Early science education - Exploring preschool children's basic conceptual knowledge along with their involvement and preschool teachers' professional competence

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Early science education - Exploring preschool children's basic conceptual knowledge along with their involvement and preschool teachers' professional competence

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Pamela Flores
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Erstgutachter: Prof. Dr. Birgit J. Neuhaus

Zweitgutachter: Prof. Dr. Beate Sodian

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Abstract

Early science education has become a crucial element of preschool. In the last years, the inquiry-based educational approach has gained increasing attention as a suitable strategy to engage preschool children with scientific topics. First studies indicate that this approach has a positive effect on children's learning experiences and outcomes, but there is still a dire need to investigate these two aspects simultaneously and explore the relation between them. The increasing importance of science in preschool entails new expectations for preschool teachers, which raises the question as to what type of knowledge they need to teach science to young children. Drawing from research with school teachers, it is believed that preschool teachers' content knowledge and pedagogical content knowledge play a role in their instructional practices. Here again, however, research is still rather scarce. This thesis consists of three research studies that aim at contributing to the still growing research in the field of early science education, specifically in the domain of life sciences. These studies are complemented by a diverse set of science outreach activities oriented towards preschool teachers and children that aim at contributing to the improvement of early science education.

Study 1 presents the development and evaluation of an instrument to examine young children's understanding of the biological concept of structure and function in the form of one-on-one interviews. Through a two-tier item structure, it allows for the evaluation of children's knowledge of the relation between structure and function as reflected by two different cognitive processes: their ability to match structures and functions (*recognize*), and their ability to explain these relationships (*explain*). The Rasch psychometric analysis that was conducted to evaluate measurement functioning includes the assessment of dimensionality, item and person reliabilities, step ordering, anchor quality, and Wright maps, which in turn consists of the evaluation of the ranges of item difficulty and person ability, test item targeting, and the position of all items along the difficulty scale. The Rasch technique allowed for the analysis of the item difficulties as a combination of their difficulty level in both tiers, resulting in a pool of 16 items that can be used in future studies.

Study 2 centres around the effect of the inquiry-based educational approach on preschool children's involvement and conceptual knowledge of structure and function, as well as the mediating role of involvement within this learning process. 59 children (mean age: 6 years, 3 months) participated in either an inquiry-based or a control learning activity on the topic of animals and plants of the forest. Their involvement was measured using an adapted version of the Leuven Involvement Scale and their conceptual knowledge using the instrument presented in study 1. Results show that the inquiry-based learning activity had no impact on children's recognition of correct structures and functions of different organisms (*recognize*), but it had a significant effect on their conceptually based explanations (*explain*). Children of the inquiry group showed significantly higher levels of involvement during the learning activity than those of the control group. No indirect effect of the inquiry-based learning activity on children's conceptual understanding through involvement after including the relevant covariates could be found. This study demonstrates that the inquiry-based educational approach is an appropriate strategy for engaging preschool children with science, as it has a positive effect on their learning experiences and outcomes.

Study 3 focuses on the relation between preschool teachers' professional knowledge and their instructional practice. 27 preschool teachers participated in a PD training that fostered either their content knowledge (CK-group), their pedagogical content knowledge (PCK-group), or both (CK+PCK-group), and then asked to conduct a learning activity with preschool children with provided materials. The instructional practice was conceptualized as consisting of a content dimension and an inquiry dimension, which consists of the subdimensions questioning, hypothesizing, testing, describing, and interpreting. The CK+PCK-group was significantly better than the PCK-group in the content dimension but not in any of the inquiry subdimensions, which suggests that preschool teachers can draw from their PCK to guide children through the inquiry process even when they lack the relevant CK. Further, the CK+PCK-group was significantly better than the CK-group in the content dimension and in the more complex inquiry subdimensions hypothesizing and interpreting but not in questioning, testing, and describing. These differences suggest that PCK is necessary for preschool teachers to conduct inquiry in a deeper and more meaningful manner and that the implementation of scientific inquiry activities provides a crucial framework in which the content of the learning activity can be explored.

Zusammenfassung

Die frühe naturwissenschaftliche Bildung ist zu einem wichtigen Element der Vorschule geworden. In den letzten Jahren hat der Ansatz des forschenden Lernens als geeignete Strategie zur Auseinandersetzung von Vorschulkindern mit naturwissenschaftlichen Themen zunehmend an Bedeutung gewonnen. Erste Studien deuten darauf hin, dass sich der Ansatz des forschenden Lernens positiv auf die Lernerfahrungen und -ergebnisse der Kinder auswirkt, aber es besteht immer noch ein dringender Bedarf, diese beiden Aspekte zu untersuchen und die Beziehung zwischen ihnen zu erforschen. Die zunehmende Bedeutung der Naturwissenschaften in der Vorschule bringt neue Anforderungen an die frühpädagogischen Fachkräfte mit sich. Dies wirft die Frage auf, welche Art von Wissen sie benötigen, um kleinen Kindern Naturwissenschaften zu vermitteln. Ausgehend von der Forschung mit Lehrkräften der Sekundarstufe I und II wird angenommen, dass das Fachwissen und fachdidaktische Wissen von frühpädagogischen Fachkräften eine Rolle bei der Durchführung von Lernangeboten spielt. Aber auch hier ist die Forschung noch recht spärlich. Die vorliegende Arbeit besteht aus drei Studien, die einen Beitrag zu der stetig wachsenden Forschung im Bereich der frühen naturwissenschaftlichen Bildung, insbesondere im Bereich der Lebenswissenschaften, leisten sollen. Diese Studien werden durch eine Reihe von Science-Outreach-Aktivitäten ergänzt, die sich an frühpädagogische Fachkräfte und Vorschulkinder richten und zur Verbesserung der frühen naturwissenschaftlichen Bildung beitragen sollen.

Studie 1 stellt die Entwicklung und Evaluation eines Instruments vor, mit dem in Form von Einzelinterviews untersucht wird, inwieweit Kleinkinder das biologische Konzept von Struktur und Funktion verstehen. Durch eine zweistufige Itemstruktur ermöglicht es die Bewertung des Wissens der Kinder über die Beziehung zwischen Struktur und Funktion. Zwei unterschiedliche kognitive Prozesse sind an diesem Wissen beteiligt: die Fähigkeit, Strukturen und Funktionen zuzuordnen (Skala: *Erkennen*) sowie die Fähigkeit, diese

Beziehungen zu erklären (Skala: *Erklären*). Um die Messfunktionalität des Instruments bewerten zu können, wurde eine psychometrische Rasch-Analyse durchgeführt. Sie umfasst die Bewertung der Dimensionalität, der Item- und Personenreliabilitäten, der Stufenanordnung, der Ankerqualität und der Wright-Maps. Das Rasch-Verfahren ermöglichte die Analyse der Itemschwierigkeiten als Kombination ihres Schwierigkeitsgrades in beiden Stufen, was zu einem Pool von 16 Items führte, die in zukünftigen Studien verwendet werden können.

Studie 2 befasst sich mit den Auswirkungen des Ansatzes des forschenden Lernens auf die Engagiertheit und das konzeptuelle Wissen über Struktur und Funktion von Vorschulkindern sowie mit der mediierenden Rolle des Engagements innerhalb dieses Lernprozesses. 59 Kinder (Durchschnittsalter: 6 Jahre, 3 Monate) nahmen entweder an einer forschungsbasierten oder einer Kontroll-Lernaktivität zum Thema Tiere und Pflanzen des Waldes teil. Ihre Engagiertheit wurde mit einer angepassten Version der Leuven Engagiertheitsskala und ihr konzeptionelles Wissen mit dem in Studie 1 vorgestellten Instrument gemessen. Die Ergebnisse zeigen, dass die forschungsbasierte Lernaktivität keinen Einfluss auf das Erkennen der korrekten Strukturen und Funktionen verschiedener Organismen (Skala: *Erkennen*), aber einen signifikanten Effekt auf ihre konzeptuellen Erklärungen (Skala: *Erklären*) hatte. Die Kinder der forschungsbasierten Gruppe zeigten während der Lernaktivität ein signifikant höheres Maß an Engagiertheit als die Kinder der Kontrollgruppe. Es konnte kein indirekter Effekt der forschenden Lernaktivität auf das konzeptuelle Verständnis der Kinder durch Engagiertheit nach Einbeziehung der relevanten Kovariaten gefunden werden. Diese Studie zeigt, dass der Ansatz des forschenden Lernens eine geeignete Strategie ist, um Vorschulkinder für die Naturwissenschaften zu begeistern, da er sich positiv auf ihre Lernerfahrungen und -ergebnisse auswirkt.

