CLASS, JUST, ALLOC, LABEL) informed together the latent construct \textit{children’s conceptual knowledge (CCK)}, which is an integrative representation of children’s performance with respect to the learning goal (i.e. constructing the \textit{concept of material kind}). Finally, children’s language competence was assessed by their teachers based on the rating of the following seven items on a five-point Likert scale (from 1 = total disagreement to 5 = total agreement): (1) “The child has an age-appropriate passive vocabulary, enabling good understanding.”, (2) “The child has an age-appropriate active vocabulary, enabling good expression.”, (3) “The child can build sentences correctly.”, (4) “The child pronounces words clearly.”, (5) “The child tells experiences or stories coherently.”, (6) “The child can recite/sing rhymes and songs by heart.”, and (7) “The child likes to express herself/himself.”. The associated scale (Cronbach’s alpha = .93) has a high internal consistency according Bühner (2011).

\textit{Assessment of teacher talk.} Teacher talk was assessed for the variables of content-specific language (CSL) and scaffolding utterances. These variables were extracted by coding the collected video material in a time-sampling procedure using the software Videograph (Rimmele, 2013). The time-samples were chosen to be of 15 second length. CSL and scaffolding utterances are not mutually exclusive, meaning that a slot could consist of both CSL and scaffolding utterances at the same time. In a first step, sequences were identified for further processing based on the identification of the classical didactic triangle, where the teacher, at least one learner and the learning content was present (see didactic triangle, Schoenfeld, 2012). Inter-rater reliability was tested several times during the process and was established on total 22.3% of the data material. Reliability was evaluated using \textit{kappa} coefficients. According to Fleiss (1981), kappa coefficients above .75 are considered as an excellent agreement. An overall kappa of .80 was obtained for CSL and .79 for scaffolding utterances respectively. Disagreements were resolved through discussion. These two types of verbal input will be described in further details below.
The variable CSL measured the occurrence of specific expressions in teachers’ talk. In this study, the characterization of objects according to their kind of materials (iron, clay, wood, polystyrene, wax, plastic) were considered as these specific expressions, since they are directly relating to the learning goal (i.e. constructing the concept of material kind). Teacher utterances were rated in every slot according to the following three levels; (i) no occurrence of these expressions (no CSL), (ii) occurrence of one or more of these expressions (Example: “Have you seen clay before?”), (iii) occurrence of one or more of these expressions in combination with the buoyancy (Example: “Because it is wooden? What will probably happen to it?”). Then, the proportion of slots consisting of CSL, i.e. either type (ii) or (iii), from total analyzed slots was calculated.

The variable scaffolding utterance measured teacher talk according to its underlying scaffolding intentions. Table 3.1 provides the analyzed types of these scaffolding intentions including examples. Type A are utterances directed at the clarification of the phenomenon, task and procedure. Teacher talk of this type should support children to establish and maintain the direction of her/his learning activities to fulfill the instructional task, respectively phenomenon at hand. The two sub-types reflect that teachers may express the scaffolding intentions either as guidance or as inquiry. Type B refers to teacher utterances that are intended to steer children’s attention to specific properties of the phenomenon. The sub-types were formulated again based on the differentiation between the aspects of guidance vs. inquiry. Type C refers to teacher utterances directed at children’s activation of prior knowledge. The associated sub-types include referencing to prior experiences (long-term/wide scope) and calling for a hypothesis formulation (short-term/narrow scope). Finally, prompting for explanations, comparisons, reasoning and cognitive conflicts fall under the Type D, which is expected to support children’s conceptual reconstruction. The proportion of slots consisting of scaffolding utterances from total analyzed slots was calculated for each main category separately. In cases where multiple types of scaffolding utterances were identified within the same time slot, a rule corresponding to the hierarchical nature of the framework was applied (D over C, over B, over A). Slots consisting only of teacher utterances not related to the topic of instruction were allocated to the category ‘outside’ (for outside the content). Further, slots were identified, where teachers were present in the didactic triangle (see above), but did not provide any verbal input. This behavior related to Type W (for waiting).
Table 3.1

Types of Scaffolding Utterances with Underlying Intention

<table>
<thead>
<tr>
<th>Type of Scaffolding Intention</th>
<th>Sub-Types and Examples</th>
</tr>
</thead>
</table>
| **A** Clarification of phenomenon, task, and procedure | A.1 Guiding of phenomenon, task and procedure  
“Well, then, you can go over to put on the ‘control’ sticker.”  
A.2 Inquiring of phenomenon, task and procedure  
“Tell me what to do next.” |
| **B** Focus of attention | B.1 Guiding observation  
“Hold it in your hands, first.”  
B.2 Inquiring observation  
“What happens when you push it [the candle] down, does it stay down?” |
| **C** Activation of prior knowledge | C1. (Re-)Activate prior knowledge  
“Have you seen something similar at home before?”  
C2. (Re-)Activate hypothesis formulation  
“What do you believe, does it float?” |
| **D** Challenging conceptual change | D.1 Prompt explanation  
“Why do you think it floats?”  
D.2 Prompt comparison  
“Do both rulers have a small hole?”  
D.3 Prompt reasoning  
“It floats. Well. And what have you said [predicted]?”  
D.4 Prompt cognitive conflicts  
“And it is light [small weight]? ... And it nevertheless sinks in water?” |
| **W** Waiting Outside | [waiting]  
“Of course, go quickly to the toilet!” |

Analysis

Two important decisions about the analysis of the data of this study included the question whether to adopt a hierarchical vs. non-hierarchical approach and whether to adopt a latent vs. non-latent approach.

Concerning the hierarchical vs. non-hierarchical question, there are two groups of researchers providing divergent recommendations: One group recommends using a multi-level analysis in any case as long as there is a naturally occurring nested structure in the sample (e.g., Nezlek, 2008). Data in the school context is typically hierarchically structured, since students are nested in classes with their respective teachers. Here, multi-level analysis is the preferred method, since one accounts for non-independence of members of a group (Raudenbush & Bryk, 2002). The other group qualifies the multi-level approach as justified, if the hierarchical structure is salient from a statistical point of view (e.g., Klein et al., 2000). The hierarchical structure of the data can statistically be described by calculating Intraclass Correlation Coefficients (ICC); the ICC(1)-value describes the proportion of between-group variance in total variance and the ICC(2)-value the reliability of the means within the groups. Higher values of ICC(1) and ICC(2) indicate a more pronounced hierarchical nature of the data. However, there is a lack of consensus about a clear cut-off point for these values. Recommendations for ICC(1) often include cut-off points at the level of .05 or .10. The ICC(2) values...
are generally interpreted in a similar way as other reliability measures: “Common practice suggests that values of 0.70 and higher are acceptable, values between 0.50 and 0.70 are marginal, and values lower than 0.50 are poor” (Klein et al., 2000, p. 518).

The analysis of the hierarchical structure for the present study was described and analyzed according to the procedure of Bliese (2016): In this procedure, it is first evaluated whether there is enough between groups variance to be explained. For this reason, the following unconditional means model (or null model) is estimated, i.e. a model that does not contain any predictors, but includes a random intercept variance term for groups.

\[ \text{Score}_{ij} = \beta_{0j} + r_{ij} \]

\[ \beta_{0j} = \gamma_{00} + u_{0j} \]

In combined form the model is:

\[ \text{Score}_{ij} = \gamma_{00} + u_{0j} + r_{ij} \]

This model states that \( \text{Score}_{ij} \), the dependent variable, is a function of a common intercept \( \gamma_{00} \), and two error terms, i.e. the between-group error term, \( u_{0j} \), and the within group error term, \( r_{ij} \). This model provides two estimate of variance \( \tau u_{00} \) and \( \sigma^2 \); \( \tau u_{00} \) is associated with \( u_{0j} \) and reflects the between-group variance (also intercept variance), i.e. the variance in how much each groups’ intercept varies from the overall intercept, and \( \sigma^2 \) associated with \( r_{ij} \) reflecting the within-group variance, i.e. how much each individuals’ score differs from the group mean. These estimates allow calculation of the Intraclass Correlation Coefficient (ICC), also referred to as ICC(1), which expresses how much of the variance in the outcome variable can be explained by group membership. It calculates with the formula: \( \text{ICC}(1) = \frac{\tau u_{00}}{\tau u_{00} + \sigma^2} \). Next, the reliability of the group means is assessed, which describes how close subjects are distributed around the respective group mean. Group-mean reliability, also referred to as ICC(2), is a function of ICC(1) and group size. The ability to detect relationships between the variables of the aggregated level and the dependent variable depends on the reliability of the group means. By convention, group mean reliability of around .70 is needed as an indication that groups can be differentiated reliably. Finally, it will be tested whether the between-group variance, \( \tau u_{00} \), is significantly different from zero. This can be done by comparing two models with and without a random intercept with respect to its -2 log likelihood values.

The above described procedure lead to the results in Table 3.2. For CLASS, JUST and ALLOC, it came out that between-group variance only accounts for a small share of the total variance, i.e. ICC(1) > .10. For these variables, the ICC(2) values were clearly below the recommended .70, needed for the reliable differentiation between groups. In contrast, the estimates for LABEL pointed more clearly to the hierarchical structure of the data. In my evaluation, the general impression of low variation
between the classes and low consistency predominated, giving not much support for the application of
a hierarchical approach.

Table 3.2
Estimates for Assessment of Group-Level Properties

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Between-Group Variance, ( \tau_{\text{between}} )</th>
<th>Within-Group Variance, ( \sigma^2 )</th>
<th>ICC(1)</th>
<th>ICC(2)</th>
<th>( \chi^2 ) Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLASS</td>
<td>15.01</td>
<td>241.80</td>
<td>.058</td>
<td>.42</td>
<td>( \chi^2(1)=4.35, p = .037 )</td>
</tr>
<tr>
<td>JUST</td>
<td>39.52</td>
<td>493.18</td>
<td>.074</td>
<td>.48</td>
<td>( \chi^2(1)=7.29, p = .007 )</td>
</tr>
<tr>
<td>ALLOC</td>
<td>19.28</td>
<td>758.82</td>
<td>.025</td>
<td>.26</td>
<td>( \chi^2(1)=1.04, p = .308 )</td>
</tr>
<tr>
<td>LABEL</td>
<td>185.52</td>
<td>595.38</td>
<td>.238</td>
<td>.78</td>
<td>( \chi^2(1)=45.68, p &lt; .001 )</td>
</tr>
</tbody>
</table>

The second important question was about whether or not to implement a latent perspective. Foremost,
this is a question of theoretical relevance: In this study, children’s attainment of the learning goal (i.e.
constructing the concept of material kind) includes not only being able to classify objects accordingly,
but also to verbally justify this classification using appropriate labels. Therefore, it was argued as
being theoretically meaningful to combine the four children’s scores (CLASS, JUST, ALLOC,
LABEL) to one single construct (CCK\(^{28}\)). From a statistical point of view, the latent framework allows
for separation of the measurement error. These theoretical and statistical considerations let me opt for
the adoption of a latent perspective.

A combination of both a hierarchical and a latent approach failed due to problems of convergence.
Therefore, the decisions was taken to apply a latent modeling approach based on conventional (non-
hierarchical) multiple regressions in this study. Latent regression modeling was used to estimate
relationships between teacher talk and children’s conceptual knowledge. Models were estimated with
the R package lavaan (Rosseel, 2012). Estimation was based on the maximum likelihood procedure
with robust standard errors (MLR), which is specifically robust for non-normally distributed data.
Missing data was imputed by the Full Information Maximum Likelihood (FIML) procedure. A three-
step modeling approach was adopted, including (1) defining the measurement model, (2) controlling
for children variables and (3) testing of hypotheses associated to the variables of teacher talk. The
graphical representation of the final model followed Schreiber, Nora, Stage, Barlow, and King (2006).
Details about the modeling procedure are provided directly in the respective result section.

\(^{28}\) Note, this latent construct has another meaning than the integrated conceptual understanding of floating and
sinking from Kleickmann, Tröbst, Jonen, Vehmeyer, and Möller (2016), which implies students’ simultaneous
adoption of scientific explanations and rejection of misconceptions.
3.4 Results

Descriptive Statistics and Correlations

Descriptive statistics of all variables and their inter-correlations are reported Table 3.3 and Table 3.4. The original table was split into two parts to increase the clarity. Generally, children variables highly correlated with each other, while cross-level correlations were smaller and rarely significant. All children performance scores were positively correlated with each other on a significance level of $p < .001$. Children’s pre-score measures correlated with each other between .28 and .41, and with respect to the post-test between .32 and .52.

Table 3.3
Descriptive Statistics and Correlations

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>M (SD)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Age</td>
<td>468</td>
<td>5.00 (0.64)</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>GermL</td>
<td>383</td>
<td>4.25 (0.85)</td>
<td>0.12*</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3</td>
<td>CLASSpre</td>
<td>442</td>
<td>55.05 (15.26)</td>
<td>0.21***</td>
<td>0.10***</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>4</td>
<td>CLASSpost</td>
<td>434</td>
<td>72.00 (18.3)</td>
<td>0.25***</td>
<td>0.35***</td>
<td>0.34***</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>JUSTpre</td>
<td>430</td>
<td>44.24 (20.0)</td>
<td>0.15**</td>
<td>0.30***</td>
<td>0.39***</td>
<td>0.34***</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>JUSTpost</td>
<td>423</td>
<td>58.05 (23.7)</td>
<td>0.16***</td>
<td>0.13***</td>
<td>0.20***</td>
<td>0.52***</td>
<td>0.54***</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>ALLOCpre</td>
<td>431</td>
<td>43.31 (27.3)</td>
<td>0.23***</td>
<td>0.27***</td>
<td>0.37***</td>
<td>0.34***</td>
<td>0.28***</td>
<td>0.23***</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>ALLOCpost</td>
<td>425</td>
<td>57.40 (28.3)</td>
<td>0.24**</td>
<td>0.29***</td>
<td>0.32***</td>
<td>0.41***</td>
<td>0.23***</td>
<td>0.22***</td>
<td>0.32***</td>
<td>0.50***</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>LABELpre</td>
<td>432</td>
<td>29.65 (20.9)</td>
<td>0.11*</td>
<td>0.40***</td>
<td>0.30***</td>
<td>0.36***</td>
<td>0.39***</td>
<td>0.16***</td>
<td>0.41***</td>
<td>0.44***</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>LABELpost</td>
<td>428</td>
<td>45.37 (27.3)</td>
<td>0.18***</td>
<td>0.26***</td>
<td>0.24***</td>
<td>0.45***</td>
<td>0.21***</td>
<td>0.50***</td>
<td>0.38***</td>
<td>0.47***</td>
<td>0.54***</td>
</tr>
</tbody>
</table>

Note. Children variables: Age, GermL = German language competence, CLASS = score of classification task, JUST = score of justification task, ALLOC = score of allocation task, LABEL = score of labeling task. Teacher variables: T_CSL = content specific language, T_Sca = variables of scaffolding utterances (type A: Clarification of phenomenon, task, and procedure, type B: Focus of attention, type C: Activation of prior knowledge, type D: Challenging conceptual change, and type W: Waiting). Differing N in children variables are due to missing values. The correlations of the teacher variables are based on a long format data set, therefore, the corresponding sample size is reported as N = 32 (N = 468).

Significance levels: *p < .05, **p < .01, ***p < .001
Table 3.4

*Descriptive Statistics and Correlations (cont.)*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
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</thead>
<tbody>
<tr>
<td>11 T_CSL</td>
<td>32</td>
<td>-</td>
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</tr>
<tr>
<td>12 T_ScaA</td>
<td>32</td>
<td>-0.13</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 T_ScaB</td>
<td>32</td>
<td>0.13</td>
<td>-0.55**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 T_ScaC</td>
<td>32</td>
<td>0.20</td>
<td>-0.31</td>
<td>0.28</td>
<td>-</td>
<td></td>
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</tr>
<tr>
<td>15 T_ScaD</td>
<td>32</td>
<td>0.09</td>
<td>-0.31</td>
<td>-0.24</td>
<td>-0.17</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>16 T_ScaW</td>
<td>32</td>
<td>-0.14</td>
<td>0.11</td>
<td>-0.18</td>
<td>-0.43*</td>
<td>-0.21</td>
<td>-</td>
</tr>
</tbody>
</table>

*Children’s Conceptual Knowledge*

Children’s conceptual knowledge scores are depicted in Figure 3.2. Paired-samples $t$-tests were conducted to compare children’s conceptual knowledge in the pre- and post-measurement. For all four tasks, there was a significant increase between the pre- and the post-test measurement: for CLASS, there was a significant difference between pre- ($M = 55.6$) and the post-measurement ($M = 72.0$), $t(410) = 18.7$, $p < .001$, Cohen’s $d = 0.92$ (large); for JUST, there was a significant difference between pre- ($M = 45.6$) and the post-measurement ($M = 58.5$), $t(400) = 12.8$, $p < .001$, Cohen’s $d = 0.64$ (medium); for ALLOC, there was a significant difference between pre- ($M = 45.2$) and the post-measurement ($M = 58.4$), $t(397) = 10.6$, $p < .001$, Cohen’s $d = .53$ (medium); for LABEL, there was a significant difference between pre- ($M = 30.7$) and the post-measurement ($M = 45.9$), $t(400) = 12.8$, $p < .001$, Cohen’s $d = 64$ (medium). Note that the mean values reported here do not necessarily have to be identical to the values reported in Table 3.3, because these $t$-tests depend on pairwise deletion leading to slightly different sample sizes.
Teacher Talk

Content-specific language (CSL). The frequency of teacher talk in the form of content-specific language (CSL) and scaffolding utterances is reported both as raw numbers across classrooms and as class-averaged proportions, for CSL in Table 3.5 and for scaffolding utterances in Table 3.6 respectively. Across all 32 classrooms, a total of 4267 slots à 15 seconds have been analyzed and coded.

On average, teachers display CSL in a proportion of 12.1% (SD=9.2) of the totally analyzed slots. Both sub-types of CSL can be observed in similar proportions. Hence, in the remaining slots (88%), teachers do not display CSL. There is substantial variation between teachers, the proportion of CSL ranges between 0% and 32%.

Table 3.5

<table>
<thead>
<tr>
<th>Type</th>
<th>Sub-Type</th>
<th>Raw number across classrooms</th>
<th>Sub-Type Proportion of total analyzed slots</th>
<th>Type Proportion of total analyzed slots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content-specific language</td>
<td>Occurrence of specific expression(s)</td>
<td>199</td>
<td>.05</td>
<td>.12</td>
</tr>
<tr>
<td></td>
<td>Occurrence of specific expression(s) in combination with buoyancy</td>
<td>320</td>
<td>.07</td>
<td>.12</td>
</tr>
<tr>
<td>Remaining (no CSL)</td>
<td></td>
<td>3748</td>
<td></td>
<td>.88</td>
</tr>
</tbody>
</table>
Scaffolding utterances. Regardless of the type of intention, the teachers displayed talk as scaffolding utterances in a proportion of 86% on average of the total analyzed slots, whereas the remaining share (14%) accounted for utterances outside the content-specific focus. Type A was by far the most frequent type of scaffolding utterances (39%), whereas the types B, C and D were associated to lower proportions. On the level of the sub-types, ‘Guiding of phenomenon, task and procedure’ was the most frequent strategy. The strategy “(Re-)Activate hypothesis formulation” was also frequently identified with a proportion of 10%. Within the type “Challenging conceptual change”, the prompt for explanations (8%) clearly dominated over the other sub-types of the main category. There was also substantial variation between teachers with regard to the types of scaffolding utterances: The proportion of types of scaffolding utterances ranged between 23% and 53% for type A, between 5% and 28% for type B, between 4% and 24% for type C, 4% and 41% for type D and between 0% and 16% for type W.

Table 3.6
Frequency of Teacher Talk as Scaffolding Utterances

<table>
<thead>
<tr>
<th>Type</th>
<th>Sub-Type</th>
<th>Raw number across classrooms</th>
<th>Sub-Type Proportion of total analyzed slots</th>
<th>Type Proportion of total analyzed slots</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Clarification of phenomenon, task, and Procedure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A.1 Guiding of phenomenon, task and procedure</td>
<td>1458</td>
<td>.34</td>
<td>.39</td>
</tr>
<tr>
<td></td>
<td>A.2 Inquiring of phenomenon, task and procedure</td>
<td>218</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Focus of attention</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B.1 Guiding observation</td>
<td>256</td>
<td>.06</td>
<td>.14</td>
</tr>
<tr>
<td></td>
<td>B.2 Inquiring observation</td>
<td>334</td>
<td>.08</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Activation of prior knowledge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C.1 (Re-)Activate prior knowledge</td>
<td>76</td>
<td>.02</td>
<td>.12</td>
</tr>
<tr>
<td></td>
<td>C.2 (Re-)Activate hypothesis formulation</td>
<td>440</td>
<td>.10</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Challenging conceptual change</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D.1 Prompt explanation</td>
<td>343</td>
<td>.08</td>
<td>.15</td>
</tr>
<tr>
<td></td>
<td>D.2 Prompt comparison</td>
<td>83</td>
<td>.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D.3 Prompt reasoning</td>
<td>113</td>
<td>.03</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D.4 Prompt cognitive conflicts</td>
<td>98</td>
<td>.02</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>Waiting</td>
<td>243</td>
<td>.06</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Remaining (Outside)</td>
<td>614</td>
<td>.14</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>4'276</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

The hypothesized general low proportions in CSL and all types of scaffolding utterances cannot be supported by the data of this study. Especially with respect to the scaffolding utterances, here teachers’ provision of scaffolding utterances in 86% of the analyzed slots is to be qualified as high (detailed discussion in the respective chapter below). In contrast, the data supported the hypothesis that scaffolding utterances in the type B, C and D occur less often compared to the type A.
Relation of Teacher Talk and Children’s Conceptual Knowledge

As described in the methods section, the following three-step modeling approach was adopted: (1) defining the measurement model, (2) controlling for children variables and (3) testing of hypotheses associated to the variables of teacher talk:

In the first step, a measurement model was specified, which consists of the pre- and post-scores of children’s conceptual knowledge as latent constructs. The latent variable \( CCK_{pre} \) was defined by the pre-test values of the four children tasks (i.e. classification, justification, allocation and labeling), the latent variable \( CCK_{post} \) accordingly by the post-test values of these tasks. Further, eight residual correlations were specified to account for the design-specific relations between the tasks (see Figure 3.3). The model fit was assessed using the chi-square test \( (\chi^2) \), the comparative fit index (CFI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR) (Hu & Bentler, 1998, 1999). The fit of the measurement model was reasonably good (quality statements are reported in brackets, from Schermelleh-Engel & Moosbrugger, 2003): Chi-square: \( \chi^2(11) = 23.17, p = .02 \) (acceptable fit); CFI = 0.988 (good fit); RMSEA = 0.049 (good fit), 90% CI [0.02, 0.08] (good fit), \( p_{RMSEA<0.05} = .490 \) (good fit); SRMR = 0.023 (good fit).

In the second step, it was controlled for children variables influencing children’s post-scores. Children’s knowledge score in the post-test (CCKpost) was regressed on children’s prior knowledge (CCKpre). The results of this structural regression model indicated that children’s prior knowledge was a strong predictor of CCKpost (\( \beta = .87, p < .001 \)), see Table 3.7. It explains 75.6% of the variance in the dependent variable. The results of this and all later models are reported in Table 5. The standardized coefficient, \( \beta \), should be read as following: An increase in one standard deviation in prior knowledge (CCKpre) leads to an increase of .87 standard deviations in the dependent variable (CCKpost). The non-standardized coefficient, \( B \), should be read as following: An increase of one unit in prior knowledge (CCKpre) leads to an increase of 1.76 units of the dependent variables (CCKpost), whereas one unit has been set as 1/10 of the total test score. The children variables age and German Language competence were dropped during the modeling process because they lead to an impairment of the model fit and were not significant predictors of CCKpost.