Studie 3 befasst sich mit der Beziehung zwischen dem professionellen Wissen von frühpä-dagogischen Fachkräften und ihrer Durchführung von Lernangeboten. Hier nahmen 27 frühpädagogische Fachkräfte aus fünf verschiedenen Kindertageseinrichtungen an einer Fortbildung teil, die entweder ihr Fachwissen (FW-Gruppe), ihr fachdidaktisches Wissen (FDW-Gruppe) oder beides (FW+FDW-Gruppe) förderte. Anschließend wurden sie gebeten, eine Lernaktivität mit Vorschulkindern mit bereitgestellten Materialien durchzuführen. Die Durchführung des Lernangebotes wurde so aufgefasst, dass sie aus einer Inhaltsdimension und einer Forschungsdimension besteht, die sich aus den Unterdimensionen Hinterfragen, Aufstellen von Hypothesen, Testen, Beschreiben und Interpretieren

zusammensetzt. Die FW+FDW-Gruppe war in der Inhaltsdimension signifikant besser als die FDW-Gruppe, jedoch nicht in der Forschungsdimension. Dies deutet darauf hin, dass frühpädagogische Fachkräfte auf ihr FDW zurückgreifen können, um Kinder durch den Forschungsprozess zu leiten, auch wenn ihnen das entsprechende FW fehlt. Darüber hinaus war die FW+FDW-Gruppe in der Inhaltsdimension und in den komplexeren Unterdimensionen Aufstellen von Hypothesen und Interpretieren signifikant besser als die FW-Gruppe, nicht aber in den Unterdimensionen Fragen, Testen und Beschreiben. Diese Unterschiede deuten darauf hin, dass FDW für frühpädagogische Fachkräfte notwendig ist, um forschende Lernangebote in einer tieferen und sinnvolleren Weise durchzuführen. Ferner zeigen sie, dass die Umsetzung wissenschaftlicher Forschungsaktivitäten, wie z.B. das Formulieren von Hypothesen und Interpretieren von Ergebnissen, einen entscheidenden Rahmen bietet, innerhalb dessen der Inhalt der Lernaktivität erforscht werden kann.

Part I

Introduction

Introduction

Young children are naturally inquisitive and show a genuine interest for the natural world and all living things. Their drive to explore, observe and understand natural phenomena is one of the reasons why science has become a crucial element of early childhood education. In this context, the field of life sciences plays an important role. Throughout their everyday life, young children gather various experiences with animals, plants, and processes in the human body, and have an intrinsic motivation to learn about topics such as the characteristics of animals, their growth and their adaptation to different environments (Staatsinstitut für Frühpädagogik München, 2006). Therefore, the field of biology seems to be naturally appropriate for engaging preschool children with science.

There is increasing agreement that the overarching goals of early science education can be defined using the concept of scientific literacy (Anders, 2012; Anders et al., 2018; Eshach, 2006; Fthenakis, Wendell, Eitel, Deutsche Telekom-Stiftung, et al., 2009; French, 2004; Gelman & Brenneman, 2004; Möller & Steffensky, 2010; Samarapungavan, Patrick, & Mantzicopoulos, 2011; Steffensky, 2017; Trundle & Saçkes, 2015). This includes the development of children's basic understanding of scientific concepts, basic skills of scientific inquiry, e.g. observing, describing, measuring, and experimenting, and basic understanding of the nature of science, i.e. how knowledge is structured and generated in the natural sciences (Steffensky, 2017). Further goals encompass the development of interest, intrinsic motivation, and self-efficacy in engaging with scientific phenomena (Anders et al., 2018). The idea here is not to set specific learning goals or standards that children must achieve by the end of the preschool year, nor is it to have children fully transform their naïve conceptions into advanced, scientifically correct knowledge. Rather, the aim is to provide children with learning opportunities that enable them to develop an initial understanding of the scientific concepts they encounter in their everyday lives, as well as a basic set of inquiry skills and affective dispositions that will allow them to discover the world around them in an autonomous and competent way (Eshach, 2006; Fthenakis et al., 2009; French, 2004; Gelman & Brenneman, 2004; Möller & Steffensky, 2010; Steffensky, 2017).These aspects of scientific literacy can be characterized as the outcomes, i.e. the desired *results* of early science education. This is, however, not the only perspective that can be taken to conceptualize the goals of early science education. Rather, the focus can be laid on children's *experiences* during a learning situation. It can be argued that young children's positive experiences with science are a crucial aspect of early education, both independently from and as mediators of the knowledge gains, given that they allow children to enjoy their encounters with scientific topics and engage as active agents in their own learning process (Andersson & Gullberg, 2014; Fleer, 2013).

In light of these educational goals, researchers and practitioners in the field of early science education are confronted with several important questions: How can preschool children's learning experiences and outcomes be measured and how do they relate to each other? What type of guidance do preschool children need in order to achieve these educational goals? And what type of knowledge do preschool teachers need in order to provide such guidance?

In the last years, there has been a surge of preschool curricula, teaching recommendations and educational initiatives that aim at providing answers to these questions (Anders et al., 2018; Eshach & Fried, 2005; Gelman & Brenneman, 2004; Gerde, Schachter, & Wasik, 2013). Given that research in this field is still in its infancy, however, these are often heavily based on the theoretical frameworks and empirical evidence stemming from research with primary and secondary school teachers and students. For example, practical recommendations for preschool teaching increasingly depict the inquiry-based instructional approach as a suitable strategy to engage kindergarteners with science (Eshach & Fried, 2005; Gerde et al., 2013). At the same time, and despite a large body of research with older students (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; J. L. Anderson, Ellis, & Jones, 2014; Furtak, Seidel, Iverson, & Briggs, 2012; Lazonder & Harmsen, 2016; Minner, Levy, & Century, 2010), there are only few studies that provide empirical evidence on the impact of this approach on young children's learning outcomes (Dickinson & Porche, 2011; French, 2004; Peterson & French, 2008; Samarapungavan, Mantzicopoulos, & Patrick, 2008; Samarapungavan et al., 2011; Steffensky, Lankes, Carstensen, & Nölke, 2012), and no study has quantitatively analysed its effect on their learning experience nor the way these experiences relate to and influence the outcomes.

Similarly, modern conceptualizations of preschool teachers' professional competence are based on the well-established and empirically grounded frameworks of primary and secondary teachers' competence (Blömeke, Felbrich, Müller, Kaiser, & Lehmann, 2008; Blömeke, Gustafsson, & Shavelson, 2015; Dunekacke, Jenßen, & Blömeke, 2015; Dunekacke, Jenßen, Eilerts, & Blömeke, 2016; Fröhlich-Gildhoff, Nentwig-Gesemann, & Pietsch, 2011; J. Lee, 2010; McCray & Chen, 2012). In the case of school teachers, their professional knowledge consists of knowledge about science concepts and phenomena (content knowledge) and knowledge about how to teach science to young children (pedagogical content knowledge), among others, and there are strong empirical findings demonstrating the relation between these knowledge facets and the instructional quality (Baumert et al., 2010; Förtsch, Werner, von Kotzebue, & Neuhaus, 2016; Kulgemeyer & Riese, 2018; Kunter et al., 2013). In the context of preschool, however, there are not yet many studies providing empirical evidence to support the assumption that this can be transferred to preschool teachers, and those that exist mainly belong to the field of early mathematics education (Dunekacke et al., 2016; Gropen, Kook, Hoisington, & Clark-Chiarelli, 2017; J. Lee, Meadows, & Lee, 2003; J. Lee, 2005; McCray & Chen, 2012; Oppermann, Anders, & Hachfeld, 2016).

There is therefore still a dire need to assess to what extent the theoretical frameworks and empirical findings originating from research at school can actually be applied to the context of preschool.

This thesis thus aims at contributing to the still growing research in the field of early science education, specifically in the domain of life sciences, by addressing three important research gaps. These concern (1) the measurement of young children's basic knowledge of an important concept of biology, namely that of structure and function (2) the effect of the inquiry-based instructional approach on young children's learning experiences and outcomes and the relation between them, and (3) the role of preschool teachers' professional knowledge on their instructional practice.

These research goals are, however, not the only ones followed in this dissertation. This thesis is positioned within the field of subject-specific science didactics, which, as a use-inspired research field, aims at both understanding the processes of teaching and learning as well as improving science education (Stokes, 1997). Therefore, the author of this dissertation subscribes to the belief that research projects in this field are to be complemented with concrete activities in which their findings are put to use for the improvement of science education, e.g. through the development and implementation of science outreach activities for teachers and students. Based on these considerations, the research studies conducted in this doctoral project were complemented with a variety of outreach activities oriented towards both preschool children and teachers.

Part II

Aims and structure of this dissertation

Aims and structure of this dissertation

The thesis presented here contains two main aspects. The first aspect refers to the research studies that were conducted with both preschool children and teachers. The second aspect refers to the outreach activities that were developed and implemented for both preschool children and teachers (for an overview, see Figure 1).

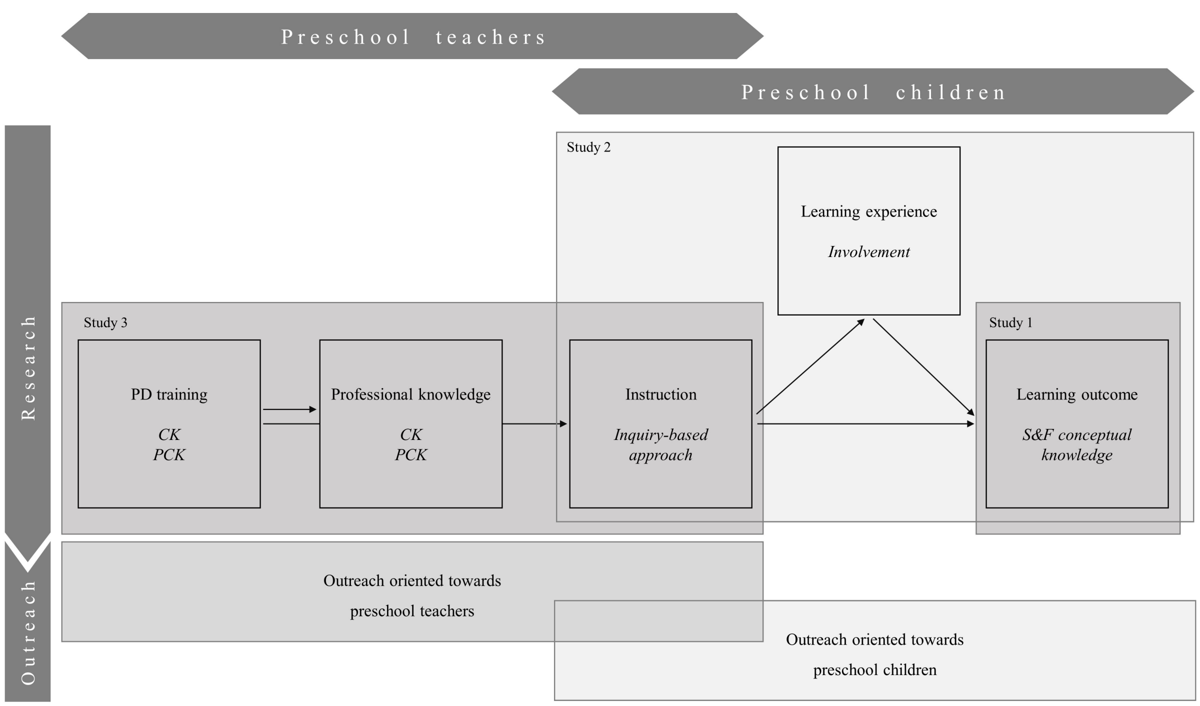


Figure 1: Overview of the aims and structure of this dissertation

The research aspect of this dissertation is covered in Part III. It consists of three main studies. Study 1 and 2 were conducted with the same sample of 59 preschool children, whereas study 3 was conducted with 27 preschool teachers.

Study 1 (chapter 1) consists on the development and evaluation of an instrument to measure young children's conceptual knowledge of structure and function through one-on-one interviews. This instrument covers a wide range of organisms and requires children to match structures and functions and to describe and explain these relationships. With this, the instrument assesses children's conceptual knowledge as reflected through the two cognitive processes labelled *recognize* and *explain*. Further, the Rasch psychometric technique is implemented to evaluate the measuring functioning of the instrument, taking into consideration that test items differ in their degree of difficulty. This includes the analysis of item fit, item and person reliability, step ordering, anchor quality, and the evaluation of the Wright maps to assess the location of items along the scale, the range of item difficulty in relation to the range of person ability, and the test item targeting. Finally, the Rasch approach is used to assess all items together regarding their difficulty level in both tiers, resulting in a pool of 16 items that can be used for further studies.

Study 2 (chapter 2) focuses on the relations between an inquiry-based learning activity, children's learning experience and learning outcome. The inquiry-based learning activity centers around the topic of animals and plants living in the forest and takes the form of guided inquiry centred in the scientific procedure of comparison. Specifically, this study investigates (a) the effect of the inquiry-based learning activity on preschoolers' knowledge of the biological concept of structure and function, (b) the effect of the inquiry-based learning activity on children's level of involvement during the activity, and (c) the mediating role of children's involvement on the relation between the inquiry-based learning activity and their learning outcome, based on Laevers's (2000) experiential education model.

Study 3 (chapter 3) centers around the relations between preschool teachers' professional knowledge and their instructional practices with preschool children. It investigates the role of preschool teachers' content knowledge and pedagogical content knowledge on the content dimension and the inquiry dimension of their instructional practice during a science learning situation. Further, in an exploratory manner, it addresses the relation between these two dimensions of the instructional practice as well as the differences in the instructional practice of preschool teachers that are native German speakers and those that are not. This study was originally planned as a pilot study to assess the feasibility of the design, evaluate and edit the knowledge tests as well as the content of the different trainings, and observe participants' use of the learning materials during the instructional practice. A following study was expected to be conducted during the year 2020, but due to the adverse circumstances unfortunately it had to be cancelled. Even though the conducted pilot study was centred around theory-based hypotheses, the original intention with such a small sample size (n = 27) was not to conduct conclusive statistical analyses, but rather to gain first insights into the relation between preschool teachers' professional knowledge and their instructional practice. Therefore, the findings of this study have to be taken as tentative and understood as a basis upon which future research can be built.

The outreach aspect of this dissertation is covered in Part IV. It consists of a diverse set of science outreach activities oriented towards preschool children and teachers. These outreach activities aimed at contributing to the improvement of early science education and can be described as complementary to the research studies.

Two types of outreach activities can be distinguished. One type refers to activities in which the author of this dissertation develops and implements science learning opportunities with/for preschool children based on the theoretical background and the findings of the conducted studies (section 4.2.1). This includes the development and implementation of a concept-based and inquiry-based learning activity about ants and snails as well as the development and implementation of an observation exercise with different bird species.

The other type refers to activities in which the author of this dissertation shares the theoretical background and the findings of the conducted studies with preschool teachers so that they themselves can make use of them in their own implementations of science learning opportunities with preschool children (section 4.2.2). This includes the publication of a practical recommendations article that provides readers with three recommendations for engaging preschool children with biological topics and a video abstract, in which the theory, methods and main findings of study 2 are presented in plain language.

This thesis is finalized with an overall discussion in Part V. This first summarizes the contribution of this doctoral project to the research gaps presented in the introduction and to the outreach movement that is increasingly becoming an important part of modern scientific endeavours. It then delineates the implications that this doctoral project entails for future research and outreach.

Part III

Research

Chapter 1

Study 1

1.1 Theoretical background

From a very young age, children show great interest in the natural world and all living things (Eshach & Fried, 2005). They possess a genuine curiosity about topics such as magnetism, the weather, and the characteristics of animals and plants, and are eager to investigate and find out how certain natural processes work and why things are the way they are (Staatsinstitut für Frühpädagogik München, 2006). Even before starting school around the age of 6, they gather diverse everyday experiences with natural phenomena and absorb information and ideas through children's books, media and interactions with family members and friends and thus make use of these primary experiences to form first basic ideas or preconceptions about diverse scientific phenomena (Duit & Treagust, 2003; Inagaki & Hatano, 1996, 2004; Kleickmann et al., 2010; Möller, 1999; Möller, Kleickmann, & Sodian, 2011). Although these preconceptions are helpful tools to interpret various aspects of everyday life, they are often not yet consistent with what is considered correct by the scientific community. Therefore, an important aim of early science education is for young children to develop a *basic* conceptual knowledge, i.e. an initial understanding of the scientific concepts that are already part of their everyday lives, so that a better understanding can help them make sense of the world around them (Gelman & Brenneman, 2004; Möller & Steffensky, 2010; Samarapungavan et al., 2011; Steffensky, 2017).

1.1.1 Conceptual knowledge

Conceptual knowledge has been defined as knowledge "about facts, concepts and principles that apply within a certain domain" (De Jong & Ferguson-Hessler, 1996, p. 107). This definition is based on an epistemological perspective, by which different aspects of knowledge are characterized depending on the function they fulfill in the performance of a task, e.g. in problem-solving. Within this context, the authors specify that conceptual knowledge "functions as additional information that problem solvers add to the problem and that they use to perform the solution" (De Jong & Ferguson-Hessler, 1996, p. 107). Within Bloom's revised taxonomy, Krathwohl (2002) differentiates between factual and conceptual knowledge. The former refers to the knowledge about specific facts or basic elements within a discipline, whereas the latter is characterized as the knowledge about the interrelationships among these basic elements, and includes the knowledge of principles and generalizations. Krathwohl (2002) additionally defines six cognitive processes that refer to "what is to be done with or to" that knowledge (p. 213). That is, these processes describe the range of cognitive activities that constitute the process of constructing meaning, and thus represent the cognitive processes by which student's conceptual knowledge is reflected (Mayer, 2002). For the purpose of this study, the focus will lie on the first two. The first process called *remember* involves retrieving knowledge from long-term memory, and includes the process *recognize*, which refers to identifying a piece of information that is consistent with one own's knowledge base. This process can take the form of rote learning, when the focus lies on merely learning isolated elements, or it can be part of meaningful deep-level learning, when it is integrated within the larger task of constructing new knowledge (De Jong & Ferguson-Hessler, 1996; Mayer, 2002). The second process *understand* refers to the integration of new knowledge within existent schemas and cognitive frameworks. It includes *explain*, which is defined as the ability to mentally construct and use cause-effect models when giving meaning to an observed phenomenon (Mayer, 2002). Along these lines, Van Boxtel, Van der Linden, and Kanselaar (2000) suggest that conceptual knowledge "is reflected in the way students participate in activities that require the use of the concepts. Students have to become able to use scientific concepts to describe, explain and manipulate phenomena" in a given domain (p. 312). Drawing from these definitions, Förtsch, Heidenfelder, Spangler, and Neuhaus (2018) define factual knowledge as the knowledge of single elements, like facts or terms that students can reproduce, and conceptual knowledge as the knowledge of the relations between single elements and of general principles in a discipline. In addition, the authors specify that conceptual knowledge is reflected in a person's ability to explain such relationships, transfer, and apply them to other contexts (Förtsch et al., 2018).

According to modern constructivist views on the conceptual change theory, the development of scientifically correct concepts is a gradual learning process in which new knowledge elements are integrated into already existing mental schemas, leading to the growth, restructuration and differentiation of such knowledge structures (Duit & Treagust, 2003; Vosniadou & Brewer, 1992). This process can also be described as cumulative learning. In cumulative learning, newly learned information is continuously added and linked to the existing knowledge base in as many ways as possible, so that meaningful relations or connections are formed between old and new elements (Freiman, 2001).