In the third step, the hypotheses about the influence of the variables of teacher talk on children’s learning were tested. First, the existing model (controlling for children’s prior knowledge) was extended by teachers’ content specific language (CSL) as a predictor. The results indicate that CSL is a significant predictor of CCKpost (\( \beta = .12, p < .01, \Delta R^2 = .023 \)). Next, this model was sequentially extended by each type of scaffolding utterance to test their additional contribution to explaining children’s post-test scores. The results are listed in Table 5. Scaffolding utterances of type A ‘Clarification of phenomenon, task, and procedure’ (\( \beta = .01, p > .05, \Delta R^2 = .000 \)), type B ‘Focus of attention’ (\( \beta = .08, p > .05, \Delta R^2 = .006 \)) and type W ‘Waiting’ (\( \beta = -.08, p > .05, \Delta R^2 = -.002 \)) cannot
significantly predict CCKpost. In contrast, scaffolding utterances of type C ‘Activation of prior knowledge’ (β = .13, p < .01, ΔR² = .003) and D ‘Challenging Conceptual Change’ (β = -.11, p < .01, ΔR² = .025) are significant predictors of CCKpost. Finally, the significant predictors were integrated to one final model (see the bottom of Table 3.7 and Figure 3.3 respectively). Correlations between the variables (T_CSL, T_ScaC, T_ScaD) were specified to account for the non-independence between the variables of teacher talk. The final model explained 80.2% of the variance in children’s conceptual knowledge. Teacher variables explained 4.6% (.802 -.756) of this variance. This final model was still associated to a reasonable model fit: Chi-square: χ²(32) = 68.05, p =.000 (below acceptable fit); CFI = 0.968 (acceptable fit); RMSEA= 0.049 (good fit), 90% CI [0.033, 0.065] (good fit), pRMSEA<0.05 =.514 (good fit); SRMR= 0.043 (good fit).
Table 3.7

Results of Latent Regression Modeling

<table>
<thead>
<tr>
<th>Regression Models</th>
<th>Description of Predictors</th>
<th>B</th>
<th>SE</th>
<th>Z-value</th>
<th>P</th>
<th>β</th>
<th>R²</th>
<th>ΔR²</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCKpost –</td>
<td></td>
<td>1.76</td>
<td>0.29</td>
<td>6.10</td>
<td>&lt;.001</td>
<td>.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCKpre</td>
<td>Prior Knowledge</td>
<td>1.86</td>
<td>0.32</td>
<td>5.89</td>
<td>&lt;.001</td>
<td>.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCKpost –</td>
<td></td>
<td>0.27</td>
<td>0.10</td>
<td>2.81</td>
<td>.005</td>
<td>.12</td>
<td></td>
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<tr>
<td>CCKpre</td>
<td>Prior Knowledge</td>
<td>1.86</td>
<td>0.32</td>
<td>5.89</td>
<td>&lt;.001</td>
<td>.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCKpre</td>
<td>Content-Specific Language</td>
<td>0.28</td>
<td>0.11</td>
<td>2.67</td>
<td>.008</td>
<td>.12</td>
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<td>CCKpost –</td>
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<td>0.03</td>
<td>0.12</td>
<td>0.27</td>
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<td>.01</td>
<td></td>
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<tr>
<td>CCKpre</td>
<td>Prior Knowledge</td>
<td>1.89</td>
<td>0.33</td>
<td>5.75</td>
<td>&lt;.001</td>
<td>.87</td>
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<tr>
<td>CCKpre</td>
<td>Content-Specific Language</td>
<td>0.25</td>
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<td>.012</td>
<td>.10</td>
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<td>0.14</td>
<td>1.91</td>
<td>.056</td>
<td>.08</td>
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</tr>
<tr>
<td>CCKpre</td>
<td>Prior Knowledge</td>
<td>1.86</td>
<td>0.32</td>
<td>5.73</td>
<td>&lt;.001</td>
<td>.87</td>
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</tr>
<tr>
<td>CCKpre</td>
<td>Content-Specific Language</td>
<td>0.20</td>
<td>0.10</td>
<td>2.04</td>
<td>.042</td>
<td>.09</td>
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<tr>
<td>CCKpost –</td>
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<td>0.52</td>
<td>0.17</td>
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<td>.002</td>
<td>.13</td>
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<td>CCKpre</td>
<td>Prior Knowledge</td>
<td>2.00</td>
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<td>5.41</td>
<td>&lt;.001</td>
<td>.88</td>
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</tr>
<tr>
<td>CCKpre</td>
<td>Content-Specific Language</td>
<td>0.31</td>
<td>0.11</td>
<td>2.90</td>
<td>.004</td>
<td>.12</td>
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<td></td>
</tr>
<tr>
<td>CCKpost –</td>
<td></td>
<td>-0.28</td>
<td>0.10</td>
<td>-2.68</td>
<td>.007</td>
<td>-.11</td>
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<tr>
<td>CCKpre</td>
<td>Prior Knowledge</td>
<td>1.84</td>
<td>0.31</td>
<td>5.93</td>
<td>&lt;.001</td>
<td>.87</td>
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</tr>
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<td>CCKpre</td>
<td>Content-Specific Language</td>
<td>0.24</td>
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<td>2.529</td>
<td>.011</td>
<td>.10</td>
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<tr>
<td>CCKpost –</td>
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<td>-0.37</td>
<td>0.20</td>
<td>-1.83</td>
<td>.068</td>
<td>-.08</td>
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</tr>
<tr>
<td>CCKpre</td>
<td>Prior Knowledge</td>
<td>2.00</td>
<td>0.37</td>
<td>5.38</td>
<td>&lt;.001</td>
<td>.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCKpre</td>
<td>Content-Specific Language</td>
<td>0.24</td>
<td>0.11</td>
<td>2.22</td>
<td>.026</td>
<td>.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCKpost –</td>
<td></td>
<td>0.47</td>
<td>0.18</td>
<td>2.58</td>
<td>.010</td>
<td>.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCKpre</td>
<td>Prior Knowledge</td>
<td>2.00</td>
<td>0.37</td>
<td>5.38</td>
<td>&lt;.001</td>
<td>.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCKpre</td>
<td>Content-Specific Language</td>
<td>0.24</td>
<td>0.11</td>
<td>2.22</td>
<td>.026</td>
<td>.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCKpost –</td>
<td></td>
<td>0.47</td>
<td>0.18</td>
<td>2.58</td>
<td>.010</td>
<td>.11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. CCK = children’s conceptual knowledge. Teacher variables: T_CSL = content specific language, T_Sca = variables of scaffolding utterances (type A: Clarification of phenomenon, task, and procedure, type B: Focus of Attention, type C: Activation of prior knowledge, type D: Challenging Conceptual Change, and type W: Waiting).
Figure 3.3. Latent regression model for the prediction of children’s conceptual knowledge (CCK). Solid lines indicate significant paths, dotted lines indicate non-significant paths. Children variables: CLASS = score of classification task, JUST = score of justification task, ALLOC = score of allocation task, LABEL = score of labeling task. Teacher variables: T_CSL = content specific language, T_Sca = variables of scaffolding utterances (type C: Activation of prior knowledge, type D: Challenging conceptual change).

Exploratory Post-Hoc Analyses

Teacher talk of the type D (Challenging conceptual change) was found to be a negative predictor (see Table 3.7) for children’s learning. This sharply contrasts the formulated hypotheses of teacher talk being an effective form of instructional support respectively a scaffolding means for children’s knowledge construction (see chapter 3.2). A detailed discussion about this unexpected finding follows in the discussion (see chapter 3.5). This unexpected finding motivated the examination of the following questions in explorative post-hoc analyses:

- Are the four subcategories of teachers’ scaffolding utterances type D (challenging conceptual change) consistently negative predictors for children’s learning?
- To what extent can specific combinations of teachers scaffolding utterances predict children’s conceptual learning?

In a first analysis, the question was investigated whether all of the subcategories of scaffolding utterance type D (i.e. prompt for explanation, comparison, reasoning, cognitive conflict, see Table 3.1) were consistently negative predictors for children’s learning. To this aim, the subcategories of
scaffolding utterance type D were separately introduced into regression models as predictors for children’s conceptual understanding after controlling for children’s prior knowledge and teachers’ content-specific language. The results are presented in Table 3.8. Indeed, negative beta-values were found for all of the four analyzed sub-categories. But, interestingly, only two out of the four sub-categories were significant as negative predictors for children’s conceptual understanding, i.e. sub-type D.3 (Prompt reasoning, \( \beta = -.14, p < .001, \Delta R^2 = .027 \)) and sub-type D.4 (Prompt cognitive conflicts, \( \beta = -.09, p < .05, \Delta R^2 = .015 \)).

Table 3.8

Post-Hoc Results of Latent Regression Modeling

<table>
<thead>
<tr>
<th>Regression Models</th>
<th>Description of Predictors</th>
<th>B</th>
<th>SE</th>
<th>Z-value</th>
<th>P</th>
<th>( \beta )</th>
<th>R^2</th>
<th>( \Delta R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCKpost ~ CCKpre</td>
<td>Prior Knowledge</td>
<td>1.76</td>
<td>0.29</td>
<td>6.10</td>
<td>&lt;.001</td>
<td>.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCKpost ~ CCKpre</td>
<td>Prior Knowledge</td>
<td>1.86</td>
<td>0.32</td>
<td>5.89</td>
<td>&lt;.001</td>
<td>.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T_CSL</td>
<td>Content-Specific Language</td>
<td>0.27</td>
<td>0.10</td>
<td>2.81</td>
<td>.005</td>
<td>.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T_ScaD1</td>
<td>Scaffolding Type D.1</td>
<td>-0.02</td>
<td>0.17</td>
<td>-1.45</td>
<td>.148</td>
<td>-.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCKpost ~ CCKpre</td>
<td>Prior Knowledge</td>
<td>1.92</td>
<td>0.34</td>
<td>5.62</td>
<td>&lt;.001</td>
<td>.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T_CSL</td>
<td>Content-Specific Language</td>
<td>0.28</td>
<td>0.10</td>
<td>2.78</td>
<td>.005</td>
<td>.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T_ScaD2</td>
<td>Scaffolding Type D.2</td>
<td>-0.10</td>
<td>0.06</td>
<td>-1.55</td>
<td>.122</td>
<td>-.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCKpost ~ CCKpre</td>
<td>Prior Knowledge</td>
<td>1.86</td>
<td>0.31</td>
<td>5.94</td>
<td>&lt;.001</td>
<td>.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T_CSL</td>
<td>Content-Specific Language</td>
<td>0.32</td>
<td>0.10</td>
<td>3.16</td>
<td>.002</td>
<td>.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T_ScaD3</td>
<td>Scaffolding Type D.3</td>
<td>-0.11</td>
<td>0.03</td>
<td>-3.55</td>
<td>&lt;.001</td>
<td>-.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCKpost ~ CCKpre</td>
<td>Prior Knowledge</td>
<td>2.00</td>
<td>0.37</td>
<td>5.45</td>
<td>&lt;.001</td>
<td>.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T_CSL</td>
<td>Content-Specific Language</td>
<td>0.27</td>
<td>0.11</td>
<td>2.60</td>
<td>.009</td>
<td>.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T_ScaD4</td>
<td>Scaffolding Type D.4</td>
<td>-0.09</td>
<td>0.05</td>
<td>-1.99</td>
<td>.047</td>
<td>-.09</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. CCK = children’s conceptual knowledge. Teacher variables: T_CSL = content specific language, T_Sca = variables of scaffolding utterances (type D.1: Prompt explanation, type D.2: Prompt comparison, type D.3: Prompt reasoning, type D.4: Prompt cognitive conflicts).
In a second analysis, teachers’ scaffolding utterances were analyzed as to whether utterances of the type D might affect children’s learning as a function of occurring in specific combinations. The following two examples should help to clarify this idea:

- It might be that children can only profit from teacher talk of type D, if shortly before the teacher clarified the task and the procedure (type A).
- It might be that children can only profit from teacher talk of type D, if shortly before they were prompted to activate their prior knowledge (type C).
- Etc.

To identify and count these combinations, the dataset of the coding of teacher talk was re-examined using an algorithm that identified slots where teachers provided scaffolding utterances of type D and then, new variables were calculated expressing the occurrence of the scaffolding utterance of interest in a defined time leading up to the identified type D utterance. This time span was set covering four slots à 15 seconds each, respectively one minute in total. This duration was decided based on the assumption that children are able to maintain information of several scaffolding moves in their working memory within this time span, which in turn might influence their knowledge construction. Variables were calculated that express the relative frequency of specific combinations of scaffolding utterances. The two imaginary examples of sequences in Figure 3.4 should clarify the applied procedure: In both examples, the algorithm would identify the scaffolding utterance D.1 in the slot 16:00 and check for the utterances of interest in the four preceded slots (15:00 to 15.45). At the level of the main types of teacher utterances, the algorithm returns “true” for the combinations D-A and D-C and “false” for D-B in both examples identically. At the level of sub-types, the algorithm returns “true” for D-A.1, D-C.1 and D-C.2 and “false” for all other combinations in the first example. In the second example, “true” will be additionally assigned to the combination of D-A.2.

![Figure 3.4](image)

**Figure 3.4.** Representations of procedure of identifying combinations of teacher utterances in two imaginary sequences.

The results are presented in Table 3.9 and should be read as follows: Given an identification of any type of teachers’ scaffolding of type D (see Table 3.9, column D), in 43.1% (SD = 25.6) of the cases,
averaged over all teachers, there was at least one scaffolding utterance of type A.1 (Guiding of phenomenon, task and procedure) or type A.2 (Inquiring of phenomenon, task and procedure) being observed in the minute just before this event. Hence, it can be read in the column D that scaffolding utterances of the type D were most frequently recorded in combination with the type A (43.1%), followed with the type B (23.2%) and the type C (22.2%). At the level of sub-types, utterances of the type D were recorded most frequently in combination with sub-type A.1 (39.3%), followed by sub-type C.2 (19.6%), etc. Combinations with C.1, (Re-)Activate previous knowledge, occurred least frequently. The columns D.1 to D.4 in Table 3.9 report the respective relative frequencies of scaffolding combinations with the sub-categories of type D as identifiers.

Table 3.9

<table>
<thead>
<tr>
<th>Identifier (→)</th>
<th>Challenging conceptual change</th>
<th>Prompt explanation</th>
<th>Prompt comparison</th>
<th>Prompt reasoning</th>
<th>Prompt cognitive conflicts</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Clarification of phenomenon, task, and procedure</td>
<td>43.1 (25.6)</td>
<td>24.2 (15.7)</td>
<td>7.0 (5.3)</td>
<td>9.5 (7.4)</td>
<td>7.3 (6.8)</td>
</tr>
<tr>
<td>A.1 Guiding of phenomenon, task, and procedure</td>
<td>39.3 (23.8)</td>
<td>22.0 (14.6)</td>
<td>6.2 (5.0)</td>
<td>8.5 (7.4)</td>
<td>7.0 (6.6)</td>
</tr>
<tr>
<td>A.2 Inquiring of phenomenon, task, and procedure</td>
<td>9.1 (9.9)</td>
<td>5.9 (7.2)</td>
<td>1.4 (2.3)</td>
<td>1.6 (2.6)</td>
<td>1.2 (2.3)</td>
</tr>
<tr>
<td>(B) Focus of attention</td>
<td>23.2 (13.7)</td>
<td>11.8 (8.4)</td>
<td>4.4 (4.4)</td>
<td>4.7 (4.1)</td>
<td>5.0 (5.6)</td>
</tr>
<tr>
<td>B.1 Guiding observation</td>
<td>12.0 (8.9)</td>
<td>6.0 (6.1)</td>
<td>2.5 (2.9)</td>
<td>2.3 (2.7)</td>
<td>2.6 (4.0)</td>
</tr>
<tr>
<td>B.2 Inquiring observation</td>
<td>13.7 (10.9)</td>
<td>7.3 (6.5)</td>
<td>2.1 (3.5)</td>
<td>2.8 (3.2)</td>
<td>3.1 (3.5)</td>
</tr>
<tr>
<td>(C) Activation of prior knowledge</td>
<td>22.2 (14.6)</td>
<td>14.3 (10.6)</td>
<td>3.3 (2.8)</td>
<td>3.7 (4.4)</td>
<td>3.3 (4.0)</td>
</tr>
<tr>
<td>C.1 (Re-)Activate prior knowledge</td>
<td>3.79 (6.7)</td>
<td>2.5 (5.0)</td>
<td>0.7 (1.8)</td>
<td>0.4 (1.0)</td>
<td>0.6 (1.5)</td>
</tr>
<tr>
<td>C.2 (Re-)Activate hypothesis formulation</td>
<td>19.6 (11.9)</td>
<td>12.7 (9.1)</td>
<td>2.7 (2.3)</td>
<td>3.4 (4.4)</td>
<td>2.8 (3.4)</td>
</tr>
</tbody>
</table>

* The value of the main type is not the sum of the respective values of the sub-types, because of the described algorithm is applied separately for each condition.

The calculated measures of the combinations of teachers’ scaffolding utterances were tested as predictors for children’s conceptual knowledge scores by means of latent regression modeling, after having controlled for children’s prior knowledge. Results are provided in Table 3.10. This table should be read as follows: An increase in one standard deviation of the scaffolding utterance combination D-A, would lead to a decrease of -0.09 standard deviations in children’s conceptual knowledge, which is significant on \( p < .05 \). In contrast, those scaffolding utterances occurring in combination with utterances of type B (Focus of attention) and with utterances of type C (Activation of prior knowledge) are positively related to children’s conceptual knowledge (\( b = .11, p < .01 \), respectively \( b = .16, p < .001 \)). The tendency of negative predictors of combinations with type A and positive predictors of combinations with type B and type C were relatively consistent also when using the sub-types D.1 to
D.4 as identifiers. On the level of the analyzed precursor sub-types, it is noteworthy that combinations with the sub-type A.1 (A.1 Guiding of phenomenon, task and procedure) were mostly negative predictors and, interestingly, combinations with the sub-type C.1 ((Re-)Activate prior knowledge) were throughout positive predictors. In other words, these results support the hypothesis that teachers’ scaffolding utterances indeed seem to affect children’s learning as a function of previously provided scaffolds.

Table 3.10
Standardized Beta Coefficients From Regression of Scaffolding Utterances Combinations on Children’s Conceptual Knowledge

<table>
<thead>
<tr>
<th>Identifier (→)</th>
<th>Challenging conceptual change</th>
<th>Prompt explanation</th>
<th>Prompt comparison</th>
<th>Prompt reasoning</th>
<th>Prompt cognitive conflicts</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Clarification of phenomenon, task, and procedure</td>
<td>-0.09*</td>
<td>-0.06</td>
<td>-0.06</td>
<td>-0.11**</td>
<td>-0.12*</td>
</tr>
<tr>
<td>A.1 Guiding of phenomenon, task, and procedure</td>
<td>-0.11**</td>
<td>-0.07</td>
<td>-0.08</td>
<td>-0.10**</td>
<td>-0.14**</td>
</tr>
<tr>
<td>A.2 Inquiring of phenomenon, task, and procedure</td>
<td>0.02</td>
<td>0.01</td>
<td>0.03</td>
<td>-0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>(B) Focus of Attention</td>
<td>0.11**</td>
<td>0.09*</td>
<td>-0.01</td>
<td>0.12**</td>
<td>0.06</td>
</tr>
<tr>
<td>B.1 Guiding observation</td>
<td>0.07</td>
<td>0.03</td>
<td>0.03</td>
<td>0.08</td>
<td>0.05</td>
</tr>
<tr>
<td>B.2 Inquiring observation</td>
<td>0.10*</td>
<td>0.07</td>
<td>-0.01</td>
<td>0.09</td>
<td>0.13**</td>
</tr>
<tr>
<td>(C) Activation of prior knowledge</td>
<td>0.08*</td>
<td>0.06</td>
<td>0.16**</td>
<td>-0.08*</td>
<td>0.09*</td>
</tr>
<tr>
<td>C.1 (Re-)Activate prior knowledge</td>
<td>0.16***</td>
<td>0.12**</td>
<td>0.13**</td>
<td>0.10*</td>
<td>0.13**</td>
</tr>
<tr>
<td>C.2 (Re-)Activate hypothesis formulation</td>
<td>0.03</td>
<td>0.03</td>
<td>0.08</td>
<td>-0.08*</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Note. The reported regression coefficients were based on regression models using the latent construct of children’s conceptual knowledge as criterion. The variables of teachers’ scaffolding utterances combinations were set as predictors in individual models, after controlling for children’s prior knowledge. Children’s prior knowledge was a significant predictor in all these models.

***p < .001, **p < .01, *p < .05

3.5 Discussion

This is one of the few studies, in which teacher behavior was systematically related to children’s performance in kindergarten science instruction. The aim was to investigate in-service teachers’ naturally occurring talk according its scaffolding function in a valid situation of kindergarten science instruction.

Discussion of Four Main Findings

Four main findings emerged from the present study. First, the sampled kindergarten teachers showed content-specific language more frequently than expected. Teachers’ provision of content-specific language and scaffolding utterances was hypothesized to occur only rarely, because early-science
teachers are generally considered as having limited science content knowledge and low self-confidence in science teaching (Appleton, 2003, 2008). On average, teachers displayed content-specific language in approximately 12% and scaffolding utterances in 86% of the totally analyzed slots. These values are substantially above the proportions reported in British pre-school institutions according the REPEY-study (Siraj-Blatchford et al., 2002). Probable explanations for the high proportions of domain-specific verbal support in the analyzed sample might be rooted in differences between the professionalization of pre-school teachers in different countries. It might be that Swiss teachers have higher levels of professional knowledge, which in turn might result from a higher quality in professional education or professional development in Switzerland. However, this explanation cannot be substantiated because of the lack of empirical evidence in preschool science (Greenfield et al., 2009). Another probable explanation is that the learning materials themselves function as a scaffold, not for children’s conceptual learning alone, but also for teachers’ scaffolding behavior. In this study, learning materials were implemented that were specifically structured to initiate and structure processes of conceptual reconstruction (Leuchter et al., 2014). It seems plausible that learning materials having an implicit structure to challenge conceptual change also encourage teachers to provide respective types of scaffolding utterances. For instance, the prompt for activating the hypothesis formulation (see sub-type C.2 in Table 3.6) occurred with 10% of the total analyzed slots relatively frequently. This type of scaffolding utterance directly relates to the structure of the work-sheet (see Figure 3.1), where the children are asked to express their hypotheses about the floating behavior by putting a corresponding sticker to the respective field. Otherwise, the prompt of cognitive conflicts (see sub-type D.4) occurred in only in 2% of the total analyzed slots. Accordingly, this might be explained by the fact that cognitive conflicts do not directly emerge from the work-sheet itself, but instead, need to be consciously and specifically formulated by the teachers. The relative occurrence of the different types of scaffolding utterances was largely as expected: Type A (Clarification of phenomenon, task, and procedure) could be identified clearly as the most frequent type of scaffolding utterance (39%), whereas higher types were associated to lower frequencies (see again Table 3.6). Here the interpretation seems plausible that higher categories of verbal support indeed pose a higher challenge for teachers, because they presumably depend on higher levels of associated content knowledge and pedagogical content knowledge. This would support theoretical models of teacher professional knowledge respectively competence that rely on the components of content and pedagogical content knowledge (Baumert et al., 2010; Fröhlich-Gildhoff et al., 2011; Magnusson, Krajcik, & Borko, 1999; Shulman, 1987).

The second main finding was that children’s conceptual learning was positively predicted by children’s prior knowledge, but not by their age and level of German language competence. The revealed strong relation between children’s prior knowledge and their conceptual learning performance accords with theories about learning as conceptual change (Carey, 1985; Chi, 2008;
Vosniadou & Brewer, 1992). It substantiates the argumentation that domain-specific knowledge boosts children’s domain-specific learning, because higher levels of domain-specific prior knowledge enables children to process, remember and integrate novel domain-specific information more efficiently (Schneider, 1993; Schneider, Korkel, & Weinert, 1989). This finding underlines the importance of prior knowledge for science learning even for young children. At first glance, it might be unexpected that children’s age and their German language competence did not significantly predict children’s learning performance, since these can be thought of as proxies for children’s general level of cognitive abilities. The inspection of the correlation matrix (see Table 3) shows that age and German language competence are both positively linked to all test scores (from $r = .11$ to .27 for the variable age; from $r = .27$ to .40 for the variable German language competence). In other words, the variables of children’s age and their German language competence were, within each task (classification, justification, allocation, labeling), similarly linked to the initial state and the outcome state of children’s conceptual knowledge. Thus, age and German language competence were not significant predictors of children’s post-score, after controlling for prior knowledge.

The third main finding was that teacher talk in the form of content-specific language was a positive predictor of children’s conceptual learning. This finding suggests that simply being exposed to a restricted set of content-specific vocabulary supports children in their domain-specific conceptual learning. This is remarkable, because the construction of adequate science conceptions is generally described as being a tedious process, which depends on considerable effort and time (Carey, 1985, 2000; Chi, 2008; Posner et al., 1982; Vosniadou, 1994). This finding highlights the importance of language for children’s cognitive development in general (Saalbach et al., 2013; Saalbach et al., 2010; Tomasello, 1999) and for domain-specific conceptual learning specifically (Klibanoff et al., 2006; Leuchter & Saalbach, 2014).