Modern educational standards across the world emphasize the importance of cumulative learning for the development of conceptual knowledge (Standards, 2013; Kultusministerkonferenz, 2004). The idea behind it is that science instruction can foster conceptual learning by consistently and systematically making connections between new learning material and content learned in previous lessons and even in different subjects (Freiman, 2001; Neuhaus & Spangler, 2018; Wadouh, Liu, Sandmann, & Neuhaus, 2014). For this, educational standards define specific disciplinary core concepts that reflect the most important and prevalent principles within a domain. These core concepts are thus used as a framework to structure the learning content and provide recurrent points of reference by which the seemingly chaotic and unrelated wealth of scientific phenomena can be organized (Kultusministerkonferenz, 2004; Förtsch et al., 2018; Neuhaus & Spangler, 2018). The systematic structuring of science lessons based on the same core concepts throughout several school years allows learners to recognize the same principles in a variety of learning contexts and thus continuously expand their network of interrelated knowledge, ultimately leading to the cumulative development of conceptual knowledge.

In America's Next Generation Science Standards, a distinction is made between "crosscutting concepts" and "disciplinary core ideas". Crosscutting concepts can be applied across all domains of science, and include *cause and effect*, *structure and function* and *stability and change*, whereas the core ideas represent the most important principles within specific science disciplines (Standards, 2013). In the life sciences, the core ideas mentioned here are, for example, *structure and function*, *growth and development of organisms*, and *natural selection* (Standards, 2013). Similarly, the German National Education Standards for the subject biology specify three core concepts: *system*, *development*, and *structure and function* (Kultusministerkonferenz, 2004).

Looking at these international education standards, it becomes clear that the concept of structure and function plays an important role in the life sciences. This concept represents the relation that exists between certain features of an organism and the purpose they serve (Standards, 2013; Kultusministerkonferenz, 2004). It can be found within all organisational levels ranging from cells to ecosystem; it can relate to an organisms' daily functions, such as the relation between a birds' beak form and its eating habits or the role of a plant's stomata structure in the process of gas exchange, as well as to internal processes, such as the relation between the chemical structure of an antibody and its ability to detect specific antigens within an organisms' immune response. That is, animals and plants have physical, chemical and behavioural traits that help them adapt to their environment and survive (Samarapungavan et al., 2008). Given that this relation is present in every topic of the life sciences, a solid understanding of this concept is an important foundation for further learning in this field.

This concept is not only relevant in science lessons in school, but also in the context of early science education. Young children's everyday life allows them to gather various experiences with animals, plants, and their own body in which they naturally encounter many concrete examples of the relation between biological structures and their functions (Staatsinstitut für Frühpädagogik München, 2006). Thus, compared to other biological principles, such as the more abstract concept of biological systems or the long processes of growth and development, the relation between structure and function seems to be easily accessible to preschool children. Moreover, it is the basis for understanding further biological processes and principles, such as evolution and the adaptation of organisms to their environment (Samarapungavan et al., 2008; Steffensky, 2017). Therefore, this is one of the concepts that are recommended to be integrated as a disciplinary core idea when engaging young children with biological topics (Samarapungavan et al., 2008; Steffensky, 2017).

1.1.2 Assessment of conceptual knowledge of structure and function

An important line of research has focused on the measurement of students' knowledge of different scientific concepts. Recent studies have developed diverse instruments to measure student's conceptual knowledge of structure and function in all levels of education. In a study about the influence of concept-based instruction on high school student's knowledge development, Förtsch et al. (2018) developed a paper-pencil test to measure participants' knowledge of the biological concept of structure and function, among others. They differentiated between factual knowledge tasks, in which students had to name one or more facts about a given content, and conceptual knowledge tasks, in which students had to describe at least one relation or a concept, e.g. describe a specific structure based on a given function. In the level of primary school, Kümpel (2019) developed an instrument to assess children's knowledge of different biological concepts considering three levels of knowledge. The factual level tasks assessed children's ability to reproduce certain terms or details, e.g. to label the different body parts of an animal. The relational level tasks required children to describe and explain relationships between specific biological structures and their functions. The conceptual level tasks assessed children's knowledge of the general principles behind this biological concept, for example children were asked to explain why birds have different beak shapes.

These instruments are useful for assessing primary and high school student's conceptual knowledge. However, the measurement with younger children cannot be conducted in the same way, as they usually cannot read and write, and their language ability is still evolving. Research on the field of early science education has tackled this and developed different methods to measure young children's conceptual knowledge, including the assessment of their drawings and interview responses, amongst others. Especially in young children, language is considered a crucial factor influencing science knowledge development (Gentner & Goldin-Meadow, 2003). This is based on the notion that language structures how science concepts are constructed and communicated (Lemke, 1990). For instance, learning often take place during linguistic interactions, such as asking questions, describing phenomena and giving explanations, all of which can support the construction of conceptual understanding (Akerson, Flick, & Lederman, 2000; Van Boxtel et al., 2000; Hong & Diamond, 2012). This goes in line with the Vygotskian sociocultural perspective on learning, which emphasizes the role of dialogue in the co-construction of knowledge (Vygotsky, 1978). Therefore, when assessing young children's conceptual knowledge, their level of language ability must be taken into consideration.

A yet small number of studies has investigated preschool children's understanding of the relation between structure and function in animals, plants, and processes in the human body. In the studies of Samarapungavan et al. (2008, 2011), preschoolers took part in an extended science project about the life cycle of monarch butterflies. Here, the authors made use of several sources of evidence to assess children's learning. On one hand, the authors compiled portfolios consisting of all artifacts the children produced during the project, which included drawings, posters and science notebook entries. These were evaluated using a portfolio rubric that consisted of several dimensions, e.g. the dimension "Understands and can give examples of the relationship between biological structure and function", which were scored from "somewhat proficient" to "highly proficient". On the other hand, the authors developed and implemented the Science Learning Assessment (SLA) instrument (Samarapungavan, Mantzicopoulos, Patrick, & French, 2009). This instrument includes items regarding structure and function, in which children are asked to match specific body parts of a caterpillar with the function they serve, e.g. their mouth, spiracles or legs. The results of these studies demonstrate that preschool children can learn that animals have specific physical and behavioural characteristics that allow them to adapt to their environment and to survive, grow and reproduce. For example, after engaging in the project on the monarch butterfly, children could recognize and name the function of some of this animal's body parts, such as its legs, mouth and antennae (Samarapungavan et al., 2008, 2011). J. L. Anderson et al. (2014) investigated kindergarten and first grade children's conceptual knowledge in plants. The authors collected data from three sources to assess children's understanding of what constitutes a plant and what plants need in order to survive. First, they employed the "Draw-A-Plant" instrument, in which children were asked to think about and draw a plant with all its parts and all the things it needs to grow. The drawings were rated based on whether they depicted certain features, such as flowers, roots, the sun and rain. Second, a plant survey was conducted, in which children had to select out of a set of pictures the ones that were plants or derivatives of plants, and out of another set the ones that contained materials or objects that plants need to survive. Lastly, the authors conducted semi-structured interviews with the participants in order to further comprehend the children's reasoning behind their drawings and their choices in the survey. Based on these data sources, the authors concluded that some of the children possessed a basic understanding about plant structures, but less about their functions. Compared to these emerging abilities to recognize observable structures and associate them with the correct functions, kindergarteners seem to have more difficulties in recognizing the structural and functional relationships of biological processes that they cannot see. This became apparent in the study of Ahi (2017), which focused on children's understanding of the digestive system. That is, this study assessed children's knowledge of the structural und functional relationships of a biological process that they know from their everyday lives but cannot observe directly. Participants were provided with a pencil and an illustration of the outer lines of a human body. During a one-on-one interview with a think-aloud protocol, they were required to draw on the human figure the path that food follows, and the interviewer asked them about the organs they drew and the functions they fulfill.

Together, the results of all these studies indicate that preschool children possess and can develop a basic understanding of structural and functional relationships that can be directly observed, e.g. children can perceive how an animal opens and closes its mouth to eat, but have more difficulties regarding those cases in which the function cannot be derived from the structure through direct observation, e.g. children cannot deduce purely from observation that leaves are responsible for gas exchange or the intestines for nutrient absorption.

The instruments presented above, although useful for the measurement of children's conceptual knowledge of structure and function, entail three main limitations. First, they are limited to specific contents, such as plants or the digestive system. Second, they mostly require children to merely match structures with their functions and lack a systematic assessment of children's reasoning, thus lacking a focus on different cognitive processes. Third, they do not consider that test items have differing degrees of difficulty and therefore raw scores are not optimal to reliably assess children's conceptual knowledge. Thus, there is currently no instrument to assess preschoolers' knowledge of this concept that covers a wide range of organisms, requires children to not only match structures and functions but also to describe and explain which characteristics of a structure allow it to fulfil the given function, and takes into consideration the degrees of difficulty of different items.

1.1.3 This study

The focus of study 1 is to develop and evaluate an instrument to measure young children's knowledge of the concept of structure and function that tackles the limitations of existing instruments. Based on the theoretical frameworks described above, children's conceptual knowledge of structure and function shall be differentiated in two dimensions, representing two different cognitive processes. The first dimension refers to children's ability to match different biological structures with the functions they serve, and thus it represents the cognitive process labeled *recognize*. The second dimension refers to children's ability to describe and explain which specific characteristics of the structures allow them to fulfill their functions, and therefore it represents the cognitive process called *explain*. The measurement of these two dimensions is achieved through a two-tier item structure. The development of instruments that consist of two-tier items is a common approach to assess students' knowledge as well as their reasoning behind it (Treagust, 1988). In such instruments, the 1^{st} tier requires respondents to answer a multiple-choice or true/false content knowledge question, and then in the 2^{nd} tier they must justify their 1^{st}-tier answer by either giving an open response or choosing out of a multiple-choice set of reasons the one that most resembles their own (Liu, Lee, & Linn, 2011; Treagust, 1988; Treagust & Mann, 1998). These justifications reveal the degree to which respondents' reasoning is based on a conceptual understanding of the topic that is being addressed. Several studies have implemented two-tier instruments to assess students' knowledge of a wide range of scientific concepts. For example, Haslam and Treagust (1987) assessed students' understanding of photosynthesis and respiration in plants using a 13 two-tier item instrument, Treagust and Mann (1998) developed a 12 two-tier item instrument focused on students' knowledge about breathing, gas exchange and respiration, and Lin (2004) implemented a 13 two-tier item instrument to measure students' conceptual knowledge of plant growth and development.