The fourth main finding was that teacher talk in the form of scaffolding utterances was both positively and negatively predicting children’s conceptual learning. Teachers’ scaffolding utterances intending to stimulate prior knowledge were positively predicting children’s learning outcomes. Again, this finding re-affirms the importance of prior knowledge supporting theories about conceptual change (Carey, 1985; Chi, 2008; Vosniadou & Brewer, 1992). On the other hand, teacher talk coded according to the underlying scaffolding function of clarifying the phenomenon, task and procedure (type A) and of directing children’s focus of attention (type B) could, contrasting the formulated hypotheses, not explain children learning outcomes. The observed irrelevance of these types of teacher talk is surprising from the background of literature stressing teacher clarity and guided approaches for instruction on the one hand (Hattie, 2009; Kirschner et al., 2006), and young children’s limitations with respect to prior knowledge and self-regulation on the other hand (Center on the Developing Child at Harvard University, 2011; Morrison et al., 2010; Ruff & Lawson, 1990; Saalbach et al., 2013). This finding might be again related to the highly structured learning materials applied in this study (see
above), which presumably made this type of verbal teacher input redundant or even unnecessary. Here, further research is needed investigating the influence of domain-specific verbal support for children’s learning in conditions of differing levels of structuring of the learning materials. Surprisingly, ‘Challenging Conceptual Change’ (type D) had a negative effect on children’s knowledge construction. This outcome contrasts with the expectations based on literature on the importance of prompting children for explanations, comparisons, reasoning and cognitive conflicts (see theoretical section). Here, possible explanations can be formulated out of a child-, teacher- and interaction-oriented perspective: From a teacher-oriented perspective, negative effects may be ascribed to primary teachers’ limited science knowledge and associated confidence in science teaching (Appleton, 2003, 2008). It might be that the teachers themselves provided teacher talk in the category of ‘Challenging Conceptual Change’ predominantly in a poor quality that prevented the children from benefitting from it. From a child-oriented perspective, negative effects may be explained by children’s limited prior knowledge and self-regulation skills (Center on the Developing Child at Harvard University, 2011; Morrison et al., 2010; Ruff & Lawson, 1990; Saalbach et al., 2013). As outlined in the theoretical section, the comprehension of a cognitive conflict depends on a sufficient level of prior knowledge. Limited prior knowledge might make it impossible that children reach the intended state of a meaningful conflict, and in turn consequences in an unproductive confusion instead (Dreyfus et al., 1990). From an interaction-oriented perspective, there might be a problem of adaptiveness. Effective teacher support must fit to the learners’ actual needs (van de Pol et al., 2010; Vygotsky, 1978). In this study, children’s cognitive processes might be over-challenged by the amount of information provided in teacher talk in the form of ‘Challenging Conceptual Change’ (see cognitive load theory, Chandler & Sweller, 1991; Sweller, 1994; Sweller et al., 1998). The problem of missing adaptiveness could also be framed in the ‘assistant dilemma’ described by Koedinger and Aleven (2007), which describes the difficulty in finding the optimal balance between giving and withholding information/support. This challenges the applied underlying assumption of a linear relationship between teachers’ offering of teacher talk and children’s learning gain. The data of this study suggest that ‘giving’ prompts of the type of challenging conceptual change does not support but actually harm children’s learning. It seems that ‘the more the better’ applies not to this type of scaffolding utterances in kindergarten science instruction.

The role of teacher talk of type D (challenging conceptual change) within the teacher-child discourse was more closely investigated in exploratory post-hoc analyses. Specific combinations of teacher utterances were tested as to whether they relate to children’s conceptual learning. Interestingly, these analyses showed indeed that teacher talk seems to influence children’s learning as a function of the analyzed combinations: There was a tendency that combinations of teacher talk as challenging conceptual change (type D) with the clarification of phenomenon, task, and procedure (type A) was negatively and in combination with focusing attention (type B) and with activating prior knowledge.
(type C) was positively related to children’s learning. It seems that children can profit more from cognitively demanding scaffolds (such as type D) if shortly before they received prompts to direct their attention towards the most important aspects of the learning content (type B) or to activate their prior knowledge. This finding suggests that future analysis about the effects of teacher talk should stress temporal and situation-specific aspects of the teacher-child interaction discourse. This underlines the importance of the quality of teacher-child interaction as an important determinate of instructional quality in institutions of early childhood respectively preschool education (e.g., Curby et al., 2009; Hamre et al., 2012; Siraj-Blatchford et al., 2002).

To sum up, teachers’ provision of content-specific language was identified as being an effective strategy to support children’s learning. With respect to teacher talk in the function of underlying scaffolding intentions, the situation seem more complex: Structuring and problematizing were introduced as two main mechanisms of teachers’ talk for scaffolding children’s science learning (cf. to Reiser, 2004). The data of this study did not support the structuring function (type A and B) and revealed both benefits and damage to children’s learning related to the problematizing function. Interestingly, teacher talk in the problematizing function was identified as being effective under the condition of preceding prompts of directing children’s focus and activation of prior-knowledge.

Limitations

This study was conducted in the natural environment of kindergarten. Validity was upheld with respect to the instructional situation, in which teachers assisted a group of children in regular free-play time on a regular kindergarten day. On the other hand, the validity might be challenged with respect to the fact that these situations were recorded on videotape: Teachers might show a different instructional behavior in absence/presence of the person recording the videotape (social desirability bias). Further, the verbal speech from the teachers served as the primary information source for coding a set of underlying scaffolding functions. Hence, the chosen approach had a strong teacher-oriented focus, which allowed the analysis of the data quantitatively also. However, the adaptive and dynamic nature of scaffolding (see the characteristic of ‘contingency’ in van de Pol et al., 2010) would call for the integration of a child-, respectively discourse-oriented perspective too. For instance, it could be investigated, whether specific patterns in teacher-child interaction effects children’s learning (for language learning, see for instance Mascareño et al., 2016). To date, studies about teacher-child discourses in science instruction were restricted to qualitative analyses in small samples and lack of a direct link to children’s learning performance (e.g., Chin, 2006; Eshach et al., 2011; Mercer, Dawes, & Staarman, 2009). Future research should aim to integrate qualitative discourse-oriented analyses and quantitative modelling approaches to shed further light on the complex relations between teacher talk, teacher-child interactions and the children’s learning in science instruction.
The identified effects of teacher talk on children’s learning were rather small. The analyzed latent regression models indicate that teacher talk can explain children’s learning outcomes to a much smaller extent compared to children’s prior knowledge (explained variance of approx. 5% and 75% respectively). Of course, it seems obvious that subject-specific variables are more closely connected to a subject-specific behavior (a one-to-one-relation) compared to the teacher-child relationship (a one-to-group-relation). The small effect sizes of teacher talk might be due to the short intervention period of only four weeks. The reported effects in early mathematics instruction were based on a much longer study time (see Klibanoff et al., 2006).

This study focused on the verbal input in teacher talk. Another thread of research would include teachers’ gestures, which are also reported to influence children’s domain specific learning (e.g., Congdon et al., 2017).

**Conclusions and Implications**

For early science instruction, it seems enormously helpful for children to be confronted with domain-specific vocabulary (content-specific language) during inquiry-based learning settings. More elaborated teacher talk with an underlying scaffolding function (scaffolding utterances) can both have beneficial and adverse effects on children’s learning. Hence, elaborated forms of teacher talk need to be provided carefully because they are strongly dependent upon what discursive context they are applied. Programs of professional education and development should therefore primarily focus on teachers’ understanding and application vocabulary directly related to the content to be taught. Elaborated scaffolding strategies should only be covered when their implementation in early science instruction can be discussed and analyzed in depth. Otherwise, the targeted professional competence might be lost.
3.6 References


Hardy, I., Jonen, A., Möller, K., & Stern, E. (2006). Effects of instructional support within constructivist learning environments for elementary school students’ understanding of


4 The Effects of a Short-Term Intervention in Early Science Professional Development on Teachers’ Pedagogical Content Knowledge, Instructional Practices, and Children’s Conceptual Learning

4.1 Introduction

The education of scientifically literate people in the face of the challenges of the 21st century is seen as a societal necessity (Bybee, 2006; OECD, 2013). In many countries around the world, educational reforms strive to foster students’ learning towards building scientific literacy (Bybee, McCrae, & Laurie, 2009; French, 2004; National Research Council, 2012; OECD, 2013). There is a strong consensus among researchers and politicians that achieving this goal needs a change in instructional practices, which ultimately rely on teachers and their continuous professional development (Borko, 2004; Haney & Lumpe, 1995). If any educational reform is to have the desired impact in the field, it is of utmost importance to understand the effects of teacher professional development (Desimone, 2009; Fishman, Marx, Best, & Tal, 2003). Although there is extensive literature on the determining features of professional development effectiveness, the evidence base is still weak and the applied methods frequently do not meet current methodological standards (Wayne, Yoon, Zhu, Cronen, & Garet, 2008; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007).

Many researchers agree upon an early start of science education (Cabe Trundle, 2015; Eshach, 2011; Eshach & Fried, 2005; French, 2004; Ginsburg & Golbeck, 2004). One of the main reasons for starting science education as early as in preschool age is young children’s longtime underestimated cognitive potential for domain-specific learning (Carey, 1985; Eshach & Fried, 2005; Metz, 1995). In developmental research, the view gained recognition that children are biologically prepared for science learning as they naturally learn about the world around them in a process of intuitive theory building (Baillargeon, 1994; Carey, 1985; Cohen & Cashon, 2007; Gopnik, 2012; Mandler, 2008; Metz, 1995). Therefore, science instruction in early childhood and primary education should be targeted at children’s construction of basic conceptual knowledge, which serves as a fundament for later conceptual learning.

Effective science instruction is assumed to depend on knowledgeable, competent, and confident teachers (Baumert et al., 2010; Magnusson, Krajcik, & Borko, 1999; Shulman, 1987). Early science teachers need a solid base of knowledge about the subject matter (content knowledge) and knowledge about how children learn within a certain domain (pedagogical content knowledge). However, primary science teachers are reported to be deficient in science-specific content and pedagogical content knowledge, and as a consequence, often experience unease when it comes to science teaching.
(Appleton, 2003, 2007). For these reasons, initiatives of professional development seem to be extremely important, especially in early science education.

**The Conceptualization and Measurement of Professional Education**

Research about professional development includes is highly complex (Avalos, 2011). The complexity arises from a multitude of interwoven elements and characteristics: For instance, it includes multiple stakeholders (teachers, facilitators, children, heads of school institutions, researchers, etc.), a wide temporal scope (one-shot interventions vs. professional learning as a life-long process), a wide spatial scope (on-site vs. off-site teacher learning), hierarchical dimensions (school, teacher/class, student), and, last but not least, multiple bodies of theoretical thought (a theory of teacher learning, a theory of instruction, a theory of student learning, etc.).

In an attempt to reduce this complexity, researchers have established numerous frameworks, conceptualizations, and models of teacher professional development. For instance, Borko (2004) suggested understanding professional development as a system consisting of the following four elements: (i) the professional development program, (ii) the teachers who are the learner in the system, (iii) the facilitator who guides teachers as they construct new knowledge and practices, and (iv) the context in which the professional development occurs. She further describes three phases of studying these systems: In the first phase, research should aim at creating an “existence proof” (Borko, 2004, p. 5), which means obtaining evidence for effects of a specific professional development program on teacher learning (i.e. single program at a single site). In the second phase, research should aim at testing whether a well-specified professional development program (based on evidence from the first phase) can effectively be enacted by multiple facilitators in multiple settings (i.e. single program at multiple sites). Finally, in the third phase, research should aim at the comparison of the implementation, effects, and resource requirements of well-defined professional development programs (i.e. multiple programs at multiple sites). Further, Haney and Lumpe (1995) proposed a framework for professional development specifically for science teachers. They have structured a set of literature-based characteristics about effective programs according to three stages, i.e. the planning stage, training stage, and follow-up stage. They highlight the teacher as being the central figure in professional development and specifically advocate addressing teachers’ beliefs about science teaching and learning throughout all these stages. Another science-specific model of professional development is suggested by Supovitz and Turner (2000). They highlight the importance of relating the quality of professional development to the use of inquiry-based teaching practices and student achievement. Again another example, Lipowsky and Rzejak (2015) suggested to frame professional
development into an offer-and-use model\(^{29}\). Their conceptualization include all elements of a professional development system as suggested by Borko (2004), but, it additionally stresses that the program’s effectiveness would depend on how teacher perceive, interpret and utilize information provided during the professional development intervention.

In this study, the effectiveness of a teacher professional development program will be analyzed with reference to the framework suggested by Desimone (2009) (see Figure 4.1). According to this framework, an effective professional development intervention should be designed based on a set of core features (explained in more detail further below) enabling teachers to strengthen their knowledge respectively alter their beliefs, which in turn increases the quality of their instructional practices, and finally leads to improved children’s learning. Desimone (2009) persuasively justified her model with ample of references to empirical studies demonstrating links between teacher knowledge and beliefs, their practice, and student achievement. She recommends using this model in all empirical studies of professional development to increase the validity of comparisons and conclusions among studies of professional development effectiveness. Recent research about the effectiveness of professional development programs was frequently based on this basic model, respectively on adapted versions of it (e.g., Hamre, Pianta, et al., 2012; Kleickmann, Tröbst, Jonen, Vehmeyer, & Möller, 2016). The framework presented in Figure 4.1 is an adapted version of the original version of Desimone (2009) in order to fully serve the purpose of this study, including slightly reformulated components. In detail, the term Teachers’ Professional Competence including the differentiation between disposition and performance was added to the figure to correspond with research highlighting the need to integrate both dispositional and performance-related measures for an adequate representation of teachers’ professional competence (Blömeke, Gustafsson, & Shavelson, 2015; Nentwig-Gesemann, Fröhlich-Gildhoff, & Pietsch, 2011).

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\(^{29}\) This model relates to the more commonly known utilization of learning opportunities model (in German: Angebots-Nutzungs-Modell), in which pupils (not teachers) are in focus.
The high complexity in professional development described above results in various possibilities about measuring its effectiveness (Avalos, 2011). Lipowsky and Rzejak (2015) separate the following four levels of the assessment: (1) measuring teachers’ reactions immediately after the intervention covering their satisfaction and acceptance, (2) measuring teachers’ changes in their knowledge, attitudes, beliefs, and motivation, (3) measuring teachers’ in-class instructional behavior, and (4) measuring learning outcomes of the participants’ students. In general, those studies are considered as especially significant, which take a comprehensive perspective by combining measurements of all three levels, i.e. studies investigating the intervention-induced change with respect to teachers’ professional knowledge, their instructional practices, and student outcomes (Desimone, 2009; Lipowsky & Rzejak, 2015). In this study, the conceptual framework of Figure 4.1 has been chosen, because it adopts such a comprehensive perspective that not only considers teacher learning, but also instructional practices, and children learning. The drawback of such a comprehensive perspective is, obviously, that the associated research is labor and cost intensive. In consequence, research implementing such a comprehensive perspective on teacher professional effectiveness is comparably rare (Desimone, 2009).

Core Features of Effective Professional Development

The understanding of effective professional development includes, according to Wayne et al. (2008), at least two types of theories: a theory of teacher change and a theory of instruction. According to this differentiation, the theory of teacher change informs how professional development alters teacher knowledge, beliefs, and practices and the theory of instruction how that changed practice influences student achievement. It is beyond the scope of this thesis to provide a comprehensive review of empirical studies investigating the effectiveness of professional development programs. Instead, a reference is being made to the set of core features of professional development as proposed by Desimone (2009). Based on empirical studies about the effectiveness of professional development, she proposes five core features for the design of effective professional development interventions: (a) content focus, (b) active learning, (c) coherence, (d) duration, and (e) collective participation. Content focus is often considered the most important feature of effective professional development programs. It means that a program should have a sharp focus on selected curricular contents and on how students learn about these contents. Active learning describes forms of teacher learning that offer ample of opportunities for engagement. Typically mentioned forms include observations of expert teachers or own teaching, followed by feedback and discussions, or evaluating steps in or aspect of children’s learning processes. Here, video of instructional sequences are considered an adequate means for active learning. The feature coherence emphasizes the importance of the alignment of the contents and goals of the professional development intervention with teachers’ prior knowledge and their beliefs about teaching and learning on the one hand, and with educational reforms and policies on
the other hand. Then, the change of teachers’ competence including their behavior in classroom generally takes considerable time and effort. Therefore, the duration of an intervention is often also considered as an important feature of effectiveness. A sufficient duration is considered important both with respect to the time span of an intervention and the number of hours spent in the activity (contact hours). Generally, effective interventions include generally a time span of at least one semester and at least 30 contact hours (Guskey & Yoon, 2009). Finally, the feature of collective participation characterizes effective interventions with respect to the degree of exchange among the professionals. Arrangements including a rather homogenous group of professionals, for instance teachers of the same grade or school district, are considered having a greater potential for fruitful interaction and discourse among the participants. The intervention of this study largely coheres to these core features of professional development effectiveness (see methods section).

Of course, the above introduced core features by Desimone (2009) are not the only way to define professional education effectiveness. However, it seems that the features suggested by other research largely converge with Desimone’s list (Birman, Desimone, Porter, & Garet, 2000; Garet, Porter, Desimone, Birman, & Suk Yoon, 2001; Guskey & Yoon, 2009): For instance, Guskey and Yoon (2009) likewise highlight the importance of expanding teachers’ knowledge about how students learn in specific subjects or domains (referring to Desimone’s content focus) or the amount of time devoted (duration). Although there seems substantial agreement about the most important features of effective programs, at the same time, many scholars argue that the evidence base for this consensus is still weak (Wayne et al., 2008).

The features suggested by Desimone (2009) or Guskey and Yoon (2009) describe effective professional development in general, i.e. not specific to an educational level. However, in this study, the professional development effectiveness was investigated specifically for early education (directed at teachers who teach children aged from four to eight years). Therefore, literature about professional development was screened for an approach that specifically addresses early education, additional to the general features described above. This search lead to the identification of the Intentional Teaching approach from Hamre, Downer, Jamil, and Pianta (2012). According to this approach, they suggest concentrating in professional development on advancing the understanding of effective teacher-child interactions, as these interactions have been identified as a key quality criterion in preschool education in numerous studies (e.g., Burchinal et al., 2008; Curby et al., 2009; Howes et al., 2008; Siraj-Blatchford & Manni, 2008). They suggest designing interventions according the aspects of knowledge, perception, action, and reflection with respect to effective teacher-child interactions: (1) The component of Knowing stands for understanding information on how to efficiently interact with children; (2) the component of Seeing points to the building of awareness respectively the ability to identify effective teacher-child interactions; (3) the component of Doing describes that teachers enact effective teacher-child interactions in the classroom; and finally (4) the component of Reflecting
means that teachers are engaged in critical analyses and discussions about teacher-child interaction. In this study the *Intentional Teaching* approach served as a frame for the design of the professional development intervention (see methods section). Going several times through the cycle of knowing, seeing, doing, and reflecting is aimed at helping teachers to become intentional, meaning that they are more purposeful and deliberate about their practice.

**Knowledge and Beliefs: Pedagogical Content Knowledge in Science**

One of the primary goals of professional development is to broaden teachers’ pedagogical content knowledge (Desimone, 2009; Haney & Lumpe, 1995; Wayne et al., 2008). Pedagogical content knowledge is seen as a knowledge component uniquely important for teachers (Shulman, 1987). It represents teachers’ understanding of how students’ learning can be facilitated within a certain domain. The general hypothesis is that teachers having a stronger knowledge base provide better instruction, including adequately adapted support for children’s learning. Research on teachers’ pedagogical content knowledge includes both aspects of knowledge and beliefs (for details, see chapter 1.2 and 2.1 respectively). Teachers’ knowledge and beliefs are seen as important teacher cognitions, since they are considered to influence teachers’ decision taking in the classroom and in turn to affect various aspects of instructional quality (Baumert et al., 2010; Calderhead, 1996; Jones & Carter, 2007; Magnusson et al., 1999; Shulman, 1987).

Teacher beliefs are often studied in educational research (Calderhead, 1996; Jones & Carter, 2007; Reusser, Pauli, & Elmer, 2011). With respect to early instruction, teacher beliefs about teaching and learning are often mapped on current debates such as “child-centered vs. more didactic, basics skills approaches” (Stipek & Byler, 1997) or “laissez-faire/loosely structured classroom vs. didactic/highly structured classroom” (Miller & Almon, 2009). This study aims to map selected beliefs (see below) on a state-of-the-art understanding of effective science instruction and learning. The general hypothesis is here that a higher coherence between teachers’ beliefs about teaching and learning and a scientific understanding of effective teaching and learning is beneficial for instructional quality respectively student achievement.

Teacher beliefs about teaching and learning in science are often evaluated from the background of a constructivist understanding of learning (De Corte, 2011), and more specifically with respect to theories about conceptual change (e.g., Kleickmann et al., 2016). In the following, such an understanding of learning is described under the aspects of restructuring, co-constructing and situated construction of knowledge. These and later terms printed in italics refer to the labels of the beliefs scales used in this study (see methods section).

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30 This section is a condensed version of chapter 1.2 and the respective part of chapter 2.1 respectively.
Restructuring knowledge describes learning as a process where humans restructure their own knowledge base in a self-active and autonomous process (Posner, Strike, Hewson, & Gertzog, 1982; Stern, 2005; Vosniadou, 2008). Humans learn as they constantly evaluate their internal knowledge structures against new information about their surrounding world (Carey, 1985; Chi, 2008; Vosniadou, 1994). Already young children can build on an extensive base of prior knowledge and on cognitive machinery for learning in the domain of science (Carey, 1985; Gopnik, 2012; Metz, 1995). Although learning is per se a self-active process, human learning is, at the same time, largely dependent on social interactions (Vygotsky, 1978): Co-constructing knowledge describes this idea. Drawing onto this sociocultural perspective, learners should have the opportunity to make their current conceptions explicit in order to share and discuss them with peers and teachers (John-Steiner & Mahn, 1996). The importance of argumentation, dialogue and interaction in learning is often summarized with the term co-construction, which is highlighted both in a domain-general (Burbules & Bruce, 2001; Rojas-Drummond, Torreblanca, Pedraza, Vélez, & Guzmán, 2013), and a science-specific perspective on learning (Chi, Roy, & Hausmann, 2008; Erduran & Jiménez-Aleixandre, 2007; Mercer, Dawes, & Staarman, 2009; Mercer & Howe, 2012; Newton, Driver, & Osborne, 1999). Finally, Situated construction of knowledge describes another aspect the constructivist nature of learning highlighting the importance of situating learning into meaningful contexts (Brown, Collins, & Duguid, 1989; Wortham, 2001).

Besides the above-mentioned aspects of the constructivist nature of learning, primary teachers often hold beliefs about the importance of Hands-on activities (e.g., King, Shumow, & Lietz, 2001; Lavonen, Johanna, Koponen, & Kurki-Suonio, 2004). Hands-on science activities refer to a widely used instructional strategy, where students are actively engaged in manipulating materials. According to Flick (1993), situations can be defined as hands-on activities, if students are cognitively engaged in a sense that the manipulation of physical objects is directed at the understanding of a part of their natural environment. However, teachers often seem to be attracted simply by the idea of letting children freely handle with science materials (referred to as “hands-on”), without addressing the link to associated cognitive processes (referred to as “minds-off”). Such a belief contrasts evidence demonstrating that unguided hands-on approaches are not effective in terms of children’s learning (Butts, Hofman, & Anderson, 1993; Kirschner, Sweller, & Clark, 2006; Möller, 2006).

Further, play has been considered an important context for learning in early childhood education for a considerable period of time (Fleer, 2009; Miller & Almon, 2009; Saracho & Spodek, 1995; Wannack, 2004). In this study, beliefs about Play are considered as having a potential for effective early science instruction, since play-based contexts are reported to stimulate children’s cognitive activities and the exchange of ideas among peers (Fleer, 2009).

Finally, Transmission of knowledge describes an often-studied teacher belief that conceptualizes learning as a transfer of knowledge from the teacher to the learner (Staub & Stern, 2002). According to
this belief students pick up knowledge directly from teachers’ speech in the literal sense of transmission: Knowledge is transmitted into children. Such a belief is clearly not in line with a contemporary understanding of the learning, because it contradicts the constructivist nature of learning.

**Instructional Practices: Teacher Talk as an Aspect of Teacher-Child Interactions**

As mentioned further above, the quality of teacher-child interactions are a central theme in defining effective instruction in early childhood education (Hamre, Pianta, et al., 2012; Siraj-Blatchford, 2009; Siraj-Blatchford, Sylva, Muttock, Gilden, & Bell, 2002; Trawick-Smith & Dziurgot, 2011). In this study, teacher talk was examined as an important aspect of these teacher-child interactions (compare with Figure 4.1).