1.2 Materials and Methods

1.2.1 Data collection

The data presented here was collected within the framework of study 2, which focuses on the effects of an inquiry-based learning activity on children's conceptual knowledge (see chapter 2). The sample consists of 59 preschool children with an average age of 6 years and 3 months (SD = 0.44). Two forms of the test were developed and used as the pre- and the post-tests. Originally, the pre-test contained thirteen items, and the post-test consisted of twelve, of which four were identical. Five of these 21 questions were not considered for the final analysis, given that during the coding procedure it became clear that either children did not understand the question correctly or the options provided led to inconclusive answers. Therefore, the analysis was conducted on nine items of the pre-test and ten items of the post-test, of which three were identical.

The instrument is conceived as a one-on-one interview. Thus, for the implementation of the pre- and the post-tests, the interviewers were provided with a document containing the script for each question and a space to mark children's response to the 1st-tier questions, as well as the drawings that complement each item. They memorized the script beforehand to give an authentic feeling of casual conversation while ensuring that the questions are formulated in the same way with all the interviewees. Further, the interactions were recorded on audio, so that the notetaking could be held to a minimum. This way, children's answers to the 1st-tier questions were documented during the interview, while their open responses to the 2nd-tier questions were transcribed and categorized afterwards.

1.2.2 Instrument development

Pilot version of the instrument

A first version of this instrument was implemented with 74 preschoolers, 32 1st grade and 46 2nd grade children. This version consisted of some of the questions contained in the final item pool presented here, as well as other questions that were excluded in the process. Although the initial and the final versions of the instrument contain important differences, the pilot version allowed for three valuable insights. First, it functioned as a general assessment of the instrument's feasibility regarding the type of interview, the two-tier question structure, and the duration of the test. Second, the data collected shed light into children's level of conceptual knowledge. On one hand, this informed the level of difficulty necessary for this instrument. On the other, children's answers to the 2^{nd}-tier questions were the basis to determine the coding and categorization used in the final implementation of the instrument. Third, the data collected with kindergarteners, 1^{st}- and 2^{nd}-graders gave an indication of predictive validity. Figure 1.1 shows the average percentage of correctly answered items in the 1^{st} and the 2^{nd} tier in each group. As can be seen, there is an improvement in both tier answers towards the 2^{nd} grade, especially in the 2^{nd} tier. These insights were taken into consideration when developing the new item pool that will be presented below.

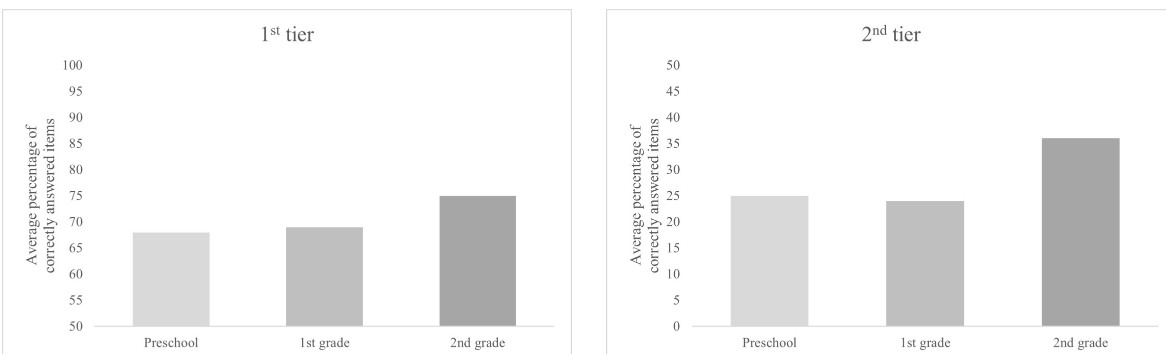


Figure 1.1: Average percentage of items answered correctly by preschoolers, 1^{st} graders, and 2^{nd} graders in the 1^{st} and 2^{nd} tier of the pilot version of the instrument

Instrument content

The instrument consists of questions that cover a wide range of organisms, including insects, plants, and specimens of the five classical groups of vertebrates, i.e. fish, amphibians, reptiles, birds, and mammals. Given the focus age group, the questions concentrated on animals and plants that are generally well known to young children, such as mice or squirrels. The functions relate mostly to four behaviors, that is eating, moving, sensing, and protecting. It could be expected that the relations between structures and functions depicted in the items were familiar to young children, like the way frogs use their hind legs to jump, or how the robustness of a turtle's shell allows it to protect itself from predators. Nevertheless, these relations could also be deduced based on the general principle behind structure and function, even if there was no previous familiarity with the specific example.

For instance, one question refers to the relation between the downturned mouth of a fish and its habit of eating things from the ground. Even though children may not know that some fish possess an epigynous mouth, they could make use of their conceptual knowledge to deduce the relation between a fish's mouth position and its eating habits. All questions are complemented with drawings in order to facilitate children's responses.

Table 1.1 contains a summary of the items of the final item pool, including the structural and functional relationships they represent and whether they were preset in the pre-test, the post-test, or both.

Table 1.1: Summary of the 16 items of the instrument

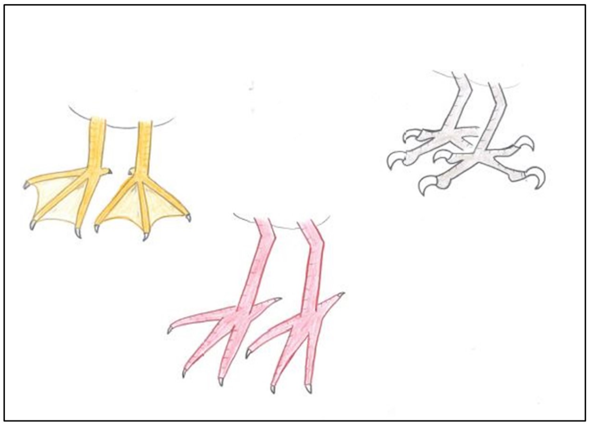
Item name	Relation between structure and function	Present in
Fish's mouth	Relation between the position of a fish's mouth and its ability to catch food from the ground	Pre-test
Duck's feet	Relation between a duck's webbed feet and its ability to swim	Pre-test
Big flower	Relation between the shape, colors and parts of the flower and their ability to attract insects, e.g. bees	Pre-test
Flying seed	Relation between the wing-shaped seed and its ability to fly away	Pre-test
Squirrel's house	Relation between the two entries of a squirrel's house and its ability to protect against predators	Pre-test
Mouse's tail	Relation between the length of a mouse's tail and its ability to balance	Pre-test
Mosquito's mouth	Relation between a mosquito's spiky mouth and its ability to go through skin and suck blood	Pre-test & Post-test (anchor)
Conifer needle	Relation between the wax layer on a conifer needle and its ability to protect against cold	Pre-test & Post-test (anchor)
Jump legs	Relation between the form of the hind legs of fleas, rabbits and kangaroos and the animals' ability to jump	Pre-test & Post-test (anchor)
Woodpecker's beak	Relation between the length of a woodpecker's beak and its ability to reach food behind the bark of a tree	Post-test
Dog's ears	Relation between the shape of a dog's ears and its ability to hear	Post-test
Frog's tongue	Relation between the length and stickiness of a frog's tongue and its ability to catch flies	Post-test
Tadpole's tail	Relation between the shape of a tadpole's tail and its ability to swim	Post-test
Rose's thorns	Relation between a rose's spiky thorns and their ability to protect against predators	Post-test
Mole's forefeet	Relation between a mole's claws and its ability to dig on the earth	Post-test
Turtle's shell	Relation between the hardness of a turtle's shell and its ability to protect itself	Post-test

Item structure

In this instrument, two dimensions of children's conceptual knowledge are distinguished, which portray two different cognitive processes. The first dimension portrays the cognitive process labelled *recognize*. It represents children's ability to match a biological structure with the function it serves, thus portraying their recognition of such relations. The second dimension represents the cognitive process called *explain*. It refers to children's reasoning with this knowledge, specifically their ability to describe and explain in a cause-effect manner which specific characteristics of a biological structure allows it to fulfil its function. This conceptualization is mirrored in the two-tier structure of the items. The 1st-tier questions require children to recognize structural and functional relations, whereas the 2nd-tier questions call for the explanation of these relations.

All 1st-tier questions are introduced following a similar format. Children are presented with the behaviour of an animal or a plant embedded in a familiar or interesting context. After this introduction, children are asked about a specific structural and functional relationship and asked to answer by choosing one out of three options. In some items, the function is given, and children are required to choose a structure. For example, in the item *Duck's feet*, the interviewer tells the children that they saw a bird swimming on the lake. In this case swimming represents the function that is given. Then, the interviewer presents the children with three different shapes of bird feet (see Figure 1.2) and asks them to choose which foot shape they think the bird on the lake would have. In other items, the structure is given, and children must choose a function. For instance, in the item *Turtle's shell*, the interviewer presents the picture of a turtle and draws attention to its shell, which represents the structure (see Figure 1.2). Then, the interviewer asks the children what they think the shell is good for and asks them to choose a function out of the options "find food, protect itself, or listen to sounds".

In the 2nd-tier questions, the children are asked to explain the reasoning behind their choice, independently of whether they selected the correct option in the 1st-tier question or not. Thus, the 1st-tier questions are constructed as multiple-choice items, whereas the 2nd-tier questions call for open answers, which are later categorized according to their content (see below).



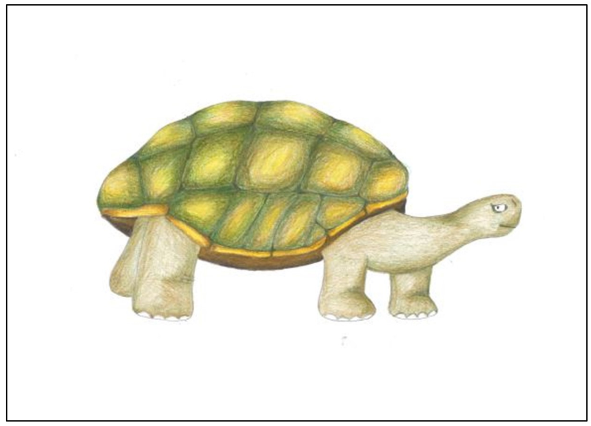


Figure 1.2: Pictures of the items *Duck's feet* (left) and *Turtle's shell* (right)

Coding and categorization

Regarding the 1st-tier multiple-choice answers, children receive 1 point if they select the correct option. For the coding of the 2nd-tier open answers, eight categories to which children's responses can be assigned were defined (see Table 1.2). These categories are based on the analysis of the data collected using a first version of this test (see above). The first three categories refer to answers in which children explain their reasoning by mentioning a relevant structure, function, or relation between them, whereas categories 4-7 represent statements in which children do not make use of their knowledge of structure and function to justify their selections. Further, one last category represented the cases in which children's selection in the 1st-tier answer is wrong, but children's explanations reveal a certain understanding of the relation between structure and function. In the implementation of this instrument, however, no child provided any answer that could be assigned to this last category.

Responses that belong to any of the first three categories receive 1 point, whereas answers corresponding to the other categories do not. In the case of the item *Duck's feet*, for example, answers such as "because these feet are webbed" are coded in the category 1 and thus score 1 point, whereas answers such as "because yellow is my favourite colour" are coded in the category 6 and do not receive a point.

To ensure reliability regarding the categorization of children's answers to the 2nd-tier questions, two raters coded the responses of 11 children (17% of the total sample) in both pre- and post-tests. The analysis of interrater reliability showed very good values for both tests ($K = .87$, 95% CI [0.78, 0.97], $p < .001$ in the pre-test; $K = .75$, 95% CI [0.62, 0.89], $p < .001$ in the post-test).

Table 1.2: Coding categories for children's 2nd-tier responses

Category Nr.	Content of children's response
1	Structure
2	Function
3	Structure & Function
4	Previous experiences (e.g. seen it on TV)
5	Fantasy
6	No relation to question/ incomprehensible answer
7	No answer/ "Don't know"
8	Structure & Function but wrong 1st-tier answer

1.2.3 Instrument evaluation

The instrument evaluation was conducted using the Rasch analysis. This is a psychometric approach to evaluate the measurement functioning of an instrument and compute a latent variable, such as student's ability in a domain (Rasch, 1960). It takes into consideration that items vary in their degree of difficulty and thus it's not appropriate to merely add the raw scores of a test to assess and compare respondents' abilities. Instead, the Rasch technique transforms the raw scores into linear "person measures", which express the respondent's performance on a linear scale that accounts for the unequal item difficulties.

The Rasch approach also allows for the construction of alternative forms of the same instrument, which are composed by different sets of items. These alternative forms can be implemented with different respondents or at different time points, and after Rasch analysis, these varying sets of items can be combined to create an item pool that can be used for further measurements. Typically, this is achieved following three steps. First, different test forms that share a certain number of identical items, also called "anchor items", are developed and used for data collection. Second, Rasch analysis is conducted with the data of one form, resulting in the definition of the anchor items' difficulty values. Lastly, these values are purposeful specified in the Rasch analysis of the other test form's data, and the difficulty of the remaining items are computed accordingly. These steps allow for all respondents' measures, regardless of test form completed, to be expressed on the same scale. This approach can be implemented in a pre-post-test design, for example, to compare a respondent's measures before and after an intervention. In the last years, it has been used to evaluate several instruments in the field of biology education, such as the Middle School-Life Science Concept Inventory (Stammen, 2018), the Pedagogical Content Knowledge in Biology Inventory (Großschedl, Welter, & Harms, 2019), and a competence model of biology observation competency (Kohlhauf, Rutke, & Neuhaus, 2011).

Regarding the instrument presented here, two test forms were implemented, i.e. the pre-test and the post-test. As the interest of the analysis laid on the two different tiers, the two tiers were evaluated separately in each form, resulting in four different variables: the 1st tier of the pre-test (*pre-recognize*), the 2nd tier of the pre-test (*pre-explain*), the 1st tier of the post-test (*post-recognize*), and the 2nd tier of the post-test (*post-explain*). Rasch analysis was performed using the program Winsteps (J. Linacre, 2021b). The analysis was first conducted on the variables of the pre-test and then the computed item difficulty of the anchor items were used to conduct the Rasch analysis on the variables of the post-test. This way, it anchored the variables *pre-recognize* with *post-recognize*, and *pre-explain* with *post-explain*.

The Rasch technique provides several sources of evidence regarding an instrument's capacity to define a single trait (Boone, Staver, & Yale, 2013). In the following, the sources of evidence used in this study will be described.

Dimensionality

An important aspect of the Rasch analysis is to evaluate whether all items contribute to the useful measurement of a single trait, that is, whether the items fit the Rasch model (Boone et al., 2013). This is achieved by reviewing the infit and outfit mean-square values of each item (MNSQ Infit and MNSQ Outfit). Mean-square values range from 0 to infinity, whereas the ideal values are close to 1. In small sample sizes, as is the case in this study, MNSQ values within the range of 0.5-1.5 are considered satisfactory (J. M. Linacre, 2002; Wright, Linacre, Gustafson, & Martin-Löf, 1994). Another source of evidence regarding dimensionality is the number of computational iterations when running the Rasch software that are necessary for obtaining good estimates from the data, as a high number reflects a poor fit of the model (J. Linacre, 2021a).

Item and person reliability

The Rasch technique provides values of item and person reliability. These range from 0 to 1, with values closer to 1 indicating a higher reliability. Item reliability is influenced by the variance of item difficulty and the person sample size, whereas person reliability depends on the variance of sample ability, the length of the test, the number of categories per item and the sample-item targeting (Moeini, Rasmussen, Klausen, & Brorson, 2016). Item reliability is considered satisfactory with values of .90 or higher, whereas person reliability is considered satisfactory with values of .80 or higher (Malec et al., 2007). It is important to highlight that these values are not to be compared with Cronbach's alpha values, as they are computed using Rasch item and person measures (Boone et al., 2013).

Step ordering

Another aspect that informs about instrument functioning is the evaluation of respondents' performance as a function of the item answer alternatives. The idea behind it is that the average measure of respondents who answered an item correctly should always be higher than the average measure of those who did not answer correctly.

Wright maps

Wright maps are used to visualize the results of a Rasch analysis by depicting the items and the respondents on the same linear measurement scale, given that both the item difficulties and the person measures are computed using the same unit called "logits" (Boone, 2016). The vertical line of a Wright map represents the single trait that is measured. To the right side of the line, each item is positioned according to its level of difficulty, with easier items plotted at the bottom and harder items plotted at the top. The "M" at the right side represents the average difficulty of all items. To the left side, each respondent is positioned according to their ability level, so that respondents with low ability are found on the bottom, and those with high ability on the top. In this side, the "M" depicts the average person measure of all respondents. The visualization of both item difficulties and person measures along the same scale reveals the probability of a given respondent correctly answering each item. That is, a respondent has a higher probability of correctly answering items with difficulty level below their person ability level than those items with difficulty levels above their ability level.

One aspect that can be reviewed using Wright maps is the range of item difficulty in relation to the range of person ability. Another aspect to be analysed is the test item targeting. Item targeting represents the distance between the mean item difficulty ("M" on the right side) and the mean person ability ("M" on the left side). This distance helps determine whether the item difficulty is appropriate for a given group of respondents, that is, whether the items are too easy or too difficult for the sample. As a rule of thumb, the two mean values should be within 1 logit of distance from each other (Finger et al., 2012).

When anchor items are used, Wright maps can present items from alternative forms along one single linear scale. By doing this, the difficulty level of all items can be examined together and as a result, an optimal item pool can be created. A good instrument should include items that cover different difficulty levels of the trait to be measured (Boone, 2016). That is, the distance between items should be similar and reveal as few gaps as possible.

Anchor quality

When different test forms are being implemented it is important to assess the anchor quality in terms of four considerations: The number of the anchor items (ideally, different test forms should be linked by a great number of items); the distribution of the anchor item locations along the difficulty scale (ideally, they should cover different difficulty levels); the certainty of the anchors' item measures, which depends on the sample size; and the drift of the anchor items, i.e. how much the location of the anchor items changes across test forms.