Previous research suggests that teacher talk can be conceptualized in two ways: First, as verbal input for incidental language and content learning (Dickinson & Porche, 2011; Foy & Mann, 2003; Huttenlocher, 1998; Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002; Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006; Mascareño, Snow, Deunk, & Bosker, 2016). From this perspective, the underlying rational is that a higher amount and a more complex verbal input generates a richer learning environment which in turn increases the chance of children’s knowledge acquisition. According to this understanding, the role of the teacher is to contribute a rich (content-specific) language environment without directly addressing specific aspects of children’s learning (such as misconceptions). In this study, the term *content-specific language* (CSL) is used to refer to this kind of teacher talk. For teachers’ content-specific language, the general hypothesis is that children are able to develop coherent conceptual knowledge simply based on being exposed to a set of content-specific vocabulary. Second, teacher talk can be conceptualized as verbal input intentionally directed at domain-specific learning (Eshach, Dor-Ziderman, & Arbel, 2011; Hardy, Jonen, Möller, & Stern, 2006; Rappolt-Schlichtmann, Tenenbaum, Koepke, & Fischer, 2007). Teacher talk in this sense relates to the scaffolding metaphor, which was originally coined by describing a tutoring situation, where a more knowledgeable person enables a novice to succeed in a task, which would be otherwise out of reach (Vygotsky, 1978; Wood, Bruner, & Ross, 1976). In this study, the scaffolding function of teacher talk is referred to by the term *scaffolding utterances*. Here, the general hypothesis is that children enhance their science learning from teacher talk having underlying scaffolding functions, such as stimulating prior knowledge, asking open-ended questions or stimulating cognitive conflicts.

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31 This section is a condensed version from the respective section in chapter 3.1.
Interrelations Between Teachers’ Pedagogical Content Knowledge/Beliefs, Their Instructional Practices, and Children’s Learning and Its Development

There is considerable body of research about interrelations between teacher knowledge, beliefs, and instructional practices, and, more rarely, including links to student’s learning. Drawn from this research, features of professional development effectiveness were cited from Desimone (2009) further above. Research about these interrelations at the educational level of kindergarten is less frequent compared to higher levels in education. The following studies are briefly described, because they are considered to be specifically relevant to this study:

Charlesworth et al. (1993) analyzed correlations between beliefs and their practices in a sample of 204 kindergarten teachers. Beliefs and practices were described according their coherence to the guidelines for developmentally appropriate practice of the National Association for the Education of Young Children (NAEYC). They found that developmentally appropriate beliefs were moderately correlated with developmentally appropriate practices ($r = .53, p = .01$) and a somewhat stronger relationship between developmentally inappropriate beliefs and inappropriate practices ($r = .66, p = .01$).

Stipek and Byler (1997) explored the relationship between beliefs and practices (among other aspects) in a sample of 60 preschool, kindergarten, and first grade teachers. Beliefs and practices were mapped onto child-centered versus more didactic, basic-skill approaches, consisting of two measures of beliefs (child-centered beliefs, basic skills beliefs) and two measures of instructional practices (basic skills practices, positive social climate). Contrasting to the study referred to above, they found relations between teachers’ beliefs and practices: for kindergarten teachers, child-centered beliefs were positively correlated with an observed positive social climate ($r = .67, p < .01$) and negatively correlated with an emphasis on basic skills ($r = -.85, p < .01$), whereas correlations with opposite signs were identified for the basic skill beliefs (with basic positive social climate, $r = -.49, p < .05$; with basic skills practices, $r = .64, p < .01$).

Cash, Cabell, Hamre, DeCoster, and Pianta (2015) examined relations between teachers’ knowledge/beliefs and children’s learning in kindergarten. They investigated to what extent teachers’ knowledge/beliefs predicted children’s development in their language and literacy skills. Teachers’ knowledge was measured by a scale consisting of items where teachers had to categorize skills by language/literacy domain, and their beliefs were measured according a scale consisting of items expressing the importance of language and literacy for children as they enter kindergarten. Children’s learning was assessed according to four typical aspects of early language competence (receptive vocabulary, expressive vocabulary, print knowledge, and phonological awareness). They found that teachers’ knowledge was predictive for two out of the four outcome measures of children’s language skills, whereas teachers’ beliefs did not predict any of these children’s measures.
The three cited studies above analyzed relationships either between teacher beliefs and practices (Cash et al., 2015; Charlesworth et al., 1993), or between teacher beliefs/practices and children’s learning (Stipek & Byler, 1997) in kindergarten. The study by Suk Lee, Baik, and Charlesworth (2006) was the only found piece of research investigating the effects of a professional development intervention on the interrelation between teacher cognitions and their instructional practice in kindergarten. In a first part they identified teachers holding beliefs about developmentally appropriate practice (DAP), respectively inappropriate practices (DIP) based on data collected by means of a questionnaire in a sample of 242 kindergarten teachers. They found no significant differences between these groups of teachers with respect to their observed scaffolding behavior. In a second part, 60 teachers were randomly assigned to a treatment group (15 DAP, 15 DIP teachers) or a control group (15 DAP, 15 DIP teachers). The treatment was a professional development intervention consisting of three meetings, including both seminars and group discussions, covering the topic of scaffolding. After the intervention, they found that DAP teachers provided significantly greater gains in a scaffolding measure compared to DIP teachers.

Contrasting the three studies cited above, the study of Kleickmann et al. (2016) did not examine beliefs, practices, and children’s learning in kindergarten, but in elementary school. Nevertheless, Kleickmann’s study deserves special attention, because it has many similarities with the study in this paper. The research questions are largely congruent with the question formulated in this study (see below). Kleickmann et al. (2016) examined in their study the effects of a professional development intervention on teachers’ beliefs, instructional practices, and children’s learning in elementary school science instruction. Comparable to this study, they also implemented a content-specific focus around learning materials about the topic floating and sinking. Besides these similarities, the study has also marked differences, foremost, with respect to the targeted educational level (elementary school vs. kindergarten), the design of the intervention (two experimental groups vs. one experimental group), the duration (extensive vs. short format), the implemented measures for teacher practices and children’s conceptual understanding, etc. In their study, they randomly allocated teachers to three groups, who participated in interventions with differing levels of expert scaffolding (extensive scaffolding, low scaffolding, self-study). The study included a sample of 73 teachers and 1,039 students. They found that the scaffolded formats (extensive and low scaffolding) were superior compared to formats with no provision of scaffolds (self-study) with respect to teacher beliefs, and motivation, instructional quality, and student achievement. Further, they analyzed the mediating role of teachers’ beliefs and their instructional practices. They found that teacher beliefs were only to a small degree mediating children’s learning, whereas their practices proved to be a strong mediator.

The above cited studies illustrate that research about the interrelations between teachers’ knowledge, beliefs, and children’s learning has produced partly inconsistent results. With respect to early science education, evidence about the influences from teachers’ knowledge/beliefs and practices on children’s
learning is still weak. Furthermore, to my knowledge, there is no study investigating the influence of professional development intervention encompassing both outcome measures of teacher cognitions and children’s learning in kindergarten science.

4.2 The Present Study

In the present study, the effects of a short-term professional development intervention for kindergarten teachers based on the *Intentional Teaching* approach were investigated in early science instruction. The intervention was designed to have a sharp content-specific focus: Teachers were stimulated to reflect about their beliefs and practices directly related to children’s learning within the topic of floating and sinking. Fifty in-service teachers were randomly assigned to three groups: A first group of teachers, the experimental group, attending one half-day session about the introduction into the learning materials and two half-day sessions designed according to the *Intentional Teaching* approach, was contrasted with a second group of teachers, the control group, only receiving the half-day introduction into the learning materials. Both groups of teachers were asked to implement the topic of floating and sinking with their classes directly after the introduction into the learning materials. Further, a third group of teachers, the baseline group, was included that did neither attend the professional development program, nor did work about the topic with their classes. The effects of the introduction into the learning material respectively the additional program based on the *Intentional Teaching* approach were assessed by selected measures of teacher cognition (pedagogical content knowledge and beliefs), instructional practice (teacher talk in its scaffolding function), and children’s conceptual knowledge (performance in tasks about floating and sinking).

This is one of the few empirical pieces of research on early science professional development that encompasses both dispositional and performance-related measures of teachers’ professional competence (Blömeke et al., 2015), respectively all elements of the conceptual framework for studying the effects of professional developments as proposed by Desimone (2009). Further, this study was based on a randomized assignment of teachers, which is only rarely implemented (Wayne et al., 2008). The intervention in this study sought to meet four out of the five core features of effective professional development as suggested by Desimone (2009), i.e. content focus, active learning, coherence, and collective participation (see below for further information). *Duration* is the only feature on this list, which was not implemented in this study; the intervention covers only a short duration (one half-day respectively three half-day sessions of four hours each) and also a relatively short time-span (four weeks). This intervention design was chosen to answer the extremely important question, whether even short-duration formats, as they are often typically offered in the field, can have effects on targeted outcomes of teachers’ professional competence, instructional practice, and children’s learning. Specifically, the research was guided by the following questions:
1. What are the effects of a short-term professional development intervention based on the *Intentional-Teaching* approach (compared to an introductory session only) on (1.1) teachers’ pedagogical content knowledge, (1.2) their instructional practices (teacher talk as content-specific language and scaffolding utterances), and (1.3) children’s conceptual learning?

An increase in teachers’ professional competence and children’s conceptual knowledge was expected for both intervention groups; a more articulated increase for the group participating the short intervention based on the *Intentional Teaching* approach (EG IT) and a less articulated increase for the group receiving only the introduction into the structured learning materials (CG IO). No changes were expected for the baseline group (BG). Positive effects of the interventions were expected because the program largely coheres to frequently reported features of professional development effectiveness (Desimone, 2009). In reference to theories about teacher change, it was expected that the implementation of the *Intentional Teaching* approach by Hamre, Downer, et al. (2012) allowed the participating teachers to strengthen respectively alter their pedagogical content knowledge and beliefs and associated instructional practices. In reference to theories about instruction, it was expected that teachers’ changed instructional practices would result in more efficient conceptual learning by the children. In detail, the expectations included an intervention-induced increase in (1.1) teachers’ science-specific pedagogical content knowledge, (1.2) the occurrence of teacher talk as content-specific language and scaffolding utterances, and (1.3) children’s conceptual understanding of the topic floating and sinking.

2. Are (potential) intervention-induced effects on children’s learning mediated through (2.1) teachers’ pedagogical content knowledge and (2.2) their talk (content-specific language, scaffolding utterances)?

It is hypothesized that both teachers’ pedagogical content knowledge and their scaffolding talk mediate the intervention-induced effects on children’s learning. Such results would cohere to the findings from Kleickmann et al. (2016) for elementary school science.

### 4.3 Method

**Overview of Design, Procedures, and Materials**

The conducted study covered a period of four weeks, where teachers participated in a professional development course about early science instruction within the curricular topic of floating and sinking. Figure 4.2 is a representation of the study design intended to clarify the general procedure and the most important measures. Teachers were randomly assigned to an experimental group, a control group, and a baseline group. Teachers of both the experimental and the control group attended the same half-day introductory meeting (i.e. Meeting 1), which covered an introduction into learning as
conceptual change and learning materials about the floating and sinking. These teachers were asked to implement the distributed learning materials in their classes directly after this first course meeting for the following four weeks. Teachers of the experimental group attended two additional half-day meetings (i.e. Meeting 2 and Meeting 3) covering inputs and discussions about verbal scaffolding strategies based on the Intentional Teaching approach (see below for detailed information). In the following, this group is referred to as Experimental Group Intentional Teaching (EG IT). The teachers of the control group only attended the introductory meeting. This group is referred to as Control Group Instruction Only (CG IO). Finally, the third group of teachers formed the Baseline Group (BG). These teachers neither participated in any professional development course nor did they implement the learning materials with their classes.

All teachers were asked to fill in a questionnaire before (i.e. before Meeting 1) and after the professional development course (i.e. after Meeting 3) in order to measure their pedagogical content knowledge (see below for details). Teacher talk was assessed based on samples of videotaped sequences at the beginning (i.e. directly after Meeting 1) and at the end (i.e. after Meeting 3) of the implementation phase. Finally, children’s conceptual knowledge was assessed in individual sessions before the professional development course (before Meeting 1) and at the end of the implementation phase (i.e. after Meeting 3).

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<td>Conceptual knowledge about floating and sinking (individual sessions)</td>
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Note. EG IT = experimental group Intentional Teaching; CG IO = control group instruction only, BG = baseline group; PCK = pedagogical content knowledge.

*Figure 4.2. Research design with professional development interventions, and pre- and post-intervention measures.*

**Sample**

The study included a sample of total 50 in-service teachers from the region of Lucerne, Switzerland, who taught children at the kindergarten level. In Switzerland, kindergarten is a compulsory part of the public educational system. In Switzerland, children generally attend kindergarten between the ages of four to six years. Different forms of this first phase of compulsory education exist. The most widespread form is that children attend kindergarten for one or two years and then proceed to the first grades in elementary school. Another form called *Basisstufe* combines the kindergarten and the two lowest grades of elementary school. The sample of this study comprises of 46 teachers teaching at
kindergarten and 4 teachers teaching at the Basisstufe. On average, these teachers were 39.1 years old (SD = 11.6) and had 14.9 years (SD = 9.4 years) of teaching experience. All participating teachers were female and held a teaching diploma either for elementary school or kindergarten or both.

The associated children sample consisted of 684 kindergarten children. They had a mean age of 5.0 years (SD = 0.7). The proportion of females was 47.8%. These and further characteristics of the participating teachers and children can be read in Table 4.1.

Table 4.1

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total</th>
<th>EG IT</th>
<th>CG IO</th>
<th>BG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>50</td>
<td>17</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>Gender: Female (%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Education in kindergarten teacher training seminar (%)</td>
<td>80</td>
<td>88</td>
<td>67</td>
<td>87</td>
</tr>
<tr>
<td>Education at university of teacher educationa (%)</td>
<td>28</td>
<td>24</td>
<td>39</td>
<td>20</td>
</tr>
<tr>
<td>Current employment as a teacher (%)</td>
<td>86</td>
<td>84</td>
<td>84</td>
<td>92</td>
</tr>
<tr>
<td>Age (M [SD])</td>
<td>39.1 (11.6)</td>
<td>38.8 (9.6)</td>
<td>40.6 (13.1)</td>
<td>37.7 (12.1)</td>
</tr>
<tr>
<td>Teaching experience, years (M [SD])</td>
<td>14.9 (9.4)</td>
<td>15.4 (8.2)</td>
<td>15.3 (11.0)</td>
<td>13.9 (9.3)</td>
</tr>
<tr>
<td>Interest in science</td>
<td>3.9 (0.6)</td>
<td>3.9 (0.6)</td>
<td>3.8 (0.5)</td>
<td>4.1 (0.7)</td>
</tr>
<tr>
<td>Self-concept of ability in science</td>
<td>3.6 (0.7)</td>
<td>3.7 (0.7)</td>
<td>3.4 (0.8)</td>
<td>3.7 (0.8)</td>
</tr>
<tr>
<td>Children</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>684</td>
<td>253</td>
<td>262</td>
<td>169</td>
</tr>
<tr>
<td>Gender: Female (%)</td>
<td>48</td>
<td>49</td>
<td>49</td>
<td>45</td>
</tr>
<tr>
<td>Age (M [SD])</td>
<td>5.0 (0.7)</td>
<td>4.9 (0.7)</td>
<td>5.1 (0.5)</td>
<td>5.2 (0.7)</td>
</tr>
</tbody>
</table>

Note. PD = professional development; EG IT = experimental group Intentional Teaching; CG = control group instruction only; BG = baseline group. Coding: Interest in science, Likert scale from 1 (fully incorrect) to 5 (fully correct); Self-concept of ability in science, Likert scale from 1 (fully incorrect) to 5 (fully correct).

a Teacher education was reformed in Switzerland around the turn of the century. Kindergarten and elementary school teacher training seminars were replaced by universities of teacher education (in German: Pädagogische Hochschulen). At the time of the study, the majority of the sample held a diploma from the kindergarten teacher training seminars and a smaller share from the teaching universities. Some teachers held diplomas from both types of teacher education.

Intervention

In this study, the intervention had a double rationale, for teachers’ professional development on the one hand, and for children’s conceptual learning on the other hand. For teachers, the intervention was a professional development course consisting of one (for the control group) respectively three course meetings (for the experimental group). For children, the intervention consisted of four consecutive weeks of regular kindergarten instruction. During this period children regularly worked, assisted by the participating teachers, with the distributed learning materials about floating and sinking during phases of free play time. The free play time is a typical phase in a kindergarten day, where the children of a class are allocated in smaller groups to different workstations. Condensed information about the professional development interventions is provided in Figure 4.3.
The additional intervention for the teachers of the experimental group (i.e. Meeting 2 and Meeting 3, see Figure 4.3) was conceptualized according to the *Intentional Teaching* approach following Hamre, Downer, et al. (2012), as introduced in the theoretical section: In the introductory meeting (Meeting 1), the participating teachers were provided with information about learning as conceptual change using the example of the topic of floating and sinking. For instance, the *concept of material kind* (see detailed information about the learning materials) was introduced and justified as intermediated stage in a process of conceptual reconstruction from naive conceptions (e.g., “Things with holes sink.”) towards later, more formal conceptions (e.g., buoyancy in the context of Archimedes principle). In this first meeting, the teachers were introduced into the learning materials about floating and sinking. The second and third meeting of the professional development course focused on teachers’ verbal input as a scaffold for children’s conceptual learning, and as such, as an important aspect of effective teacher-child interactions. In these meetings, the cycle of *Intentional Teaching* was implemented: The teachers processed information about the significance of different types of verbal support as a scaffold for children’s conceptual learning in science (component *Knowledge*), again based on the example of floating and sinking. This gave the teachers the opportunity to apply the theoretical vocabulary of theories on conceptual change from the first meeting. Using several video sequences, the participants were trained to identify and name effective scaffolding strategies (component of *Seeing*). After Meeting 2 (see Figure 4.2), the teachers had the opportunity to implement these strategies directly with their classes and to collect respective experiences. In Meeting 3 (see again Figure 4.2), these experiences were used to reflect about possible effects of specific types of verbal scaffolding strategies against the background of effective teacher-child interaction in general, and effective conceptual learning with respect to the physics of floating and sinking specifically. This meeting also consisted of additional video sequences, which were used as examples in order to restart the cycle of the process of *Intentional Teaching*. 
Teachers’ Competence and Professional Development in Early Science Education

Chapter 4 – The Effects of a Short-Term Intervention in Early Science Professional Development on Teachers’ Pedagogical Content Knowledge, Instructional Practices, and Children’s Conceptual Learning

Experimental Group: Intentional Teaching (EG IT)

Control Group: Instruction Only (CG IO)

| PD format | Three-part PD course led by an expert at teaching university covering an introduction into learning materials and a focus on effective teacher-child-interaction following the Intentional Teaching approach |
| Time span | Four weeks |
| Duration of courses at teaching university | Three half-days (about 12 hours), consisting of an introduction into the learning material (Meeting 1) and two meetings based on the IT approach focusing on teachers’ verbal input as a scaffold for children’s conceptual learning |
| Learning materials | Power point slides, learning material about floating and sinking (see below for details) |
| Content focus | Meeting 1: physics of floating and sinking; learning as conceptual change; naive conceptions commonly held by kindergarten children; idealized paths of conceptual reconstruction using the example of floating and sinking; collaborative lesson planning according to the learning materials |
| | Meeting 2: types of verbal support as important aspect of instructional support (IT component Knowing); identifying effective scaffolds in video examples (IT component Seeing) |
| | In-between meetings: enacting verbal support strategies in practice (IT component Doing) |
| | Meeting 3: reflection about effects of verbal support strategies (IT component Reflecting); restart IT cycle with additional video examples |
| | After meeting 3: enacting refined verbal support strategies in practice (IT component Doing) |
| Active learning | Active learning including discussions about several video sequences, stimulated by the expert |
| Coherence | The science topic of Floating and Sinking was aligned with early science curricula in Switzerland. |

Control Group: Instruction Only (CG IO)

| PD format | One-shot PD course led by an expert at teaching university covering only an introduction into the learning materials |
| Time span | One-half day (about 4 hours), consisting of an introduction into the learning material (Meeting 1) |
| Duration of courses at teaching university | One-half day (about 4 hours), consisting of an introduction into the learning material (Meeting 1) |
| Learning materials | Power point slides, learning material about floating and sinking (see below for details) |
| Content focus | Meeting 1: physics of floating and sinking; learning as conceptual change; naive conceptions commonly held by kindergarten children; idealized paths of conceptual reconstruction using the example of floating and sinking; collaborative lesson planning according to the learning materials |

**Figure 4.3.** Characteristics of professional development interventions. IT = Intentional Teaching, PD = professional development. The structure of this figure follows Kleickmann et al. (2016).

**Learning materials.** In this study, the learning materials about floating and sinking from Leuchter, Saalbach, and Hardy (2014) were refined. Floating and sinking is a typical curricular topic in early science education, which is often chosen in associated research (Butts et al., 1993; Hardy et al., 2006; Hsin & Wu, 2011). These learning materials aim to support children construct a concept of material kind (Dickinson, 1987). The kinds of material (such iron, clay, wood, polystyrene, etc.) function, in the learning materials of this study, as a predictor for the objects’ buoyancy, which are conceived to represent an intermediate concept in the conceptual learning process, because it does not conflict with the construction of concepts that will be targeted in higher grades, such as density or Archimedes’ principle. Although the concept of density generally cannot be understood by very young children, they have intuitive ideas based on experiences about the buoyancy when playing with objects in water (Hadzigeorgiou, 2015; Kohn, 1993). The material was structured in a way that should children enable to construct knowledge from contrasting their hypotheses with actual observations in a process of scientific inquiry (for details about science as inquiry, see Bybee, 2006). A group of two to six
children were engaged in two different workstations; the station ‘office’ for the generation and reflection of hypotheses about the buoyancy of the objects; and the station ‘lab’ for observing the real buoyancy, including a bin filled with water. This setting intended that children gather information about the buoyancy of a specifically selected set of objects in order to reason about relationship between the patterns of their observations and the physical properties of the presented objects. The learning materials were presented both as real objects and as pictorial representations on worksheets in both workstations. The worksheets consisted of three columns; a column of pictures of the objects, a column to express the hypothesis about the buoyancy and a column for reporting the observed buoyancy of the respective objects (for an example work sheet, see Figure 4.4). On each worksheet objects were specifically chosen and presented with the intention of challenging commonly prevailing misconceptions about the physics behind floating and sinking. In the example work sheet, children should be prompted to rethink the two misconceptions “Everything with a hole sinks” and “Small things sink and large things float”. These learning materials were intended to stimulate children’s conceptual restructuring about floating and sinking of objects, from one dimensional attributes (such as the shape, the volume, the weight of objects) towards the identification of the kind of material as a property of objects that inherently integrate aspects of weight and volume (such iron, clay, wood, polystyrene etc.) (Leuchter et al., 2014).

Figure 4.4. Example worksheet within the topic floating and sinking.
Measures

The effects of the professional development intervention were assessed based on measures covering the realms of teachers’ knowledge and beliefs, their instructional practices and children’s learning (see Figure 4.5). All associated measures were perceived from a domain-specific perspective.

Classification of children’s statements. The participants had to assess 19 children’s statements about the topic of floating and sinking. The children statements, example items are provided in Table 4.2, had to be rated either as being a “misconception” or as being “correct, respectively in line with conceptions targeted later in school”. This instrument was newly developed for this study, based on the KiNT$^{33}$ materials developed by the group around Kornelia Möller. The number of correct classifications was divided by total classifications to attain a performance score.

Assessment of the importance of learning goals. Teachers’ knowledge and beliefs about curricular goals are seen as an important component of teacher knowledge (Magnusson et al., 1999; Shulman, 1987). The two applied constructs differentiate between domain-specific vs. domain-general learning

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32 The information in this sub-chapter is a partly identical with the respective sections in chapter 2.3 and chapter 3.3 respectively.

goals with the topic of natural phenomena around the farm respectively farming, which is also a
typical curricular topic in primary education. The participating teachers were asked to rate these items
on a five-point Likert scale from 1 (not important at all) to 5 (very important).

**Beliefs about teaching and learning.** Teacher beliefs about teaching and learning in science were
measured by six scales consisting of a total of 31 items. These items had to be rated on a five-point
Likert scale from 1 (not important at all) to 5 (very important). All items (with one exception, see
below) were taken from an existing item pool from Kleickmann (2008), who has analyzed teacher
beliefs in a sample of N = 46 in-service elementary school teachers (grade three and four) in Germany.
These items were slightly adapted for this study (for details see chapter 2.3 and Appendix B respectively).
The exception concerns the scale “Play” and the associated items, which was newly
developed to specifically address the play-based pedagogy, which is considered typical for early
childhood education (Miller & Almon, 2009; Wannack, 2004).

**Table 4.2**
**Measures, Example Items, and Internal Consistency Estimates of Teachers’ Pedagogical Content
Knowledge**

<table>
<thead>
<tr>
<th>Construct</th>
<th>Example items</th>
<th>N of items</th>
<th>Cronbach’s alpha Pre-PD</th>
<th>Cronbach’s alpha Post-PD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification of children’s statements</td>
<td>“This button has four small holes. It is certainly going to sink.” (misconception)</td>
<td>19</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>“Heavy things sometimes float too. Then, these things are rather big and need a lot of space in water.” (correct, respectively in line with conceptions targeted later)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessment of the importance of learning goals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domain-specific learning goals</td>
<td>Being able to justify the relevance of weather and climate (for instance drought, thunder) for a farm.</td>
<td>7</td>
<td>.80</td>
<td>.80</td>
</tr>
<tr>
<td>Domain-general learning goals</td>
<td>Being able to ask a question to an unfamiliar person in comprehensible and understandable way.</td>
<td>7</td>
<td>.62</td>
<td>.74</td>
</tr>
<tr>
<td>Beliefs about teaching and learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restructuring knowledge</td>
<td>Children may already have persisting concepts that may make learning a demanding process.</td>
<td>7</td>
<td>.78</td>
<td>.90</td>
</tr>
<tr>
<td>Co-constructing knowledge</td>
<td>Children should be encouraged to share their ideas even if their concepts about a science phenomenon are wrong.</td>
<td>7</td>
<td>.75</td>
<td>.81</td>
</tr>
<tr>
<td>Situated construction of knowledge</td>
<td>Every-day problems are the starting point for science learning.</td>
<td>4</td>
<td>.67</td>
<td>.90</td>
</tr>
<tr>
<td>Hands-on activity</td>
<td>In science, it is enough if children are having hands-on experiences.</td>
<td>5</td>
<td>.74</td>
<td>.82</td>
</tr>
<tr>
<td>Transmission of knowledge</td>
<td>Teachers should transfer important domain-specific knowledge before children are allowed to make their own experiences in science.</td>
<td>5</td>
<td>.70</td>
<td>.78</td>
</tr>
</tbody>
</table>

*Note. Internal consistency estimates were calculated based on N = 50 teachers. PD = professional development.

* This measure consists of dichotomous variables; therefore Cronbach’s alpha is not reported (Sijtsma, 2008).
Teachers’ Talk. Instructional practices were assessed by coding teacher talk with the function of providing scaffolds for children’s conceptual learning. Teacher talk was analyzed for the variables of content-specific language (CSL) and scaffolding utterances. These variables were extracted by coding the collected video material in a time-sampling procedure using the software Videograph (Rimmele, 2013). The time-samples were chosen to be of 15 second length. In a first step, sequences were identified for further analysis based on the identification of the classical didactic triangle, where the teacher, at least one learner and the learning content was present (see didactic triangle, Schoenfeld, 2012). Inter-rater reliability was tested several times during the process and was established on total 22.3% of the data material. Reliability was evaluated using kappa coefficients. According to Fleiss (1981), kappa coefficients above .75 are considered as an excellent agreement. An overall kappa of .80 was obtained for CSL and .79 for scaffolding utterances respectively. Disagreements were resolved through discussion. These two types of verbal input will be described in further details in the following.

Content-specific language. The variable CSL measured the occurrence of specific expressions in teachers’ talk. In this study, the characterization of objects associated to the concept of material kind (iron, clay, wood, polystyrene, wax, plastic) were considered as these specific expressions, since they are directly related to the learning goal (i.e. constructing the concept of material kind). Teacher utterances were rated in every slot according to the following three levels; (i) no occurrence of these expressions (no CSL), (ii) occurrence of one or more of these expressions (Example: “Have you seen clay before?”), (iii) occurrence of one or more of these expressions in combination with the buoyancy (Example: “Because it is wooden? What will probably happen with it?”). Then, the proportion of slots consisting of CSL, i.e. either type (ii) or (iii), from total analyzed slots was calculated.

Scaffolding utterances. The variable scaffolding utterances measured teacher talk according to its underlying scaffolding intention. Table 4.3 provides the analyzed types of these scaffolding intention including examples. Type A are utterances directed at the clarification of the phenomenon, task, and procedure. Teacher talk of this type should support children to establish and maintain the direction of her/his learning activities to the instructional task, respectively phenomenon at hand. The two subtypes reflect that teachers may express the scaffolding intentions either as guidance or as inquiry. Type B refers to teacher utterances that are intended to steer children’s attention to specific properties of the phenomenon. The sub-types are formulated again on the differentiation between the aspects of guidance vs. inquiry. Type C refers to teacher utterances directed at children’s activation of prior knowledge. The associated sub-types include referencing to prior experiences (long-term/wide scope) and calling for a hypothesis formulation (short-term/narrow scope). Finally, prompting for explanations, comparisons, reasoning and cognitive conflicts fall under the Type D, which is seen as a support for processes of conceptual reconstruction. The proportion of slots consisting of scaffolding utterances from total analyzed slots was calculated for each main category separately. In cases where
multiple types of scaffolding utterances were identified within the same time slot, a rule corresponding
to the hierarchical nature of the framework was applied (D over C, over B, over A). Slots consisting
only of teacher utterances not related the topic of instruction were allocated to the category ‘outside’
(for outside the content). Further, slots were identified, where teachers were present in the didactic
triangle (see above), but did not provide any verbal input. This behavior related to the category W (for
waiting).

Table 4.3
Types of Scaffolding Utterances With Underlying Intention

<table>
<thead>
<tr>
<th>Type of Scaffolding Intentions</th>
<th>Sub-Types and Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Clarification of phenomenon, task, and Procedure</td>
<td>A.1 Guiding of Phenomenon, task and procedure “Well, then, you can go over to put on the ′control′-sticker.”</td>
</tr>
<tr>
<td></td>
<td>A.2 Inquiring of Phenomenon, task and procedure “Tell me what to do next.”</td>
</tr>
<tr>
<td>B Focus of attention</td>
<td>B.1 Guiding observation “Hold it in your hands, first.”</td>
</tr>
<tr>
<td></td>
<td>B.2 Inquiring observation “What happens when you push it [the candle] down, does it stay down?”</td>
</tr>
<tr>
<td>C Activation of prior knowledge</td>
<td>C1. (Re-)Activate prior knowledge “Have you seen something similar at home before?”</td>
</tr>
<tr>
<td></td>
<td>C2. (Re-)Activate hypothesis formulation “What do you believe, does it float?”</td>
</tr>
<tr>
<td>D Challenging conceptual change</td>
<td>D.1 Prompt explanation “Why do you think it floats?”</td>
</tr>
<tr>
<td></td>
<td>D.2 Prompt comparison “Do both rulers have a small hole?”</td>
</tr>
<tr>
<td></td>
<td>D.3 Prompt reasoning “It floats. Well. And what have you said [predicted]?”</td>
</tr>
<tr>
<td></td>
<td>D.4 Prompt cognitive conflicts “And it is light [small weight]? … And it nevertheless sinks in water?”</td>
</tr>
<tr>
<td>W Waiting Outside</td>
<td>[waiting]</td>
</tr>
<tr>
<td></td>
<td>“Of course, go quickly to the toilet!”</td>
</tr>
</tbody>
</table>

**Children’s Learning.** Children’s learning was examined looking at their development of the concept of material kind. The conceptual knowledge was measured before and after the intervention with respect to the four tasks labeled as (i) Classification, (ii) Justification, (iii) Allocation and (iv) Labeling. Children’s knowledge was assessed in one-to-one sessions in a quiet place in their kindergarten during a regular kindergarten day. Each testing session lasted for approximately 10 minutes.

**Classification.** In the first task, the children had to classify 16 objects according to their predicted buoyancy. The children could express their buoyancy prediction either verbally or with gestures. The predictions were coded as correct/false with respect to the real buoyancy of the respective objects. The respective measure reflects the relative proportion of correct predictions.
Justification. In the second task, the children were asked to justify these 16 buoyancy predictions verbally. Children’s statements were coded according to its coherence the concept of material kind (see section “learning materials”). Statements consisting with regard to this concept (example “it floats, because it is iron”) were rated as fully correct (1 point), statements consisting of a single dimension such as weight, form, etc. (example “it floats, because it is not heavy”) were rated as partly correct (0.5 points), statements as “I don’t know” were rated as incorrect (0 points). The respective measure reflects the proportion of correct justifications with respect to the coherence to the concept of material kind and for the buoyancy prediction respectively.

Allocation. In the third task, the children had to match six pairs of objects according to the kinds of materials. For instance, a wooden toothpick had to be matched to a larger wood piece. The respective measure reflects the proportion of correct allocations to total allocations.

Labeling. Finally, the fourth task consisted of labeling these six objects according to the material kind. The respective measure reflects the proportion of correct labeling to total labeling.

The internal consistency of these score variables were evaluated according to Bühner (2011) as follows, for Classification for t1 .34 (low) and for t2 .53 (low), for Justification for t1 .90 (high) and for t2 .93 (high), for Allocation for t1 .63 (low) and for t2 .67 (low), and for Labeling for t1 .52 (low) and for t2 .62 (low). These partly low internal consistency estimates are not surprising, because formal conceptual learning in science is just about to start at kindergarten age. With respect to the classification task, it must be assumed that some of children’s classification of the objects buoyancy was, especially in the pre-test, a mere guess and therefore not a reliable representation of a knowledge structure (see Leuchter & Saalbach, 2014). Nevertheless, the constant improvement of the internal consistency estimates between the measured time points indicated that conceptual reconstruction had indeed taken place. In modeling the measures of the four tasks (Classification, Justification, Allocation, Labeling) inform together a latent construct of Children’s conceptual knowledge (CCK), which is an integrative representation of children’s understanding of the concept of material kind.

Attrition and Missing data

Information about the attrition is reported in Table 4.4. The questionnaire was completed by all 50 teachers before the intervention and by 46 teachers after the intervention. Video data for the assessment of instructional quality was available for 32 teachers in the pre-measurement and for 34 teachers in the post-measurement (from a total of 35 teachers participating in the experimental and control group). The missing video data is due to filming the wrong teacher (concerns teacher ID = 46 for t1 and t2, and teacher ID = 52 for t1) and deleting a video by mistake by a research assistant (concerns teacher ID = 47). There are children measures for all 50 teachers for t1 and t2 and for all 35 teachers for t3. The exact number of children participating in the tasks about floating and sinking can be read in the last column of Table 4.4.
Table 4.4
Attrition With Respect to Measurement Instruments

<table>
<thead>
<tr>
<th></th>
<th>Teacher questionnaire</th>
<th>Video analysis</th>
<th>Children tests (classes)</th>
<th>Children tests (individuals)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t1 t2</td>
<td>t1 t2</td>
<td>t1 t2 t3</td>
<td>t1 t2 t3</td>
</tr>
<tr>
<td>BG</td>
<td>15 12</td>
<td>- -</td>
<td>15 15 -</td>
<td>162-168 157-158 -</td>
</tr>
<tr>
<td>CG IO</td>
<td>18 18</td>
<td>16 17</td>
<td>18 18 18</td>
<td>246-252 235-241 226-228</td>
</tr>
<tr>
<td>EG IT</td>
<td>17 16</td>
<td>16 17</td>
<td>17 17 17</td>
<td>226-234 227-234 213-215</td>
</tr>
<tr>
<td>Total</td>
<td>50 46</td>
<td>32 34</td>
<td>50 50 35</td>
<td>634-654 619-633 439-443</td>
</tr>
</tbody>
</table>

Note. EG IT = experimental group *Intentional Teaching*; CG IO = control group instruction only; BG = baseline group. For the children tests (individuals), sample sizes are reported as a range from minimal to maximal number of subjects with respect to the four tasks about floating and sinking.

For the pre- and post-measures of teachers’ beliefs and knowledge (questionnaire), there were between 0.0% and 8.0% of the data missing, for those of instructional practice (video) between 2.9% and 8.6%, and for children’s conceptual knowledge (tests) between 4.4% and 7.5%.

The regression analyses with respect to the prediction of teacher outcomes (question 1.1 and 1.2) were conducted using case-wise deletion of missing values. The latent regression modeling with respect to the prediction of children’s outcomes was based on the FIML procedure, which allows the use of all available information.

**Analyses**

The effects of the professional development intervention on teacher and children variables were assessed by means of regression analyses. Each post-measure (after the intervention) associated with the respective research question (see above) acted as dependent variable in separate regression models. In each of these models, the respective pre-measure (before the intervention) was set as the first predictor in order to control for the effect of prior knowledge. Orthogonal contrasts were built to allow the comparison of the groups of interest (see Figure 4.6 and Table 4.5 respectively): Contrast 1 describes the comparison of the average of the intervention groups (CG IO & EG IT) against the baseline group (BG). This contrast tests whether either an introduction into the learning materials or a short-term professional development program based on the *Intentional Teaching* approach leads to effects on the outcome measure compared with those teachers only doing the test battery. Contrast 2 describes the comparison of the experimental group (EG IT) against the control group (CG IO). This contrast allows the assessment of the additional effects of the short-term professional development intervention compared to only receiving the introduction into the learning materials. Note, positive coefficients were chosen to indicate a “high dose” and negative coefficients for a “low dose” of a
respective intervention. These contrasts are orthogonal because they have a zero sum of the products of their coefficients \((-2/3) * 0 + 1/3 * (-1/2) + 1/3 * 1/2 = 0\).

Figure 4.6. Graphical representation of contrasts.

<table>
<thead>
<tr>
<th>Table 4.5 Orthogonal Contrasts for Group Comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contrasting Groups</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Baseline Group (BG)</td>
</tr>
<tr>
<td>Control Group (CG IO)</td>
</tr>
<tr>
<td>Experimental Group (EG IT)</td>
</tr>
</tbody>
</table>

Effects on children’s conceptual understanding were analyzed based on non-hierarchical latent regression modeling. The four tasks (classification, justification, allocation, labeling, see above for further details) informed a latent construct of children’s conceptual knowledge about floating and sinking. A non-hierarchical procedure was chosen because three of four measures did not show substantial between-group variance (for a detailed description see chapter 3.3). Models were estimated with the R package lavaan (Rosseel, 2012). Estimation was based on the maximum likelihood procedure with robust standard errors (MLR), which is specifically robust for non-normally distributed data. Missing data are imputed by the full information maximum likelihood (FIML) procedure.

4.4 Results

Preliminary Results: Group Equivalence Before the Intervention

Equivalence between the pre-intervention measures of the three groups (BG, CG IO, and EG IT) was expected because of the random assignments. This expectation was tested by means of several regression analyses with the respective pre-intervention measures as dependent variables and the built contrasts for group affiliation (see methods section for detailed information). With respect to the comparison of the intervention groups against the baseline group (i.e. Contrast 1: CG IO & EG IT vs. BG), group affiliation was in three out of total nine of the analyzed measures a significant predictor, i.e. ‘Restructuring’ \((b = 0.47, SE = 0.18, p = .013)\), ‘Co-construction’ \((b = 0.42, SE = 0.15, p = .008)\), the latent construct of children’s conceptual knowledge \((b = -0.51, SE = 0.11, p < .001)\).

With respect to the comparison of the experimental group against the control group (i.e. Contrast 2: EG IT vs. CG IO), group affiliation was in one single of total fifteen of the analyzed measures a
significant predictor, i.e. teachers’ scaffolding utterances of type (D) Challenging conceptual change ($b = -7.78, SE = 2.87, p = .011$).

Any identified significant contrast violates the expectation of group equivalence and impairs accordingly the validity of conclusions concerning the comparison of these groups, at least with respect to the respective measures. The problem of non-equivalent groups was graver with respect to the comparison between the intervention group (CG IO & EG IT) and the baseline group (BG) (i.e. Contrast 1) and less grave for the comparison between the experimental group and the control group (Contrast 2). To answer the research question, the problem is reduced to some extent, because the respective models will all control for prior knowledge before analyzing the effects of group affiliation. Descriptive statistics of all measures of teacher cognition, instructional practice and children’s conceptual learning are presented in Table 4.6.
### Table 4.6

**Means and Standard Deviations for Teachers’ Pedagogical Content Knowledge, Teachers’ Talk, and Children’s Learning by Group**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Measure Description</th>
<th>Time</th>
<th>Total</th>
<th>EG</th>
<th>IT</th>
<th>CG</th>
<th>IO</th>
<th>BG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers’ classification of children’s statements</td>
<td></td>
<td>t1</td>
<td>63.69 (15.28)</td>
<td>62.50 (16.29)</td>
<td>65.20 (13.16)</td>
<td>63.16 (17.34)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>71.05 (15.16)</td>
<td>74.67 (14.41)</td>
<td>72.22 (9.86)</td>
<td>64.47 (20.95)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teachers’ assessment of the importance of learning goals</td>
<td>Domain-specific learning goals</td>
<td>t1</td>
<td>3.76 (0.64)</td>
<td>3.87 (0.67)</td>
<td>3.70 (0.76)</td>
<td>3.71 (0.43)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>3.66 (0.64)</td>
<td>4.00 (0.60)</td>
<td>3.47 (0.68)</td>
<td>3.48 (0.46)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Domain-general learning goals</td>
<td>t1</td>
<td>3.65 (0.53)</td>
<td>3.50 (0.50)</td>
<td>3.82 (0.53)</td>
<td>3.61 (0.56)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>3.58 (0.55)</td>
<td>3.52 (0.59)</td>
<td>3.56 (0.51)</td>
<td>3.70 (0.57)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teachers’ beliefs about teaching and learning</td>
<td>Restructuring knowledge</td>
<td>t1</td>
<td>3.06 (0.62)</td>
<td>3.17 (0.54)</td>
<td>3.24 (0.51)</td>
<td>2.73 (0.74)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>3.45 (0.85)</td>
<td>4.04 (0.63)</td>
<td>3.33 (0.71)</td>
<td>2.86 (0.83)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Co-constructing knowledge</td>
<td>t1</td>
<td>4.07 (0.53)</td>
<td>4.08 (0.36)</td>
<td>4.32 (0.33)</td>
<td>3.77 (0.74)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>4.06 (0.52)</td>
<td>4.09 (0.52)</td>
<td>4.07 (0.49)</td>
<td>4.02 (0.61)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Situated construction of knowledge</td>
<td>t1</td>
<td>3.58 (0.66)</td>
<td>3.68 (0.66)</td>
<td>3.57 (0.67)</td>
<td>3.47 (0.68)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>3.43 (0.88)</td>
<td>3.41 (1.10)</td>
<td>3.40 (0.81)</td>
<td>3.49 (0.70)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hands-on activity</td>
<td>t1</td>
<td>3.41 (0.61)</td>
<td>3.48 (0.54)</td>
<td>3.51 (0.59)</td>
<td>3.21 (0.70)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>3.09 (0.70)</td>
<td>2.71 (0.77)</td>
<td>3.34 (0.44)</td>
<td>3.20 (0.75)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transmission of knowledge</td>
<td>t1</td>
<td>2.71 (0.77)</td>
<td>2.61 (0.67)</td>
<td>2.56 (0.63)</td>
<td>2.99 (0.72)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>2.73 (0.72)</td>
<td>2.81 (0.87)</td>
<td>2.57 (0.59)</td>
<td>2.88 (0.69)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teachers’ content-specific language</td>
<td></td>
<td>t1</td>
<td>12.05 (9.21)</td>
<td>11.92 (11.50)</td>
<td>12.18 (6.57)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>16.18 (9.85)</td>
<td>21.48 (9.69)</td>
<td>10.88 (6.81)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teachers’ scaffolding utterances</td>
<td>(A) Clarification of phenomenon, task, and procedure</td>
<td>t1</td>
<td>39.26 (8.51)</td>
<td>41.68 (8.02)</td>
<td>36.84 (8.55)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>30.52 (7.61)</td>
<td>29.40 (5.55)</td>
<td>31.63 (9.27)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(B) Focus of attention</td>
<td>t1</td>
<td>13.85 (6.57)</td>
<td>13.49 (7.26)</td>
<td>14.21 (6.02)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>16.03 (6.49)</td>
<td>16.84 (6.26)</td>
<td>15.22 (7.67)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(C) Activation of prior knowledge</td>
<td>t1</td>
<td>12.04 (5.52)</td>
<td>13.16 (6.44)</td>
<td>10.91 (4.34)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>11.71 (5.38)</td>
<td>13.69 (5.92)</td>
<td>9.74 (4.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(D) Challenging conceptual change</td>
<td>t1</td>
<td>14.78 (8.91)</td>
<td>10.89 (4.73)</td>
<td>18.67 (10.46)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>22.20 (10.66)</td>
<td>27.97 (9.28)</td>
<td>16.44 (8.82)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[Waiting]</td>
<td>t1</td>
<td>5.70 (4.61)</td>
<td>5.00 (4.63)</td>
<td>6.40 (4.63)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>5.48 (5.41)</td>
<td>2.92 (3.06)</td>
<td>8.03 (6.10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children’s conceptual knowledge</td>
<td>Classification</td>
<td>t1</td>
<td>56.70 (15.49)</td>
<td>54.25 (16.77)</td>
<td>56.13 (13.28)</td>
<td>60.97 (15.92)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>69.20 (16.25)</td>
<td>71.42 (15.93)</td>
<td>71.99 (15.53)</td>
<td>61.67 (15.52)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t3</td>
<td>67.48 (15.60)</td>
<td>65.76 (16.79)</td>
<td>69.11 (14.24)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Justification</td>
<td>t1</td>
<td>46.02 (19.88)</td>
<td>43.76 (20.47)</td>
<td>44.93 (18.84)</td>
<td>50.83 (19.89)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>56.37 (21.93)</td>
<td>57.48 (22.72)</td>
<td>57.97 (22.02)</td>
<td>52.37 (20.22)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t3</td>
<td>54.82 (18.32)</td>
<td>54.24 (19.12)</td>
<td>55.37 (17.55)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Allocation</td>
<td>t1</td>
<td>45.71 (28.06)</td>
<td>42.98 (27.18)</td>
<td>44.85 (27.70)</td>
<td>50.70 (29.29)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>59.22 (28.59)</td>
<td>56.83 (28.46)</td>
<td>58.89 (28.42)</td>
<td>63.16 (28.81)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t3</td>
<td>64.20 (27.75)</td>
<td>65.65 (27.19)</td>
<td>62.85 (28.27)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Labeling</td>
<td>t1</td>
<td>31.11 (20.94)</td>
<td>28.36 (21.04)</td>
<td>31.17 (20.27)</td>
<td>34.87 (21.34)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>43.33 (26.35)</td>
<td>46.01 (27.73)</td>
<td>44.40 (26.59)</td>
<td>37.79 (23.06)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t3</td>
<td>46.61 (26.17)</td>
<td>43.65 (25.71)</td>
<td>49.34 (26.34)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CCK</td>
<td>t1</td>
<td>44.39 (15.86)</td>
<td>41.52 (16.50)</td>
<td>43.99 (14.39)</td>
<td>49.05 (16.08)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t2</td>
<td>56.72 (17.79)</td>
<td>57.51 (18.81)</td>
<td>58.02 (17.65)</td>
<td>53.57 (16.09)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>t3</td>
<td>58.07 (16.68)</td>
<td>56.96 (17.63)</td>
<td>59.12 (15.71)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. EG IT = experimental group Intentional Teaching; CG IO = control group instruction only; BG = baseline group; CCK = children’s conceptual knowledge (performance averaged over all four tasks). Coding: Classification of children’s statements, performance from 0 to 100; Assessment of the importance of learning goals, Likert scale from 1 (not important at all) to 5 (very important); Beliefs about teaching and learning, Likert scale from 1 (not important at all) to 5 (very important); Children’s conceptual knowledge, performance from 0 to 100.*

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Question 1.1: Effects on Teacher Cognition

Research question 1.1 addressed the effects of two types of professional development interventions (consisting of an introduction into the learning materials respectively additionally two sessions based on the Intentional-Teaching approach) on several facets of teachers’ pedagogical content knowledge. Descriptive results on this question are presented in Figure 4.7, Figure 4.8 and Figure 4.9 and the results of the respective regression analyses in Table 4.7. In the following, these results are described in detail.

The first facet of teachers’ pedagogical content knowledge covered teachers’ classification of children’s statements about floating and sinking. The visual inspection of Figure 4.7 coheres with the formulated hypotheses: The largest increase in correct classifications is associated to those teachers, who participated the professional development based on the Intentional Teaching approach (i.e. EG IT), the second largest increase to those teachers, who only received an introduction into the learning materials (i.e. CG IO) and the smallest change to the teachers of the baseline group (BG). The regression analysis in Table 4.7 showed a significant increase in correct classifications for the teachers of the intervention groups (Contrast 1, \(b = 9.58\)), but no significant additional increase associated to the experimental group.

Teachers’ assessment of the importance of domain-specific respectively domain-general learning goals represented the second studied outcome measure of teachers’ pedagogical content knowledge. For domain-specific learning goals, the visual inspection of Figure 4.8 reveals partly unexpected results, because the largest (negative) mean gain score was observed for the BG. With respect to the regression analysis, teachers of the intervention groups, CG IO and EG IT together (i.e. Contrast 1), did not show a significant change in their assessment of domain-specific learning goals (\(b = 0.22\); see Table 4.7. However, teachers participating in the intervention following the Intentional Teaching approach (i.e. EG IT) showed significantly higher agreement with domain-specific learning goals (\(b = 0.42\)). No significant changes with respect to both contrasts were identified for teachers’ assessment of domain-general learning goals.