Additionally, the correlation between children's conceptual knowledge and their language ability was evaluated. The data on children's language skills was collected through a questionnaire that was completed by preschool teachers based on their every-day observations of the children (see section 2.3.3). The questionnaire consisted of the section "speaking and comprehension" of the KOMPIK Observation Form (Mayr, Krause, & Bauer, 2011), which includes items such as "The child answers questions appropriately regarding the content" and "The child actively participates in group conversations and discussions", and was rated using a 5-point Likert scale ranging from one (strongly disagree) to five (strongly agree).

1.3 Results

1.3.1 Dimensionality

Table 1.3 displays the MNSQ Item Infit and Outfit values of each item and the mean values for each of the variables. All values are located within the range of .5-1.5, and the mean values of all four variables are very close to 1, which indicates a good model fit.

Table 1.3: MNSQ Infit and Outfit for each item of the variables *pre-recognize*, *pre-explain*, *post-recognize* and *post-explain*

	Pre-recognize		Pre-explain	
Item	MNSQ Infit	MNSQ Outfit	MNSQ Infit	MNSQ Outfit
Fish's mouth	1.17	1.42	1.09	1.01
Duck's feet	0.83	0.71	0.90	0.84
Fly's mouth	0.94	0.81	1.14	1.07
Big flower	0.95	0.91	0.85	1.15
Flying seed	1.09	1.41	0.98	0.94
Conifer needle	1.02	1.08	0.94	0.80
Squirrel's house	0.94	0.86	0.84	0.59
Mouse's tail	0.92	1.01	1.04	0.53
Jump legs	1.02	1.02	1.27	1.47
Mean	0.99	1.03	1.01	0.93

	Post-recognize		Post-explain	
Item	MNSQ Infit	MNSQ Outfit	MNSQ Infit	MNSQ Outfit
Woodpecker's beak	1.04	1.26	1.16	1.22
Dog's ears	0.93	0.85	0.97	0.80
Jump legs	1.05	1.15	0.91	0.87
Long tongue	0.90	0.60	0.93	0.89
Tadpole's tail	1.00	1.25	0.92	0.94
Conifer needle	0.92	0.86	0.79	0.71
Rose's thorns	1.16	1.26	1.02	1.24
Mole's forefeet	1.01	0.95	0.96	0.86
Fly's mouth	0.97	0.96	0.95	0.84
Turtle's shell	0.91	0.76	1.14	1.28
Mean	0.99	0.99	0.98	0.97

Further, the number of iterations for all four variables were within an acceptable range (W. Boone, personal communication, August 16, 2021): 4 iterations for the variable *pre-recognize*, 6 iterations for *pre-explain*, 3 iterations for *post-recognize*, and 12 iterations for *post-explain*.

1.3.2 Item and Person reliability

Table 1.4 shows the item and person reliability for each of the four variables. All variables show an item reliability higher than .80, which indicates that our instrument possesses a high variance in item difficulty. On the other hand, the person reliabilities show rather low values.

Table 1.4: Item and person reliability for the variables *pre-recognize*, *pre-explain*, *post-recognize* and *post-explain*

	Item reliability	Person reliability
Pre-recognize	.92	.41
Pre-explain	.81	.13
Post-recognize	.91	.59
Post-explain	.83	.66

1.3.3 Step Ordering

In all four variables of this instrument, the average measure of respondents who answered an item correctly was always higher than the average measure of those who did not answer correctly, as can be seen in Table 1.5.

Table 1.5: Average ability of respondents who answered incorrectly and correctly each item of the variables *pre-recognize*, *pre-explain*, *post-recognize* and *post-explain*

	Pre-recognize		Pre-explain	
	Average ability of respondents who answered...		Average ability of respondents who answered...	
Item	...incorrectly	...correctly	...incorrectly	...correctly
Fish's mouth	0.50	1.38	-1.50	0.50
Duck's feet	-0.24	1.33	-1.98	0.32
Fly's mouth	-0.19	1.21	-2.07	-0.03
Big flower	-0.50	0.92	-2.54	-0.05
Flying seed	0.03	1.04	-2.13	0.09
Conifer needle	0.28	1.45	-1.74	0.51
Squirrel's house	0.37	1.73	-1.50	1.02
Mouse's tail	0.12	1.45	-1.22	1.25
Jump legs	-0.15	1.06	-1.58	0.08

	Post-recognize		Post-explain	
	Average ability of respondents who answered...		Average ability of respondents who answered...	
Item	...incorrectly	...correctly	...incorrectly	...correctly
Woodpecker's beak	-0.02	1.30	-2.69	-0.11
Dog's ears	-0.32	1.75	-2.11	0.25
Jump legs	-0.29	1.61	-1.33	0.86
Long tongue	-0.78	1.37	-2.17	0.22
Tadpole's tail	-0.25	1.43	-1.80	0.43
Conifer needle	-0.04	2.21	-1.49	0.91
Rose's thorns	-0.01	1.61	-1.98	0.18
Mole's forefeet	-0.31	1.37	-2.52	0.06
Fly's mouth	-0.24	1.64	-2.12	0.19
Turtle's shell	-0.48	1.57	-1.92	0.10

1.3.4 Wright map

Figures 1.3 and 1.4 present the Wright maps of the four variables of the instrument. Regarding the range of item difficulty in relation to the range of person ability, the Wright maps depicted in Figures 1.3 and 1.4 reveal that there is a good overlap between the two scales, although there is a certain ceiling effect of the person measures in the variables *post-recognize* and *post-explain*.

As stated before, the test item targeting represents the difference between the mean item difficulty and the mean person ability. Figures 1.3 and 1.4 shows that in the variables *pre-recognize*, *pre-explain*, and *post-explain*, the two mean values are within 1 logit of distance from each other. In the case of *post-recognize*, the distance is slightly higher than 1. These results indicate that the items of this instrument have a difficulty level that is appropriate for preschool children.

The data was anchored according to the tiers, i.e. *pre-recognize* with *post-recognize*, and *pre-explain* with *post-explain*. Figure 1.5 shows the item difficulty scale with all items together regarding the 1st tier (*recognize*) on the left side and the 2nd tier (*explain*) on the right side. This figure therefore show which items were easier and which were harder to solve in each of the tiers. The anchor items are marked in dark grey (for more on anchor quality, see below). As stated before, the distance between all items should be similar and reveal no gaps or overlaps. An evaluation of these scales reveals that the items of this item pool mark different locations and have rather similar distances between each other, although some gaps and overlaps can be observed. In the scale of the 1st tier, for example, the items *Big flower* and *Long tongue* cover the same point along the difficulty continuum, and a small gap can be found between *Mouse's tail* and *Duck's feet*. Regarding the scale of the 2nd tier, there is an overlap in the items *Dog's ears* and *Rose's thorns* as well as in the items *Turtle's shell* and *Long tongue*, which is aggravated by the fact that these two sets of items are positioned next to each other. Further, a gap can be found in the upper end of the continuum between *Mouse's tail* and *Squirrel's house*. Apart from these few exceptions, Figure 1.5 indicates that the item pool is appropriate to cover the different levels of difficulty in both tiers.