The third facet of pedagogical content knowledge covered beliefs about teaching and learning in science. The visual inspection of Figure 4.9 reveals that the largest changes for the EG IT in the beliefs ‘Restructuring knowledge’ and ‘Hands-on activity’. These changes are in accordance to the formulated hypotheses, i.e. an increased agreement with respect to restructuring and a decreased agreement with respect to hands-on beliefs. The regression analyses in Table 4.7 show that teachers of the intervention groups (Contrast 1) and those of the experimental group (Contrast 2) showed significantly higher changes in the belief ‘Restructuring knowledge’ (\(b = 0.60\), respectively 0.78). Interestingly, no significant changes were observed in the other constructivism-based scales ‘Co-constructing knowledge’ and ‘Situated construction of knowledge’, nor in the scale ‘Transmission of knowledge’.
However, the teachers of the experimental group (Contrast 2) were associated to a decrease with respect to the belief scale ‘Hands-on activity’.

**Figure 4.7.** Mean gain scores for teachers’ classification of children’s statements. EG IT = experimental group Intentional Teaching; CG IO = control group instruction only; BG = baseline group. Coding: Performance from 0 to 100.

**Figure 4.8.** Mean gain scores for teachers’ beliefs about the importance of learning goals by group. EG IT = experimental group Intentional Teaching; CG IO = control group instruction only; BG = baseline group. Coding: Likert scale from 1 (not important at all) to 5 (very important).

**Figure 4.9.** Mean gain scores for teachers’ beliefs about teaching and learning in science by group. EG IT = experimental group Intentional Teaching; CG IO = control group instruction only; BG = baseline group. Coding: Likert scale from 1 (not important at all) to 5 (very important).
Table 4.7

Intervention Effects on Teachers’ Pedagogical Content Knowledge

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Class. of children’s statements</th>
<th>Assessment of the importance of learning goals</th>
<th>Beliefs about teaching and learning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Domain-specific learning goals</td>
<td>Domain-general learning goals</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>40.21***</td>
<td>1.27**</td>
<td>1.31**</td>
</tr>
<tr>
<td></td>
<td>(8.40)</td>
<td>(0.40)</td>
<td>(0.48)</td>
</tr>
<tr>
<td>Respective pre-intervention</td>
<td>0.48***</td>
<td>0.63***</td>
<td>0.68***</td>
</tr>
<tr>
<td>measure</td>
<td>(0.13)</td>
<td>(0.11)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>Contrast 1: BG (-2/3) vs. EG IT</td>
<td>9.58*</td>
<td>0.22</td>
<td>0.60**</td>
</tr>
<tr>
<td>CG IO &amp; EG IT (1/3)</td>
<td>(4.43)</td>
<td>(0.15)</td>
<td>(0.21)</td>
</tr>
<tr>
<td>Contrat 2: CG IO (-1/2) vs. EG IT</td>
<td>5.21</td>
<td>0.42*</td>
<td>0.78***</td>
</tr>
<tr>
<td>EG IT (1/2)</td>
<td>(4.62)</td>
<td>(0.16)</td>
<td>(0.21)</td>
</tr>
<tr>
<td>(R^2)</td>
<td>.31</td>
<td>.55</td>
<td>.53</td>
</tr>
</tbody>
</table>

Note: Unstandardized regression coefficients; standard errors in parentheses. PD = professional development; EG IT = experimental group Intervention Teaching; CG = control group instruction only; BG = baseline group. Coding: Classification of children’s statements, performance from 0 to 100; Assessment of the importance of learning goals, Likert scale from 1 (not important at all) to 5 (very important); Beliefs about teaching and learning, Likert scale from 1 (not important at all) to 5 (very important).

***p < .001, **p < .01, *p < .05

Question 1.2: Effects on Instructional Practices

Research question 1.2 addressed the intervention-induced effects on teachers’ instructional practices. Descriptive results on this question are presented in Figure 4.10 and Figure 4.11 and the results of the respective regression analyses in Table 4.8. In the following, these results are described in detail.

Teachers’ content-specific language represented the first studied outcome measure of instructional practice. The visual inspection of Figure 4.10 reveals a small decrease of teachers’ use of content-specific language in the control group (CG IO) and a substantial increase in the experimental group (EG IT). The regression analyses in Table 4.8 shows that the participation in the experimental group was associated with a significant increase in content-specific language (\(b = 8.86\)).

The second facet of instructional practices covered teachers’ scaffolding utterances. Figure 4.11 shows, in accordance to the expectations, more articulated changes over three out of four of the analyzed types of scaffolding utterances (types A, B and D). The intervention lead to a substantial decrease of scaffolding utterances of type A (Clarification of phenomenon, task, and procedure) for both groups, an increase of type B (Focus of attention) to a smaller extent, almost no changes in
type C (Activation of prior knowledge) and changes of opposite direction with respect to type D (a decrease and increase for the control and experimental group respectively). The regression analyses, reported in Table 4.8, show that the teachers of the experimental group significantly increased their scaffolding utterances of the type C and D. Interestingly, the teachers of the experimental group showed also a significant decrease in the category ‘waiting’. To recall, this category stands for instances during instruction, where the teachers were not providing any talk, but instead, just were observing the learners.

![Figure 4.10](image)

*Figure 4.10. Mean gain scores for teachers’ content-specific language. EG IT = experimental group Intentional Teaching; CG IO = control group instruction only; BG = baseline group. Coding: frequency from 0 to 100%.*
Figure 4.11. Mean gain scores for teachers’ scaffolding utterances by group. EG IT = experimental group Intentional Teaching; CG IO = control group instruction only. Coding: frequency from 0 to 100%.

Table 4.8

Intervention Effects on Teachers’ Instructional Practice

<table>
<thead>
<tr>
<th>Post-intervention measures (as dependent variables)</th>
<th>Scaffolding utterances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>(A) Clarification of phenomenon, task, and procedure</td>
</tr>
<tr>
<td>Intercept</td>
<td>6.22** (2.21)</td>
</tr>
<tr>
<td>Respective pre-intervention measure</td>
<td>0.42** (0.13)</td>
</tr>
<tr>
<td>Group: CG IO (0), EG IT (1)</td>
<td>8.86*** (2.27)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>.47</td>
</tr>
</tbody>
</table>

Note. Unstandardized regression coefficients; standard errors in parentheses. PD = professional development; EG IT = experimental group Intentional Teaching; CG = control group instruction only. Coding: frequency from 0 to 100%.

***p < .001, **p < .01, *p < .05

Question 1.3: Effects on Children’s Conceptual Learning

Research question 1.3 addressed the intervention-induced effects on children’s conceptual learning. Descriptive results to this question are presented in Figure 4.12 and the results of the respective latent regression modeling in Table 4.9. In the following, these results are described in detail.

The visual inspection of Figure 4.12 reveals largely expected results for three out of the four facets of children’s conceptual understanding of floating and sinking: There are small changes associated to the
tasks classification, justification and labeling for the baseline group (BG), larger changes for the control group (CG IO) and the largest changes for the experimental group (EG IT). It is unexpected though for the allocation task, that the children of the baseline group show a similar mean gain compared to the intervention groups. In the latent regression analysis, four models were constructed: In the first model (M1), children measures were introduced as predictors only, in the second model (M2), the contrasts for the respective groups were additionally integrated, in the third model (M3), further teacher’ variables were integrated irrespective the contrasts and, finally, in the fourth model (M4), all measures (children, teacher, and group contrasts) were integrated. Note that the latent construct of children’s conceptual knowledge, informed by the four tasks classification, justification, allocation and labeling, was set as dependent variable in all these models. The model M2 directly relates to the research question mentioned above. In this model, it should be noted that only Contrast 1 ($b = 1.46$) but not Contrast 2 ($b = 0.29$) was a significant predictor of children’s conceptual knowledge. This suggests that participating in the additional two meetings following the Intentional Teaching approach (EG IT) is not relevant with respect to children’s learning achievement. This interesting result will be discussed in the next chapter. Note further that model M2 explained 80% of the total variance in the dependent variable, whereas the additional introduction of further teacher variables into the model (refers to M4) only accounted for an increase of 2% of total explained variance. Interestingly, teachers’ interest in science significantly predicted children’s conceptual knowledge ($b = 0.21$ in M3, respectively $b = 0.32$ in M4). Teachers’ age, their work experience and their self-concept of ability were not significant predictors in M3 and M4. For teachers’ employment grade and their education, the results between the M3 and M4 were not consistent.

![Figure 4.12](image.png)

*Figure 4.12. Mean gain scores of children’s conceptual knowledge by group. EG IT = experimental group *Intentional Teaching*; CG IO = control group instruction only; BG = baseline group. Coding: performance scores from 0 to 100.*
### Table 4.9

**Intervention Effects on Children’s Conceptual Knowledge**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Children</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-intervention measure</td>
<td>1.47*** (0.19)</td>
<td>1.88*** (0.29)</td>
<td>1.52*** (0.20)</td>
<td>1.98*** (0.32)</td>
</tr>
<tr>
<td>Age (z-standardized)</td>
<td>0.15* (0.06)</td>
<td>0.25*** (0.07)</td>
<td>0.12* (0.06)</td>
<td>0.23** (0.07)</td>
</tr>
<tr>
<td>Gender: female (0), male (1)</td>
<td>0.09 (0.12)</td>
<td>0.17 (0.14)</td>
<td>0.10 (0.12)</td>
<td>0.17 (0.15)</td>
</tr>
<tr>
<td><strong>Teacher</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contrast 1: BG (-2/3) vs. CG IO &amp; EG IT (1/3)</td>
<td>1.46*** (0.23)</td>
<td></td>
<td>1.63*** (0.28)</td>
<td></td>
</tr>
<tr>
<td>Contrast 2: CG IO (-1/2) vs. EG IT (1/2)</td>
<td>0.29 (0.18)</td>
<td></td>
<td>0.34 (0.19)</td>
<td></td>
</tr>
<tr>
<td>Age (z-standardized)</td>
<td>-0.16 (0.15)</td>
<td></td>
<td>-0.17 (0.18)</td>
<td></td>
</tr>
<tr>
<td>Work Experience (z-standardized)</td>
<td>0.29 (0.15)</td>
<td></td>
<td>0.20 (0.17)</td>
<td></td>
</tr>
<tr>
<td>Employment grade (z-standardized)</td>
<td>0.07 (0.06)</td>
<td></td>
<td>0.23** (0.8)</td>
<td></td>
</tr>
<tr>
<td>Education: TTS (0), UTE (1)</td>
<td>0.59** (0.18)</td>
<td></td>
<td>0.36 (0.23)</td>
<td></td>
</tr>
<tr>
<td>Interest (z-standardized)</td>
<td>0.21** (0.08)</td>
<td></td>
<td>0.32** (0.10)</td>
<td></td>
</tr>
<tr>
<td>Self-concept of ability (z-standardized)</td>
<td>-0.14 (0.08)</td>
<td></td>
<td>-0.16 (0.10)</td>
<td></td>
</tr>
<tr>
<td><strong>R²</strong></td>
<td>.69</td>
<td>.80</td>
<td>.71</td>
<td>.82</td>
</tr>
</tbody>
</table>

**Note.** Unstandardized regression coefficients; standard errors in parentheses. Dependent variable is the latent construct of children’s conceptual knowledge (CCKpost), informed by the four tasks classification, justification, allocation and labeling. PD = professional development; EG IT = experimental group Intentional Teaching; CG = control group instruction only; BG = baseline group; UTE = university of teacher education, TTS = teacher training seminar. ***p < .001, **p < .01, *p < .05

### 4.5 Discussion

This study investigated the effects a professional development intervention on teachers’ professional competence and children’s conceptual learning in early science instruction. This is one of the few studies taking a comprehensive perspective on teacher education effectiveness in early science education: It included both dispositional and performance-related aspects of teachers’ professional competence and also students’ achievement as outcome measures (Blömeke et al., 2015; Desimone, 2009; Lipowsky & Rzejak, 2015). A sample of 50 teachers were randomly assigned to either (i) an experimental group participating in a short-term program based on the Intentional-Teaching approach, (ii) a control group receiving only an introduction into children’s learning material, or to (iii) a baseline group neither participating in an intervention nor working with the learning materials.

**Discussion of Main Findings**

The three subsequent main findings will be discussed in detail in the following:

1. **With respect to teachers’ pedagogical content knowledge:** There was a substantial effect of the conducted short-term intervention based on the Intentional Teaching approach on teachers’ beliefs about teaching and learning.

2. **With respect to teachers’ instructional practices:** There was a substantial effect of this short-term intervention on teacher talk.
With respect to children’s conceptual learning: There was no effect of this short-term intervention on children’s conceptual learning.

**Substantial effects on teachers’ beliefs about teaching and learning.** Teachers of the experimental group showed a more articulated shift in their beliefs system compared to the teachers of the control group: They substantially increased their agreement on ‘Restructuring knowledge’, respectively decreased their agreement on ‘Hands-on activity’ (see Figure 4.9 and Table 4.7). These shifts in teachers’ belief system were in line with the targets of the conducted professional development intervention, which centered on a *content focus* on children’s science learning under a constructivist perspective (Desimone, 2009; Guskey & Yoon, 2009). The observed shift in the belief scale ‘Restructuring knowledge’ is remarkable, because both the teachers of the experimental and the control group received information in theories about learning as conceptual change in the introductory session (see Figure 4.3, Meeting 1), but only the teachers of the experimental group substantially shifted their beliefs (see Figure 4.9). It seems that the additional sessions following the *Intentional Teaching* approach (see Figure 4.3, Meeting 2 and Meeting 3) stimulated the teachers of the experimental group specifically to shift their beliefs towards a higher acceptance of learning as knowledge restructuring. This gives support to the fruitfulness of the *Intentional Teaching* approach, which highlights the importance of repeatedly covering the components Knowing, Seeing, Doing, and Reflecting with respect to the teacher-child interaction (Hamre, Downer, et al., 2012). Similar conclusions could be drawn for the observed shift in the belief scale ‘Hands-on activity’: It seems that substantial shifts in teachers’ belief system does not result merely by being introduced to learning materials, but indeed depends on a more in-depth and content-focused professional development intervention. The observed changes in teachers’ beliefs are also remarkable from a theoretical point of view, because beliefs are often described as having a stable nature (being resistant against change), because they are deeply rooted in teachers’ experiences and serve as lenses through which reality is being constructed (Reusser et al., 2011). The considerations described above validate that *content focus* is indeed a key feature of effective professional development (Birman et al., 2000; Desimone, 2009; Garet et al., 2001; Guskey & Yoon, 2009).

**Substantial effects on teachers’ talk.** Teacher talk in the form of content-specific language and scaffolding utterances was argued to play an important role in scaffolding children’s conceptual learning. The teachers participating in the intervention based on the *Intentional Teaching* approach (experimental group) markedly changed their teacher talk, whereas the teachers only receiving an introduction into the learning materials (control group) were associated to only marginal changes in their talk. Teachers of the experimental group substantially increased their provision of content-specific language, which was measured in the occurrence of vocabulary with a specific relevance to the curricular topic of floating and sinking. With respect to teacher talk with underlying scaffolding intentions (scaffolding utterances), the teachers of the experimental group strongly shifted during the
intervention period in their provision from offering clarifications of the phenomenon, task, and procedure (type A) towards challenging conceptual change via prompts for explanation, comparison, reasoning, and cognitive conflict (type D). These changes are evaluated as being beneficial, since more content-specific language and more prompts challenging conceptual reconstruction contribute to a rich and stimulating language environment (Eshach et al., 2011; Klibanoff et al., 2006). In conclusion, the observed intervention-induced changes suggest that Intentional Teaching seem to be a fruitful approach not only for stimulating teachers to alter their beliefs, but also for changing their instructional practices in classroom. These findings substantiated other studies demonstrating that teachers’ instructional practices can be altered through professional intervention (Kleickmann et al., 2016; Suk Lee et al., 2006). This study further demonstrated that such a change is even possible in a short format.

No effects on children’s conceptual learning. Theoretical models of professional development effectiveness highlight the importance to not only consider teacher variables (pedagogical content knowledge, beliefs, teacher talk, etc.) as outcome measures but also measures of students’ achievement (Desimone, 2009; Fishman et al., 2003; Lipowsky & Rzejak, 2015; Scheerens & Blömeke, 2016; Supovitz & Turner, 2000). Although the short-term intervention following the Intentional Teaching approach was associated to substantial changes in teachers’ cognitions and behavior (as discussed above), the data of this study did not support the hypothesized effects on the level of children’s learning. From the regression analyses, it could be inferred that being taught by a teacher from the experimental group could not explain the observed increase in children’s conceptual understanding of floating and sinking. This leads to the hypothesis that already working on the structured learning material per se was leading to substantial increase of children’s conceptual knowledge (see Figure 4.7 and Table 4.7), regardless of the offered types of professional development interventions. In order words, from the perspective of children’s learning, it seems to suffice to simply being confronted with stimulating learning materials. This finding contrasts results from a study conducted by Kleickmann et al. (2016), where student learning could additionally be explained by programs consisting of higher degrees of expert scaffolding. Besides many similarities between the study of Kleickmann and this study (curricular topic floating and sinking, beliefs, instructional practices, several key features, etc.), the professional development interventions in the study of Kleickmann et al. (2016) comprised of a much longer duration compared to this study (100 hours/5 months vs. 12 hours/four weeks). It might be that the intervention offered in this study would also have led to improved children’s learning, if more time had been devoted.

Limitations

In this study, a short-term professional development intervention based on the Intentional Teaching approach was compared to a course only consisting of an introduction into the learning materials,
respectively to not receiving any intervention at all. This study adhered to principles of an experimental design, where the teachers were randomly assigned to different, purposefully manipulated, conditions of professional development interventions. Experimental designs are considered to be very important if one wants to infer causal inference in research about professional development effectiveness (Wayne et al., 2008). Although this study adhered to these principles, two major reservations have to be expressed: First, the study design was not a classical experiment in the sense, that only one variable has been manipulated keeping all others constant. In contrast, the experimental condition (intervention based in Intentional Teaching approach) and the control condition (intervention including the instruction only) in this study differed with respect to many variables: duration (three meetings vs. one meeting), content focus (Intentional Teaching vs. instruction only), active learning (analyzing teacher behavior in videos vs. none), etc. Hence, this study does not allow the drawing of specific conclusions between one single feature of the professional development intervention and the observed changes in teachers’ professional competence. Casual inference between independent and dependent variables would ask for controlling independent variables more strictly. At the same time, this study controlled for many variables, for instance, with respect to the chosen curricular topic/learning materials (floating and sinking), the targeted group of teachers (kindergarten), the facilitator (an outside expert), etc. Research about professional development effectiveness in early science education is still a relatively new research field. Following the phases of research on teacher development suggested by Borko (2004), in a first phase of research, it is important to provide an “existence proof” meaning to obtain evidence for effects of a specific program. Not until having created this proof, can an intervention be analyzed in more depth with respect to further aspects. The results of this study suggest that this “existence proof” is only partly obtained (clear intervention effects on aspects of teacher cognition and no effects on children’s learning respectively). The second major reservation of this study relates to the reported non-equivalences between groups with respect to pre-measurements. Differences were more articulated between the baseline and the intervention groups and less articulated between the two interventions groups (EG IT vs. CG IO). These differences lead to the question why the randomization process partly failed. All participating teachers were administered through the same procedure. They subscribed for the study because of their personal interest towards a professional development course. Teachers not allocated to the experimental group were invited to participate in a similar professional development course after having collected the data material for this study. It remains unclear whether the differences between the groups resulted from naturally occurring variation or from an unidentified systematic error in the sampling/randomization.

Besides these two major caveats, the following further limitations are to be mentioned: The generalizability of the findings might be restricted to the relatively small sample on the one hand, and to a possible selection bias on the other hand, since the participating teachers subscribed for the study
because of their personal interest towards early science teaching. It is a recognized problem that studies about professional development interventions are often conducted with volunteering teachers only (Borko, 2004; Fishman et al., 2003; Wayne et al., 2008). Volunteers may differ from non-volunteers both with respect of their cognitions (knowledge, beliefs, motivation) and their instructional practices (teacher talk, gestures, etc.) (Wayne et al., 2008).

As mentioned in the introduction, Borko (2004) suggested investigating professional development as systems consisting of the program, the participating teachers, the facilitator and the context. This study described in detail the program and analyzed in-depth changes in teachers’ competence for early science education. This study, however, did neither focus on variables associated to the facilitator (experience, knowledge, beliefs, motivation, etc.), nor on those associated to the context (environment at school/kindergarten institution, political and economic aspects, etc.).

Conclusions and Implications

The results of this studied suggest that Intentional Teaching from Hamre, Downer, et al. (2012) is a fruitful approach for teachers’ professional development in early science education. Learning opportunities based on cycles of knowing, seeing, doing, and reflecting about effective teacher-child interactions induced the participating teachers to substantially change both their belief system and their instructional practices. The participating teachers strengthened their understanding of science learning as conceptual reconstruction and abandoned their beliefs about science learning as being primarily dependent on behaviorally (rather than cognitively) active children. These shifts in teachers’ belief system are to be qualified as beneficial, because they cohere with state-of-the-art theories about science learning. Further, the participating teachers were observed to increasingly provide teacher talk in the form of content-specific language and in elaborated types of scaffolding utterances. Therefore, this study suggests applying the idea of Intentional Teaching in future programs of professional development in early science education. For future research, it will be of importance to test the validity and reliability of the described results in the context of other curricular topics.

This study provided further support for four of the five features of professional development effectiveness as suggested by Desimone (2009): content focus, active learning, coherence, and collective participation. Against the background of the complexity in research about professional development, this list represents a useful heuristic for the design of future professional development interventions. The fifth feature, duration, needs particular consideration. The results of this study suggest that even a short-term intervention (12 contact hours over four weeks) implementing the other four features named above can be effective in terms of teacher learning. The observed changes in teacher cognition and practices challenge the consensus among researchers in the field of professional development that duration is a key determinant in the definition of effective programs (Birman et al., 2000; Desimone, 2009; Garet et al., 2001; Guskey & Yoon, 2009). Professional development
interventions are often reported to result only in significant change when interventions consist of 30 contact hours or more (Guskey & Yoon, 2009). The results of this study have demonstrated that substantial gains in teachers’ professional competence are feasible even in short-format professional development programs. This finding seems important for practice, since short formats of professional development will presumable dominate also in future in times of economic pressure.
4.6 References


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5 General Discussion

The remainder of this thesis aims at providing an overview of the main results and discussing their contribution to the field of early science education. Figure 5.1 provides an overview of the main findings of the three papers at one glance. To recall, the three papers were situated in this conceptual framework, because this thesis focused on studying professional development effectiveness.

![Figure 5.1. Overview of the main findings of the three papers of this thesis according to the conceptual framework for studying professional development effectiveness.](image)

5.1 Integrative Summary and Discussion of the Main Findings

In Paper 1, kindergarten (KG) and lower grade elementary school (LGES) teachers’ pedagogical content knowledge for early science education was investigated. Differences between these groups...
were expected because of a presumed distinct professional socialization according their job environment and professional education. The reported lack of pedagogical content knowledge and confidence in primary science teachers led to the expectation that these deficiencies are increasingly a problem at lower teaching grades. The results revealed only small support for marked differences in pedagogical content knowledge between KG- and LGES-teachers. They did not differ in their classification of children’s statements, in their assessment of domain-specific learning goals, and in their interest and self-concept of ability. Differences with respect to teachers’ pedagogical content knowledge were only observed with respect to two out of six belief scales: Compared to LGES-teachers, KG-teachers agreed more with beliefs about play, and less with beliefs about the importance of situated construction of knowledge. These results contribute to research investigating differences and commonalities between kindergarten and elementary school teachers (Wannack, 2004). Since no marked differences were found, it can be concluded that both groups of teachers seem to have similar cognitive dispositions for facilitating effective science education (cf. to Blömeke, Gustafsson, & Shavelson, 2015). Surprisingly, KG-teachers reported spending more teaching time for investigating science contents, which gives rise to an advantageous impression for science education at kindergarten level. After controlling for teaching at the KG- or LGES-level, regression analyses revealed further that being educated at a university of teacher education (compared to being educated at teacher training seminars) was associated to higher agreements in beliefs about restructuring knowledge and co-constructing knowledge, and to lower agreements in beliefs about the transmission of knowledge, which, altogether, cohere with the constructivist nature of learning. However, no differences were found with respect to the other two aspects of pedagogical content knowledge. From this, it can be concluded that shifting teacher education from the secondary level (teacher training seminars) to the tertiary level of education (universities of teacher education) is associated to teachers’ increased appreciation of the constructivist nature of learning, but not to an increased understanding of how to qualify children’s statements, nor to an increased appreciation of domain-specific learning goals.

In Paper 2, the effects of teacher talk on children’s conceptual learning were examined. This study was built on the premise of the importance of language for children’s development in general, and, more specifically, for facilitating effective early science instruction. Teacher talk was analyzed for content-specific language and four types of scaffolding utterances, which are utterances having an underlying scaffolding function. Teachers’ content-specific language and the four types of their scaffolding utterances were expected to have a positive influence on children’s conceptual learning. Indeed, a latent modeling approach revealed positive effects for teachers’ content-specific language. For teachers’ scaffolding utterances, the model revealed partly expected and partly unexpected effects: Teachers’ prompts to activate children’s prior knowledge (type C) were a positive predictor, whereas, unexpectedly, their prompts for explanation, comparison, reasoning, and cognitive conflict (type D) were altogether a negative predictor for children’s learning. This surprising result was examined in
exploratory post-hoc analyses in more depth. These analyses revealed that especially prompts for reasoning (type D.3) and cognitive conflicts (type D.4) seem to be responsible for the negative effect discovered, and not prompts for explanation (type D.1) and comparison (type D.2). Further, analyzing in which combination utterances of type D occurred, it was found that these utterances can have both positive effects and negative effects on children’s learning. Interestingly, utterances of type D were a positive predictor of children’s learning, when these prompts were preceded by prompts for the activation of prior knowledge (type C), and they were a negative predictor of children’s learning in combination with clarifying the phenomenon, task, and procedure (type A). These results suggest that teacher talk has an important and, at the same time, highly complex effect on children’s conceptual learning.

In Paper 3, the effects of a professional development intervention were investigated with respect to changes in teachers’ competences and children’s learning in early science education. Following an experimental design, the participating teachers were allocated to three groups. In the experimental group, teachers participated in a short professional development program covering three meetings (12 contact-hours in total), one introductory meeting about learning materials and two further meetings based on the Intentional Teaching approach. This approach focuses on effective teacher-child-interactions and fosters teacher learning in cycles comprising the aspects of knowing, seeing, acting, and reflecting (see Hamre, Pianta, et al., 2012). Further, the intervention was designed to conform to features widely acknowledged in research about professional effectiveness, including content focus, active learning, coherence, and collective participation. The short format was purposefully chosen to investigate the question whether even a short intervention, which is typical in the practice of professional development, can lead to effects in teachers’ cognitions and children’s learning. In the control group, teachers participated only in the introductory meeting. Teachers in both the experimental and the control group implemented inquiry-based learning materials about the topic floating and sinking during four weeks in the kindergarten classroom. In the baseline group, teachers only participated in the testing. According to regression analyses, it was found that the professional development course according to the Intentional Teaching approach (experimental group) led to substantial changes in teachers’ competence (knowledge/beliefs and instructional practices), but not with respect to children’s conceptual learning. With respect to teachers’ pedagogical content knowledge, significant intervention-induced effects were identified in their increased appreciation of domain-specific learning goals, their increased agreements with beliefs about teaching and learning as restructuring knowledge, and their decreased agreements with beliefs about the effectiveness of hands-on activities. These observed changes can be considered beneficial for effective early science instruction, because they cohere to the constructivist nature of learning (cf. to the increase in the belief ‘restructuring knowledge’) and the reduction of a common misconception (cf. to the decrease in the belief ‘Hands-on activity’). With respect to teachers’ instructional practices, significant intervention-
induced effects were found in the increased provision of content-specific language and scaffolding utterances of type D (challenging conceptual change). These changes can also be evaluated as beneficial for early science education by referencing the importance of language and scaffolds for effective science education. The question about the mediating role of aspects of teachers’ competence could not be answered, since no intervention-induced effects were found down to the level of children’s conceptual learning.

The three studies together contribute in many ways to the under-researched field of early science education (Greenfield et al., 2009):

In early education, there is a debate about when to begin with science education (as addressed in chapter 1.1). In this thesis, it could be demonstrated that children aged from four to eight years can substantially increase their conceptual understanding of floating and sinking within a period of only four weeks (Paper 2 and 3 respectively). This newly acquired knowledge is expected to serve as a foundation for their later conceptual learning (Cabe Trundle & Saçkes, 2012; Eshach & Fried, 2005; Plummer & Krajcik, 2010). The results revealed by this study provide further support for starting in science education as early as in preschool or kindergarten age, as advocated by many researchers (Cabe Trundle, 2015; Eshach, 2011; Eshach & Fried, 2005; French, 2004; Ginsburg & Golbeck, 2004).

The comparison of kindergarten and lower grade elementary school teachers in Paper 1 suggests that these teachers have rather similar dispositions for competently offering early science education. One of the few marked identified difference relates to Kindergarten teachers’ higher reporting of instruction time in science. This study contributes to research investigating education at early years of schooling, where science learning is only rarely in focus (Faust, 2006; Moser, Bayer, & Berweger, 2008; Rathbun & West, 2004; Wannack, 2004). The observed common base between kindergarten and elementary school teachers should be utilized to move closer together in striving for further improvements in early science education.

The results of Paper 2 contribute to research of early science education by pointing to the importance of language in domain-specific learning (Eshach, Dor-Ziderman, & Arbel, 2011; Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006; Rappolt-Schlichtmann, Tenenbaum, Koepke, & Fischer, 2007). It could be shown that teacher talk can have both beneficial (with respect to content-specific language) and adverse effects (with respect to elaborated forms of scaffolding utterances) on children’s learning. The positive effects support theories about the scaffolding role of teachers’ speech, whereas the negative effects remind us to acknowledge that the provision of learning support needs to be carefully adapted to the needs of children’s learning (Eshach et al., 2011; van de Pol, Volman, & Beishuizen, 2010; Wood, Bruner, & Ross, 1976). Post-hoc analyses revealed here that the scaffolding function of teacher talk is complex and needs to be analyzed not just aggregated over period of time, but also more fine-grained in respective situations.
Further, it could be further shown in Paper 3 that a carefully designed professional development intervention can lead to substantial changes in teachers’ professional knowledge and their instructional practices. These effects can be attributed to designing an intervention according the *Intentional Teaching* approach by Hamre, Downer, Jamil, and Pianta (2012) on the one hand, and according to content focus, active learning, coherence, and collective participation as core features of professional development effectiveness on the other hand (Birman, Desimone, Porter, & Garet, 2000; Garet, Porter, Desimone, Birman, & Suk Yoon, 2001; Guskey & Yoon, 2009). Interestingly, these effects were observed despite the short format (three meetings including a total of 12 contact-hours) of the intervention. This challenges to some extent the core feature of duration in research of professional effectiveness, where generally only much longer formats are considered effective (Birman et al., 2000; Desimone, 2009; Garet et al., 2001; Guskey & Yoon, 2009).

### 5.2 Implications and Further Considerations for Early Science Education

High quality early science education depends on dedicated and knowledgeable teachers, who are able to provide an environment in which children can exploit their cognitive potentials for learning. This thesis aimed at understanding how teachers can expand their knowledge base for early science education. In the beginning of this thesis, it was reported that primary science teachers are often described as being deficient in science-specific professional knowledge, including content knowledge and pedagogical content knowledge, and associated confidence for science teaching. This study has demonstrated that even a short professional development intervention can lead to considerable changes in their knowledge and competence for early science education. Therefore, professional education and development certainly will play a very important role also in future to produce dedicated and knowledgeable science teachers. Still, time and resources allocated to professional education and development in early science education will remain scarce in future too. Therefore, teachers need to have strategies in mind how to cope with their limited science-specific pedagogical content knowledge. Informed and inspired by the experiences and the findings of this thesis, this section intends to provide strategies for dealing with the problem of limited pedagogical content knowledge in early science education:

*Participate in professional development courses having a clear content focus.* An important strategy for dealing with limited science-specific professional knowledge is, obviously, to enlarge this knowledge base through respective professional development. This thesis suggests that especially those courses are valuable, in which teachers are stimulated to develop their understanding of (i) children’s learning and (ii) strategies of verbal scaffolding, by the example of a carefully selected and narrowly defined curricular science topic. This description directly relates to the importance of a
clear content focus, which is widely recognized as a key feature for effective professional development programs (Birman et al., 2000; Desimone, 2009; Garet et al., 2001; Guskey & Yoon, 2009).

Select the most important science-topics. The problem of teachers’ lack of professional knowledge for early science education might be reduced to some extent, if a teacher is able to identify and select the most relevant topics for science instruction. Two of the main criteria for this choice are (i) its relatedness to children’s environment, including their prior knowledge, experiences, their interest, their strengths, etc., and (ii) its suitability to build basic knowledge needed for future learning. Primarily, curricula should give orientation for selecting science contents for instruction that meet these two criteria. Curricula for early science instruction often include a set of key concepts, which are considered to be of overarching importance for science in general and for later learning respectively (e.g., Gelman & Brenneman, 2004; National Research Council, 2012; Wodzinski, 2015). Depending on the source, these concepts are named “central concepts” (Gelman & Brenneman, 2004), “crosscutting concepts” (National Research Council, 2012), “Basiskonzepte” (Wodzinski, 2015), etc. For instance, Gelman and Brenneman (2004) propose in an integrated mathematics and science program for preschool children to choose topics for instruction according to the following central concepts: “change (biological, chemical, and/or physical), insides and outsides of a wide variety of objects, the differences between animate (living) and inanimate (artifacts and non-living things of nature) objects, form and function, and systems and interactions” (p. 155). Such frameworks assist teachers not only in identifying and selecting the most relevant topics for early science instruction, but also provides orientation for the development of own content and pedagogical content knowledge.

Draw upon existing resources. Teachers can enlarge their science-specific professional knowledge by tapping existing resources. Four of them are briefly described in the following: (i) Teachers can draw on their own resources. Science curricula leave some degree of freedom with respect to what specific science topics are chosen for science education. Here, teachers can select topics for instruction, at least some of them, according to their existing science-specific knowledge, personal interest, and motivation, as long as they match with respective curricular goals. (ii) Teachers can strengthen their knowledge base by studying science-specific publications (books, journals, scientific articles, websites, etc.) covering science topics, the nature of children’s learning, or specifically the didactics of early science education. For teachers, so-called educative curriculum materials are suggested as being an especially important source for teachers’ professional development (Davis & Krajeik, 2005; Davis et al., 2014; Drake, Land, & Tyminski, 2014). These materials combine teacher-addressed information about specific curricular topics and children’s associated learning and further contain learning materials for the students. These materials are intended to promote teacher learning in addition to student learning (Davis & Krajeik, 2005). (iii) Knowledge in science might be accessed via experts. Experts might be directly invited into the classroom or, conversely, the expert is visited at her/his workplace. To access pedagogical content knowledge, experts can be found in universities and
universities of teacher education. To access expert knowledge in specific fields related to curricular topics, experts might be found among the parents of the pupils. Here professionals such as doctors, farmers, forest rangers, building workers, lab assistants, etc., would probably be of interest. Parents of the class would almost certainly be prepared to share their field of expertise with the children. (iv) Children themselves can be regarded as a resource for teachers’ own science learning, as they naturally pose, often quite challenging, questions about fascinating natural phenomena around them. There are many books, websites, etc. listing typical and frequent science-related questions children ask. For instance: Why is the Moon sometimes out in the day? Why is the sky blue? Will we ever discover aliens? How much does the earth weigh? How do airplanes stay up? Many teachers might feel unease when confronted with such challenging questions. Instead of giving brief, inadequate (and probably wrong) answers, teachers should learn along with their children. They should engage the class and themselves in an inquiry and could respond, for instance: “I don’t know the answer of your question – but, let’s think about it together. Have we any possibility to find out about it? What could we do? Have you experienced something similar before?” Such an answer relates to understanding children and the teacher as a community of learners, in which one seeks together an answer to a question or a problem (Rogoff, 1994).

Aspire for an appropriate level of mastery. It might help to think about what level of mastery an early science teacher should strive for with respect to science-specific professional knowledge. In research on teachers’ professional knowledge, this issue is mainly discussed for subject matter content knowledge: For instance, Krauss, Baumert, and Blum (2008) differentiated, in the domain of mathematics, between the following three levels, first, “(1) the everyday mathematical knowledge that all adults should have, (2) the school-level mathematical knowledge that good school students have, and (3) the university-level mathematical knowledge [...]” (p. 876). For early science teachers, it seems unrealistic to expect them to explain every conceivable natural phenomenon at the university-level of science knowledge (including physics, chemistry, biology, etc.). Such an expectation would sharply contrast the short study time devoted to science education in professional education and the later role as a generalist teacher in practice (being responsible not just for science education, but also for mathematics, language, social studies, arts, etc.). It seems more realistic that early science teachers acquire science knowledge directly related to only a restricted number of curricular science topics. In other words, the question of the level of mastery of knowledge is also related to the question of the coverage of knowledge. With regard to the science-specific content knowledge, I would suggest kindergarten and elementary school teachers should strive for a profound conceptual understanding (content knowledge) of concepts targeted in curricular topics as one would expect from a good student by the end of mandatory public school (cf. to the second level from Krauss et al., 2008). Importantly,

teachers should also have an understanding about how science knowledge is generated and about the epistemological quality of this knowledge. This knowledge refers to the nature of scientific knowledge and scientific inquiry (Lederman & Lederman, 2012). Such knowledge includes, for instance, recognizing that missing knowledge about a natural phenomenon should be utilized to pose questions steering a new inquiry (instead of applying science avoidance practices). With regards to science-specific pedagogical content knowledge, I would suggest that kindergarten and lower grade elementary school teachers need to strive for university-level in pedagogical content knowledge (cf. to the third level from Krauss et al., 2008). Here, the aspired level of mastery cannot be lowered, since pedagogical knowledge will remain the unique province of teachers (Shulman, 1987). The most important aspects of the pedagogical content knowledge include teachers’ understanding of children’s learning in science, including the recognition of typically occurring prior knowledge and learning paths according to the most important curricular topics. For typically occurring prior knowledge, teachers can draw upon an extensive amount of research informing about young children’s conceptual understanding in science, especially well-documented are the fields of naive physics, naive psychology, and naive biology (Akerson, Weiland, & Fouad, 2015; Baillargeon, 1987; Hadzigeorgiou, 2015; Saçkes, 2015; Spelke, Breinlinger, Macomber, & Jacobson, 1992).

5.3 Future Directions in Research and Practice in Early Science Education

The importance of language for science learning has been a central theme throughout this thesis. The development of language and building a more coherent and deep understanding of natural phenomena can go hand in hand (French, 2004; Henrichs & Leseman, 2014; Mannel, Hardy, Sauer, & Saalbach, 2016; Pearson, Moje, & Greenleaf, 2010). This thesis has demonstrated the importance of verbal support for children’s conceptual learning (see Paper 2) and possibilities to change teachers’ provision of verbal support through professional development (see Paper 3). This thesis suggests that future research should aim to deepen the understanding of the relationships between teachers’ and children’s use of language and its relevance for conceptual learning in early science education. In this very last chapter, approaches that combine language and conceptual learning are described and proposed, which are considered to have a great potential for improving early science education.

To achieve the aim of improving early science education, it is hardly a good idea to impose science as a new subject into preschool and kindergarten curricula, since respective institutions generally follow an integrated approach for good reasons (UNESCO, 2012). Instead, there are many proponents who argue for science instruction according to integrated approaches (French, 2004; Gelman & Brenneman, 2004; Henrichs & Leseman, 2014; Pearson et al., 2010). For instance, French (2004) brought forward many arguments for putting science contents at the center of curricula in early childhood education. She argues that science contents would be highly engaging for young children in
reference to developmental studies demonstrating children’s enormous potential for domain-specific learning (as highlighted several times in this thesis). The main argument in integrated science approaches is that children’s not only learn about science contents, but also acquire competence in areas of language development, pre-literacy skills, problem solving, social interactions, and self-regulation. French (2004) recommends conducting daily science lessons around science contents structured according a simple cycle of scientific reasoning (reflect and ask, plan and predict, act and observe, report and reflect). Contents from mathematics and social studies would be integrated whenever they meaningfully help to understand phenomena under investigation. Such an approach would reduce the danger that children are forced to learn language, mathematics, and social studies in arbitrary and meaningless contexts. In contrast, it would support children in building coherent and meaningful knowledge structures about the world around them.

Figure 5.2 depicts a framework for understanding children’s conceptual learning and its support through teachers’ verbal input, including imaginary examples for the topic floating and sinking for illustration. This framework highlights that teachers should be able to evaluate children’s prior knowledge according to an idealized path of conceptual learning. The arrow in the background signifies this idealized learning path from naive concepts, via intermediate concepts, towards scientific concepts. Scientific concepts are superior in the sense that they have the broadest validity, meaning that their application in new situations is most likely to be fruitful, whereas naive concepts are restricted in their application. With respect to the topic floating and sinking, typical prior knowledge includes children’s tendency to focus on one dimensional attributes, such as the shape, the volume, or the weight of objects (Leuchter, Saalbach, & Hardy, 2014). Further, teachers should grasp children’s learning as an enduring process of knowledge restructuring (Carey, 1985; Chi, 2008; Vosniadou, 1994). In the example of floating and sinking, this refers to recognizing the concept of material kind as an intermediate concept on the learning path towards later targeted concepts such as density, buoyancy force, Archimedes principle, atomic theory, etc. (Dickinson, 1987; Leuchter et al., 2014).
Finally, this framework suggests that children’s conceptual learning can be supported by teachers’ science language, consisting both of content-specific vocabulary (cf. one of the main findings in Paper 2) and process-specific vocabulary. Teachers should build awareness about the importance of language for children’s conceptual learning in general, and about the role of teacher talk as a scaffold for children’s learning in particular (Haug & Ødegaard, 2014; Henrichs & Leseman, 2014; Klibanoff et al., 2006; Saalbach, Grabner, & Stern, 2013; Saalbach, Leuchter, & Stern, 2010; Tomasello, 1999). With respect to the content-specific language, the results of Paper 2 suggest that the provision of a vocabulary specific to the curricular topic contributes to a stimulating learning environment. In the topic floating and sinking, the vocabulary associated to characterizing objects according appropriate kinds of materials (such iron, clay, wood, polystyrene, etc.) played this role. Process-specific vocabulary was added to this framework referring to the language associated to science as inquiry, which is widely recognized in literature (Eshach et al., 2011; French, 2004; Gelman & Brenneman, 2004). ‘Reflect and Ask’, ‘Plan and Predict’, ‘Act and Observe’, and ‘Report and Reflect’ is a simple model of describing the cycle of scientific reasoning, as proposed by French (2004).

This framework holds that effective science instruction should be related to conceptual learning, language, and processes, which coheres to current standard and best practices (Gelman & Brenneman, 2004).
Further research is suggested to analyze the scaffolding role of teacher talk in early science education based on both content-specific and process-specific language. This framework further intends to provide ‘food for thought’ in professional education and development and in practice, where it might be applied to other curricular topics.
5.4 References


Appendix A: Teacher Scales
### Teachers’ Classification of Children’s Statements About the Topic of Floating and Sinking (as an Aspect of PCK)

Inhaltliche Bewertung von Kinderaussagen zum Thema ‘Schwimmen/Sinken’ gemäss den folgenden Kategorien:

(1) Fehlvorstellung, (2) Ausbaufähige bzw. korrekte Vorstellung, (3) Ich weiss es nicht

<table>
<thead>
<tr>
<th>Statement</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>„Grosse Gegenstände können schwimmen oder sinken. Aber grosse Sachen werden sicher stärker vom Wasser nach oben gedrückt als Kleine.“</td>
<td>2</td>
</tr>
<tr>
<td>„Schiffe gehen nicht unter, weil sie sehr starke Motoren haben.“</td>
<td>1</td>
</tr>
<tr>
<td>„Schwere Dinge schwimmen manchmal auch. Diese sind dann ganz gross und brauchen viel Platz im Wasser.“</td>
<td>2</td>
</tr>
<tr>
<td>„Dieser Knopf hat vier kleine Löcher. Er geht bestimmt unter.“</td>
<td>1</td>
</tr>
<tr>
<td>„Ich denke im Wasser geht dieser Gegenstand unter. Aber in einer Suppe schwimmt er vielleicht.“</td>
<td>2</td>
</tr>
<tr>
<td>„Wenn dieser Knetball dem Wasser mehr Platz wegnehmen würde, dann würde er vielleicht schwimmen.“</td>
<td>2</td>
</tr>
<tr>
<td>„Je grösser ein Baumstamm, desto eher geht er unter.“</td>
<td>1</td>
</tr>
<tr>
<td>„Diese hölzernen Bauklötze würden auch schwimmen, wenn sie die Form von Kugeln oder Stangen hätten.“</td>
<td>2</td>
</tr>
<tr>
<td>„Im See hat es viel mehr Wasser als in diesem Wasserbehälter. Darum wird dieses Plastikstück im See auch eher schwimmen.“</td>
<td>1</td>
</tr>
<tr>
<td>„Alle schweren Sachen gehen unter.“</td>
<td>1</td>
</tr>
<tr>
<td>„Es kommt eigentlich vor allem darauf an, woraus die Knöpfe gemacht sind. Es gibt ja solche aus Plastik, Metall oder Holz.“</td>
<td>2</td>
</tr>
<tr>
<td>„Schwimmflügeli haben Luft drin, darum schwimmen auch alle anderen Gegenstände mit Luft drin.“</td>
<td>1</td>
</tr>
<tr>
<td>„Gabel und Messer gehen unter, weil sie aus Metall sind.“</td>
<td>2</td>
</tr>
<tr>
<td>„Dieser Knopf wird wohl sinken, weil er so klein ist.“</td>
<td>1</td>
</tr>
<tr>
<td>„Dieses Ding schwimmt, wenn es leichter ist als das weggedrückte Wasser.“</td>
<td>2</td>
</tr>
<tr>
<td>„Diese Gabel geht unter, weil sie vom Wasser nach unten gezogen wird.“</td>
<td>1</td>
</tr>
<tr>
<td>„Flache Sachen schwimmen in der Regel.“</td>
<td>1</td>
</tr>
<tr>
<td>„Schiffe aus Metall gehen nicht unter, weil das Schiff von der Luft nach oben gezogen wird.“</td>
<td>1</td>
</tr>
<tr>
<td>„Dieser Wachsklotz will eigentlich nach unten. Vielleicht schwimmt er aber trotzdem wegen dem Druck des Wassers.“</td>
<td>2</td>
</tr>
</tbody>
</table>
### Teachers’ Assessment of Learning Goals (as an Aspect of PCK)

Antworten auf 5-stufigen Likert-Skala: (1) gar nicht wichtig, (2) eher nicht wichtig, (3) teils-teils, (4) eher wichtig, (5) sehr wichtig

**Importance of domain-specific learning goals**

| A02 | Ein Kalb und eine Kuh mit passenden Begriffen beschreiben und vergleichen können. |
| A03 | Ausgewählte Produkte des Bauernhofs benennen und deren Herstellung beschreiben können (z.B. Käse, Brot, Most, Käse, etc.). |
| A05 | Aspekte einer tiergerechten Haltung nennen können. |
| A06 | Verwendungszweck und Eigenschaften von Materialien nennen und vergleichen können, welche typischerweise auf einem Bauernhof vorkommen (z.B. Stroh, Heu, Gras, Gülle, Wasser, Kraftfutter, etc.). |
| A09 | Typischer Tagesablauf eines Bauern/einer Bäuerin beschreiben können. |
| A10 | Unterschiedliche Milchprodukte (z.B. Käse, Joghurt, Milch etc.) nach verschiedenen Kriterien (z.B. Geschmack, Farbe, Konsistenz, etc.) beschreiben und vergleichen können. |

**Importance of domain-general learning goals**

| A01 | Sich während dem Besuch des Bauernhofes als Teil der Gruppe erleben und diese Zusammengehörigkeit geniessen können. |
| A04 | Fragen an eine fremde Person (z.B. Bäuerin) verständlich und deutlich stellen können. |
| A07 | Der sprechenden Person aufmerksam zuhören können (z.B. dem Bauern oder anderen Kindern). |
| A08 | Das eigene Verhalten nach dem Besuch auf dem Bauernhof selbst einschätzen können. |
| A14 | Sich in einem Gruppenauftrag aktiv einbringen können. |
| A15 | Meinungen von anderen Kindern (z.B. rund um die Schlachtung von Tieren) anhören und respektieren können. |
| A16 | Eigene Gefühle und eigene Wahrnehmungen während und nach dem Bauernhofbesuch verbalisieren und mit anderen Kindern vergleichen können. |
Beliefs about Teaching and Learning in Science (as an aspect of PCK)

Antworten auf 5-stufiger Likert-Skala: (1) stimmt gar nicht, (2) stimmt wenig, (3) stimmt teils-teils, (4) stimmt ziemlich, (5) stimmt völlig

Restructuring knowledge

B01 Kinder kommen mit teilweise tief in Alltagserfahrungen verankerten Vorstellungen zu Naturphänomenen in den Unterricht.
B03 Wenn Kinder im Bereich Phänomene der Natur lernen, stehen oft alte Vorstellungen in ständiger Konkurrenz mit neu erworbenen Vorstellungen.
B16 Lernen im Bereich Phänomene der Natur bedeutet oft ein inneres Ringen (Hin und her) zwischen alten und neuen Vorstellungen über ein Phänomen.
B34 Wenn Kinder mit ihren aktuellen Erklärungsansätzen zu einem Naturphänomen zufrieden sind, wird das Lernen neuer, sachlich angemessener Vorstellungen erschwert.
B35 Kinder lassen im Bereich Phänomene der Natur so schnell nicht ab von den Vorstellungen, die sie in den Unterricht mitbringen.
B50 Lernen im Bereich Phänomene der Natur bedeutet oft, dass sich neue Vorstellungen bei den Kindern nur langsam gegen alte Erklärungsmuster durchsetzen.
B55 Kinder können zu Phänomenen der Natur bereits hartenäckige Vorstellungen haben, die den Lernprozess erschweren.

Co-constructing knowledge

B02rec Die Themen im Bereich Phänomene der Natur sind für Diskussionen unter den Kindern eher ungeeignet.
B11 Es kommt darauf an, dass die Kinder selbst Erklärungen für ein Naturphänomen suchen, auch wenn diese nicht sachlich korrekt sind.
B21 Die LP sollte Kindern, die Probleme mit der Deutung eines Phänomens haben, Zeit für ihre eigenen Deutungsvorsuche lassen.
B29 Die Kinder sollten auch dann angeregt werden, ihre Vorstellungen untereinander zu diskutieren, wenn man als LP feststellt, dass einige Kinder falsche Vorstellungen zu einem Naturphänomen haben.
B32 Im Unterricht im Bereich Phänomene der Natur sollten die Kinder aufgefordert werden, ihre Deutungen zu einem Phänomen gegenüber anderen Kindern zu vertreten.
B46 Man sollte den Kindern ermöglichen, sich erst ihre eigenen Deutungen zu suchen, bevor die LP Hilfen gibt.
B54 Die LP sollte den Kindern auf jeden Fall genügend Zeit lassen, eigene Deutungen für ein Naturphänomen zu suchen, auch wenn diese fachlich nicht richtig sind.
### Situated construction of knowledge

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<tbody>
<tr>
<td><strong>B06</strong></td>
<td>Das Lernen im Bereich Phänomene der Natur sollte während der ganzen Zeit an Problemen oder Aspekten aus dem Alltag orientiert sein.</td>
</tr>
<tr>
<td><strong>B18</strong></td>
<td>Nur wenn Themen im Bereich Phänomene der Natur in Fragestellungen aus dem Alltag eingebunden sind, können die Kinder das erworben Wissen auch anwenden.</td>
</tr>
<tr>
<td><strong>B48</strong></td>
<td>Themen im Bereich Phänomene der Natur sollten immer an einer Fragestellung aufgehängt werden, die einen direkten Bezug zum alltäglichen Leben hat.</td>
</tr>
<tr>
<td><strong>B51</strong></td>
<td>Problemstellungen aus dem Alltag müssen der Ausgangspunkt für Unterricht im Bereich Phänomene der Natur sein.</td>
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</table>

### Hands-on activity

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<tbody>
<tr>
<td><strong>B13</strong></td>
<td>Für mich gilt der Grundsatz: Kinder sollen Experimente im Unterricht im Bereich Phänomene der Natur grundsätzlich ohne Hilfe der LP selbstständig entwickeln.</td>
</tr>
<tr>
<td><strong>B22</strong></td>
<td>Das Durchführen von Versuchen im Unterricht im Bereich Phänomene der Natur stellt eigentlich schon sicher, dass die Kinder Naturphänomene verstehen.</td>
</tr>
<tr>
<td><strong>B31</strong></td>
<td>Wenn Kinder im Unterricht im Bereich Phänomene der Natur Versuche durchführen, Dinge herstellen und viel ausprobieren können, ist eigentlich schon sichergestellt, dass sie viel lernen.</td>
</tr>
<tr>
<td><strong>B45</strong></td>
<td>Für den Unterricht im Bereich Phänomene der Natur gilt: Spass beim Handeln ist ein Garant für Lernen.</td>
</tr>
<tr>
<td><strong>B53</strong></td>
<td>Ohne Eingreifen und Lenken der LP lernen Kinder im Unterricht im Bereich Phänomene der Natur am besten.</td>
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### Play

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<tbody>
<tr>
<td><strong>B39</strong></td>
<td>Im freien Spiel machen Kinder vielfältige Erfahrungen, welche für das Lernen im Bereich Phänomene der Natur von grosser Bedeutung sind.</td>
</tr>
<tr>
<td><strong>B56</strong></td>
<td>Im freien Spiel sind die Kinder besonders motiviert um sich mit Phänomenen der Natur auseinander zusetzen.</td>
</tr>
<tr>
<td><strong>B57</strong></td>
<td>Im freien Spiel entdecken Kinder wichtige Zusammenhänge im Bereich Phänomene der Natur.</td>
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### Transmission of knowledge

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<tbody>
<tr>
<td><strong>B15</strong></td>
<td>Bevor Kinder selbst Versuche durchführen, sollte die LP ihnen einige inhaltliche Grundlagen zum jeweiligen Naturphänomen vermitteln.</td>
</tr>
<tr>
<td><strong>B28</strong></td>
<td>Damit wirklich alle Kinder ein Naturphänomen verstehen können, sind Erklärungen durch die LP unerlässlich.</td>
</tr>
<tr>
<td><strong>B43</strong></td>
<td>Bevor Kinder Zusammenhänge im Bereich Phänomene der Natur verstehen können, sollten ihnen grundlegende Inhalte vermittelt werden.</td>
</tr>
<tr>
<td><strong>B44</strong></td>
<td>Am besten lernen Kinder im Bereich Phänomene der Natur aus Erklärungen ihrer LP.</td>
</tr>
<tr>
<td><strong>B47</strong></td>
<td>Schwächeren Kindern müssen Naturphänomene erklärt werden.</td>
</tr>
</tbody>
</table>
Teachers’ Interest and Self-Concept of Ability in Science

Antworten auf 5-stufiger Likert-Skala: (1) stimmt gar nicht, (2) stimmt wenig, (3) stimmt teils-teils, (4) stimmt ziemlich, (5) stimmt völlig

**Teachers’ interest in science**

D01 Es macht mir großen Spass, mich mit Inhalten der belebten Natur zu beschäftigen.
D02 Es macht mir grossen Spass, mich mit Inhalten der unbelebten Natur zu beschäftigen.
D03 Ich beschäftige mich auch in meiner Freizeit mit Inhalten der belebten Natur.
D04 Ich beschäftige mich auch in meiner Freizeit mit Inhalten der unbelebten Natur.
D05 Ich bin bereit aktiv über ein bestimmtes Naturphänomen zu informieren (z.B. Internet, Fachliteratur, Fachperson), um mein eigenes Wissen zu erweitern.

**Teachers’ self-concept of ability in science**

D06 Ich habe ein gutes Verständnis über Phänomene der belebten Natur.
D07 Ich habe ein gutes Verständnis über Phänomene der unbelebten Natur.

**Teachers’ Self-Reported Teaching Time in Science**

Antworten auf 5-stufig Skala: (1) weniger als ½ h pro Woche, (2) ½ - 1 h pro Woche, (3) 1-2 h pro Woche, (4) 2-5 h pro Woche, (5) über 5 h pro Woche

C1 Wie viele Stunden pro Woche (Achtung: nicht Lektionen!) setzen sich die Kinder in Ihrem Unterricht durchschnittlich mit Phänomenen der belebten Natur auseinander?
C2 Wie viele Stunden pro Woche (Achtung: nicht Lektionen!) setzen sich die Kinder in Ihrem Unterricht durchschnittlich mit Phänomenen der belebten Natur auseinander?
Appendix B: Structural Analysis of Teacher Belief Scales
Exploratory Factor Analysis

An exploratory factor analysis revealed a seven factorial solution, which is depicted in the Table B.1 below. The items relate to an existing item pool from Kleickmann (2008), except those about play (spi).

Table B.1

Factor Loadings With a 7-Factorial Solution

<table>
<thead>
<tr>
<th>Items</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
<th>Factor 4</th>
<th>Factor 5</th>
<th>Factor 6</th>
<th>Factor 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>con13</td>
<td>0.696</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>con12</td>
<td>0.662</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>sch10</td>
<td>0.627</td>
<td></td>
<td></td>
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<tr>
<td>sch03</td>
<td>0.601</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>con04</td>
<td>0.531</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>con03</td>
<td>0.497</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>sch04</td>
<td>0.496</td>
<td></td>
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<tr>
<td>eig14</td>
<td></td>
<td>0.71</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>eig11</td>
<td></td>
<td>0.656</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>eig13</td>
<td></td>
<td>0.587</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>eig10</td>
<td></td>
<td>0.525</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>dis10</td>
<td></td>
<td>0.404</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>dis09</td>
<td></td>
<td>0.398</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dis05(-)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>0.394</td>
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<td>dis01</td>
<td></td>
<td></td>
<td>0.726</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>spi01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tra01</td>
<td></td>
<td></td>
<td></td>
<td>0.726</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tra10</td>
<td></td>
<td></td>
<td></td>
<td>0.634</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tra09</td>
<td></td>
<td></td>
<td></td>
<td>0.577</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tra05</td>
<td></td>
<td></td>
<td></td>
<td>0.567</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tra04</td>
<td></td>
<td></td>
<td></td>
<td>0.51</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>eig12(-)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.348</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pra05(-)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.341</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lai09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.639</td>
<td></td>
</tr>
<tr>
<td>pra07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.557</td>
<td></td>
</tr>
<tr>
<td>pra01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.515</td>
<td></td>
</tr>
<tr>
<td>lai03</td>
<td></td>
<td></td>
<td>0.365</td>
<td></td>
<td></td>
<td>0.481</td>
<td></td>
</tr>
<tr>
<td>lai05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.442</td>
<td></td>
</tr>
<tr>
<td>pra09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.434</td>
<td></td>
</tr>
<tr>
<td>lai12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>0.703</td>
</tr>
<tr>
<td>anw07</td>
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</tr>
<tr>
<td>anw06</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
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<td></td>
<td></td>
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<td></td>
<td>0.599</td>
</tr>
<tr>
<td>anw09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>spi02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.751</td>
</tr>
<tr>
<td>spi04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.694</td>
</tr>
<tr>
<td>spi03</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>0.599</td>
</tr>
<tr>
<td>eig04</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mot09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.74</td>
</tr>
<tr>
<td>mot07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.712</td>
</tr>
<tr>
<td>mot02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.556</td>
</tr>
<tr>
<td>mot06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.415</td>
</tr>
</tbody>
</table>

Note: Extraction Method: Maximum Likelihood. Rotation Method: Promax with Kaiser Normalization. Factor loadings below .33 have been blanked for better interpretability. The item labels correspond to the theoretical construct introduced in Kleickmann (2008), except those about play (Spi). Items with a grey background were excluded for later analyses in a test optimization procedure.
In Table B.1, the item factor loadings are represented as a seven-factorial solution, based on a promax-rotated ML-extraction. The investigation of the item loadings revealed that the ten theoretically proposed constructs (compare with Kleickmann, 2008) are closely reflected in the seven extracted factors. Items of the four constructs TRA, ANW, SPI, and MOT load only on one single factor each (factor 3, 5, 6 and 7 respectively). The factors 1, 2 and 4 are informed by items by two scales each (CON-SCH; EIG-DIS; LAI-PRA). Hence, participants seem not to differentiate between conceptions of CON and SCH (factor 1), EIG and DIS (factor 2) and LAI and PRA (factor 4) respectively. In other words, the discriminant validity between items of these construct-pairs is low.

**Test Optimization**

**Item exclusion**

The following items were excluded in further (items with a grey background in Table B.1): Four items (dis01, spi01, lai12, eig04) did not load at least with .33 on any of the seven factors. Further, the items ‘eig12(-)’ and ‘pra05(-)’ do not fit theoretically into the construct of TRA. Finally, the item ‘lai03’ has a substantial side loading on factor 2.

**Dimensionality**

The exploratory analysis of the item structure performed above leads to a 7-factorial solution. Kleickmann (2008, pp. 144-145) found in his work a 5-factorial solution. The different number of factors (7-factorial solution vs. 5-factorial solution) can be explained as follows: One additional factor in the solution of this stems from the newly introduced construct SPI. The other additional factor stems from the fact that Kleickmann couldn’t differentiate between items of ANW and MOT according to his structural analysis.

The item structure identified above is remarkably close to the one found in Kleickmann (2008). Interestingly, items of the above-mentioned construct pairs (CON-SCH; EIG-DIS; LAI-PRA) load each on a single factor in both structural analyses. Regardless to the empirically found 5-factorial solution, Kleickmann decided to continue his work based on the initially formulated nine constructs for theoretical reasons. In this study, the author has decided to stick to the empirically found solution instead, because it coheres with respective theoretical considerations (see chapter 2.1).

**Confirmatory Factor Analysis**

In the following, a confirmatory factor analysis was calculated to their fit to the empirical data. A set of model fit indices have been calculated with Mplus (Geiser, 2010, pp. 60-61) in order to justify the model fit. The following four models were compared:
- 1-Factor Model: The 1-Factor Model treats all 42 items as belonging to one general factor (so-called g-factor).
- 10-Factor Model: The 10-Factor Model structures the 42 items to the ten constructs, which have been initially formulated (including construct SPI) by Kleickmann (2008).
- 7-Factor Model: The 7-Factor Model structures the 42 items according to 7-factor solution found in the exploratory factor analysis above.
- Optimized 7-Factor Model: The Optimized 7-Factor Model structures 35 items (7 items were excluded; see Table B.1) according to 7-factor solution found in the exploratory factor analysis above.

Table B.2

<table>
<thead>
<tr>
<th></th>
<th>1-Factor Model</th>
<th>10-Factor Model</th>
<th>7-Factor Model</th>
<th>Optimized 7-Factor Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Χ² (df)</td>
<td>2530.758</td>
<td>1308.180</td>
<td>1376.684</td>
<td>890.926</td>
</tr>
<tr>
<td>p(Χ²)</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>CFI/TLI</td>
<td>0.289/0.256</td>
<td>0.777/0.752</td>
<td>0.759/0.740</td>
<td>0.820/0.802</td>
</tr>
<tr>
<td>RMSEA (90% Konfidenzintervall)</td>
<td>0.096</td>
<td>0.056</td>
<td>0.057</td>
<td>0.054</td>
</tr>
<tr>
<td>p(RMSEA ≤ 0.05)</td>
<td>0.000</td>
<td>0.039</td>
<td>0.012</td>
<td>0.141</td>
</tr>
<tr>
<td>SRMR</td>
<td>0.122</td>
<td>0.074</td>
<td>0.079</td>
<td>0.073</td>
</tr>
<tr>
<td>AIC</td>
<td>23524.982</td>
<td>22400.404</td>
<td>22420.908</td>
<td>18867.487</td>
</tr>
</tbody>
</table>

The results of the confirmatory factor analyses are depicted in Table B.2. The study of all fic indices altogether leads to the following conclusions: The 1-Factor Model has clearly the worst fit to the data. Further, the 10-Factor Model and the 7-Factor Model have an approximately equal fitting. Finally, the Optimized 7-Factor Model is fitting best to the data. Consequently, this model fit comparison supports the decision to opt for an optimized 7-factorial solution to adequately represent the data. The respective items are listed in Appendix A.

References


Appendix C: Teachers’ Assessment of Children’s German Language Competence
Einschätzung der Sprachkompetenz durch die Lehrperson

Name, Vorname Lehrperson

Name Kindergarten

KG-Ort: Datum

Da es nicht gerecht wäre, Kinder mit geringeren Deutschkenntnissen gleich zu beurteilen wie Kinder mit höheren Deutschkenntnissen, bitten wir Sie, für jedes Kind, welches am Wissensquiz teilgenommen hat, eine Einschätzung anhand der untenstehenden Aussagen vorzunehmen. Ihre Einschätzung wird von uns anonymisiert und vertraulich behandelt. Sie werden ausschliesslich dazu benutzt, den Einfluss der sprachlichen Kompetenzen auf das von uns erfasste naturwissenschaftliche Verständnis zu kontrollieren. Bitte benutzen Sie die Spalte „weiss nicht“ nur in Fällen, in denen Ihnen eine Einschätzung absolut nicht möglich ist. Wir danken Ihnen herzlich für Ihre Mitarbeit!

Name und Vorname des Kindes:

Code des Kindes (vom Institut auszufüllen)

<table>
<thead>
<tr>
<th>Einschätzungen Kompetenzen Deutsch, bzw. Schweizerdeutsch</th>
<th>stimmt gar nicht</th>
<th>stimmt wenig</th>
<th>stimmt teils-</th>
<th>stimmt ziemlich</th>
<th>stimmt völlig</th>
<th>weiss nicht</th>
</tr>
</thead>
<tbody>
<tr>
<td>Das Kind…</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>…hat einen seinem Alter angemessenen passiven Wortschatz, mit dem es gut verstehen kann</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>…hat einen seinem Alter angemessenen aktiven Wortschatz, mit dem es sich gut ausdrücken kann</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>…bildet Sätze richtig</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>…spricht Worte verständlich aus</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>…erzählt Erlebnisse oder Geschichten zusammenhängend</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>…kann kurze Verse oder Lieder auswendig aufsagen/singen</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>…teilt sich gerne anderen Personen mit</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

Ist das Kind mehrsprachig? (spricht zu Hause fließend eine andere Sprache als ☐ Ja
<table>
<thead>
<tr>
<th>Deutsch/Schweizerdeutsch</th>
<th>☐ 2 Nein</th>
</tr>
</thead>
</table>
| Welche Sprache spricht das Kind zu Hause? | ☐ 1 nur Deutsch/Schweizerdeutsch  
☐ 2 nur eine andere Sprache und zwar  
______________________________  
☐ 3 Deutsch/Schweizerdeutsch und eine/mehrere andere Sprachen |
| **Bemerkungen:** |

---

*Teachers‘ Competence and Professional Development in Early Science Education*  
Appendix C: Teachers‘ Assessment of Children’s German Language Competence
Appendix D: Test of Children’s Conceptual Knowledge About Floating and Sinking
Schritt 1: Gegenstände sortieren und begründen

**Intention:** Kind beurteilt Gegenstände dahingehend, ob sie schwimmen oder sinken; Kind nimmt die Gegenstände in die Hand und wird nach einer Erklärung für seine Entscheidung (schwimmt / sinkt) gefragt.

**Material und Vorbereitung:**
*Diese 16 Materialien werden von der Versuchsleitung bereitgelegt (nicht im unmittelbaren Sichtfeld des Kindes).*

![Materialien für das Experiment](image)

Die beiden Karten (A und B) und ein Behältnis mit Wasser werden für das Kind sichtbar auf den Tisch gelegt.

**Vorgehen:**
*Versuchsleitung beginnt ein kurzes einführendes Gespräch mit dem Kind:*
- „Wie heisst Du? Wie alt bist du?“
*Versuchsleitung trägt diese Informationen auf dieser Seite oben in die Tabelle.*
- „Wir sind heute hier, weil wir herausfinden wollen, warum bestimmte Dinge im Wasser schwimmen, also oben bleiben *(Versuchsleiter zeigt beim Behältnis auf den Wasserspiegel)*, und andere untergehen *(Beim Behältnis auf den Boden zeigen)*. Das hast du ja bestimmt auch schon öfters ausprobiert, vielleicht in der Badewanne oder beim Baden im See, oder?“

<table>
<thead>
<tr>
<th>Name, Vorname des Kindes</th>
<th>Alter des Kindes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Versuchsleitung</td>
<td>KG-Lp:</td>
</tr>
<tr>
<td>KG-Name:</td>
<td>KG-Ort:</td>
</tr>
<tr>
<td>Datum</td>
<td>Zeit</td>
</tr>
</tbody>
</table>
- „Kennst du Dinge die schwimmen oder andere die untergehen? Kannst du einige aufzählen?“ (Mit dieser Frage prüft die Versuchsleitung, ob das Kind versteht was mit ’Schwimmen/Sinken‘ gemeint ist.)

- „Es gibt also Dinge die schwimmen (Versuchsleitung zeigt auf entsprechendes Bild) und andere die untergehen (auf anderes Bild zeigen). Ich werde dir jetzt einige Dinge zeigen und dich fragen, ob die schwimmen oder untergehen.“

**Versuchsleitung gibt dem Kind den ersten Gegenstand gemäss der Reihenfolge der untenstehenden Tabelle.**

- „Schau mal das hier an. Nimm es in die Hand.“
- „Was meinst du, schwimmt das oder geht das unter im Wasser?” Kind antwortet und die Versuchsleitung legt den Gegenstand auf die entsprechende Karte.
- „Und warum glaubst du, dass das untergeht/schwimmt?“

**Versuchsleitung entfernt den zugeordneten Gegenstand von der Karte.**
So verfahren für alle Gegenstände. Das Kind kann die Gegenstände auch selbst auf die Karten legen.

**Am Ende:**
- „Das hast Du ja sehr gut gemacht!”

<table>
<thead>
<tr>
<th>Gegenstand</th>
<th>Schwimmverhalten</th>
<th>Begründung</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platte Stahl klein schwimmt ☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>sinkt ☐</td>
<td></td>
</tr>
<tr>
<td></td>
<td>weiss nicht ☐</td>
<td></td>
</tr>
<tr>
<td>Pyramide Ton gross schwimmt ☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>sinkt ☐</td>
<td></td>
</tr>
<tr>
<td></td>
<td>weiss nicht ☐</td>
<td></td>
</tr>
<tr>
<td>Bruchstück Wachs klein schwimmt ☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>sinkt ☐</td>
<td></td>
</tr>
<tr>
<td></td>
<td>weiss nicht ☐</td>
<td></td>
</tr>
<tr>
<td>Platte Holz mit Löcher schwimmt ☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>sinkt ☐</td>
<td></td>
</tr>
<tr>
<td></td>
<td>weiss nicht ☐</td>
<td></td>
</tr>
<tr>
<td>Zahnstocher schwimmt ☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>sinkt ☐</td>
<td></td>
</tr>
<tr>
<td></td>
<td>weiss nicht ☐</td>
<td></td>
</tr>
<tr>
<td>Holzscheit schwimmt ☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>sinkt ☐</td>
<td></td>
</tr>
</tbody>
</table>
### Appendix D: Test of Children’s Conceptual Knowledge About Floating and Sinking

<table>
<thead>
<tr>
<th>Material</th>
<th>Floats</th>
<th>Sinks</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naturkork Bruchstück</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Nadel Eisen (Metall)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Kugel Styropor gross</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Schleifkork</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Platte Stahl gross</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Scherbe Ton klein</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Schloss Eisen (Metall)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Kerze Wachs gross</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Bruchstück Styropor klein</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Platte Stahl mit Löcher</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
Schritt 2: Materialzuordnung und -benennung

Intention: Kind erkennt und benennt das Material.

Material und Vorbereitung:
Die beiden Karten (A) und (B) werden können auf die Seite gelegt werden.

Auswahl aus den Materialien aus Schritt 1 (ohne Nr. 3, 4, 5, 6).

Vor dem Kind werden die untenstehenden 6 Gegenstände in abgebildeter Reihenfolge aufgebaut:

Die untenstehenden 6 Gegenstände (es sind die kleinen Materialpaare der obenstehenden Reihen) werden ausserhalb des Sichtfeldes der Kinder bereit gelegt.
Vorgehen:
Die kleineren Gegenstände werden den Kindern nacheinander gemäß der Reihenfolge der untenstehenden Tabelle gezeigt.
- „Schau mal, das hier! Gibt es hier noch ein Ding, das aus dem Gleichen gemacht ist?”
Den kleinen Gegenstand wieder zurücklegen und den nächsten nehmen und dann so weiter.
Wenn die **Materialzuordnung** abgeschlossen ist werden die grösseren Gegenstände nacheinander dem Kind für die **Materialbenennung** präsentiert:
- „Weiβt du auch, woraus das gemacht ist?”
- „Prima, dann machen wir mal weiter”
Für jeden grossen Gegenstand so weiter machen.

<table>
<thead>
<tr>
<th>Materialzuordnung</th>
<th>Bemerkungen</th>
<th>Materialbenennung</th>
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<tr>
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</tbody>
</table>
Abschluss:
- „Das hast du super gemacht. Bald werden wir dazu was Spannendes im Kindergarten machen.”

Versuchsleitung trägt hier spezielle Beobachtungen/Vorkommnisse ein (z.B. Sprachdefizite, Aufmerksamkeitsdefizite, Verhaltensauffälligkeiten, etc.)