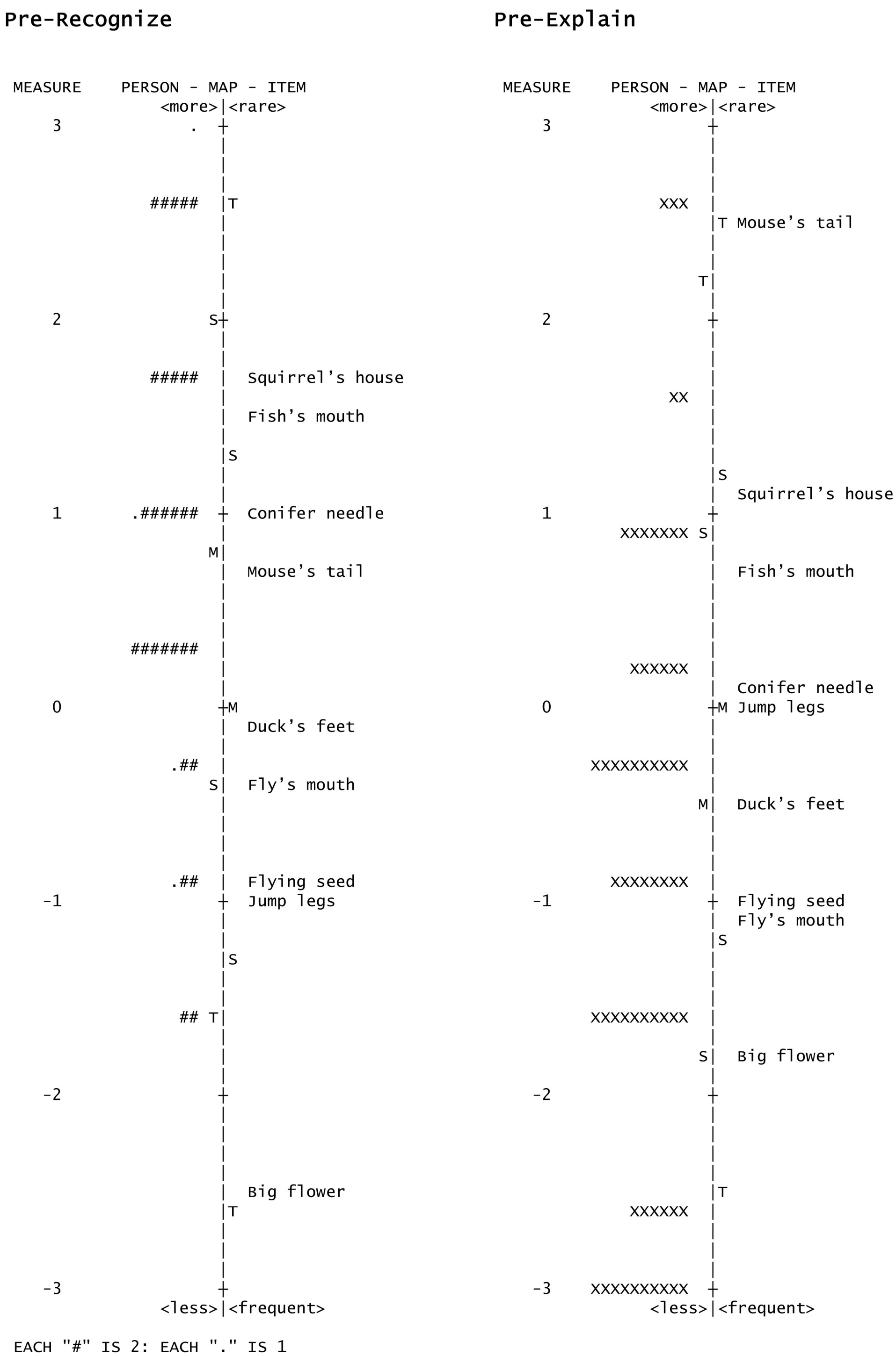


Figure 1.3: Wright maps of the variables *pre-recognize* (left) and *pre-explain* (right)

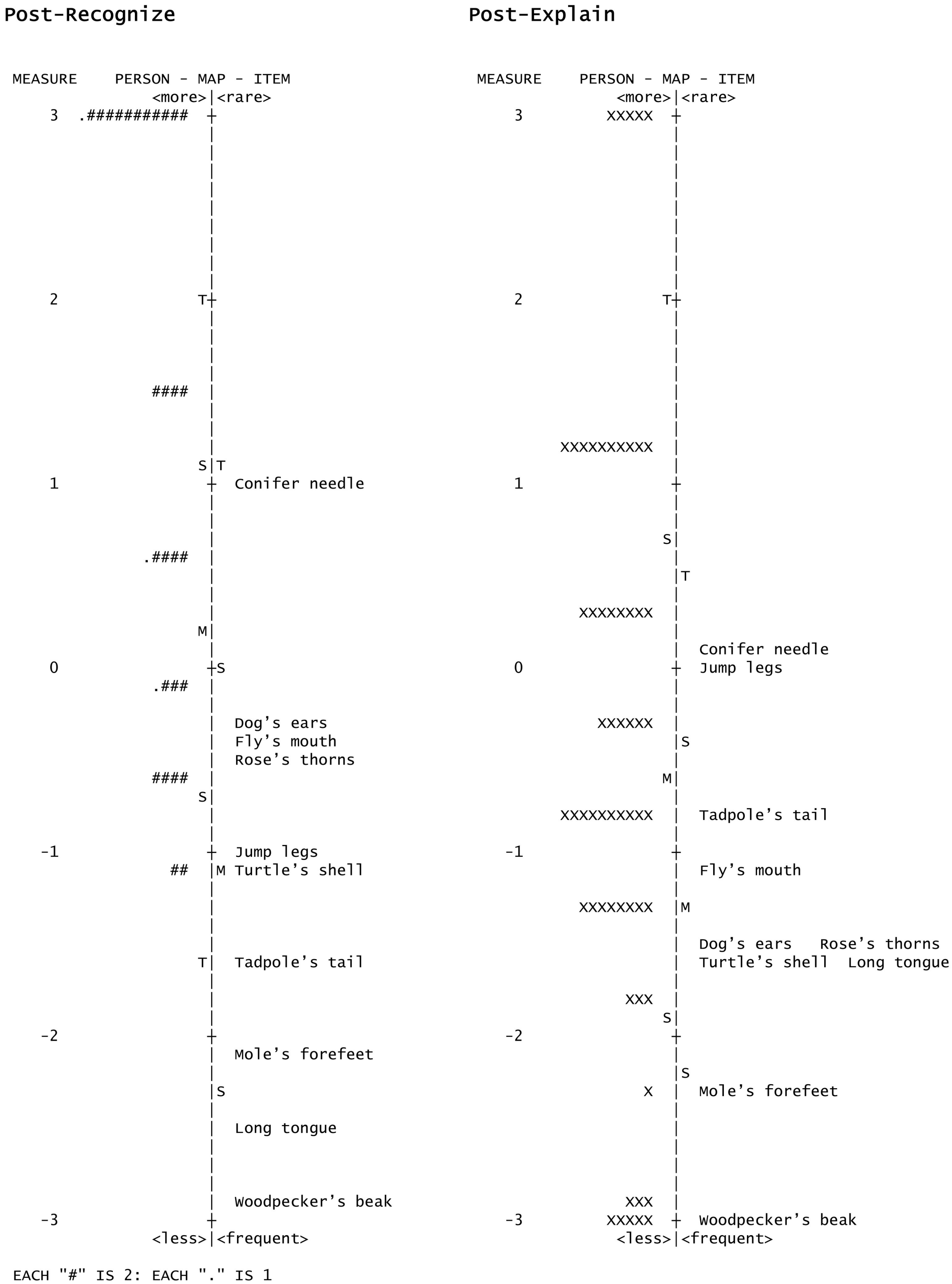


Figure 1.4: Wright maps of the variables *post-recognize* (left) and *post-explain* (right)

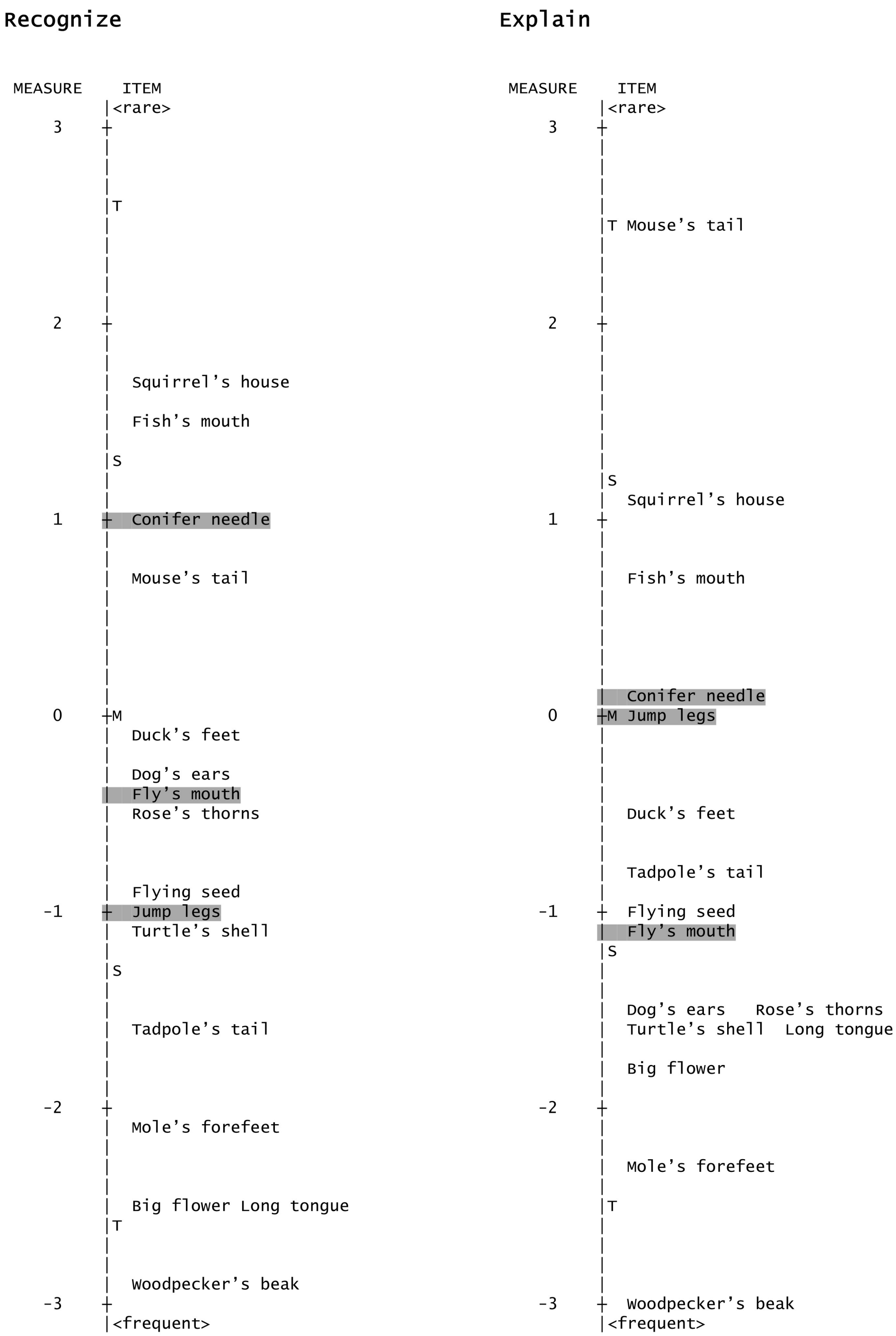


Figure 1.5: Item difficulty scales of the 1st tier Recognize (all items of *pre-recognize* and *post-recognize* combined) and the 2nd tier Explain (all items of *pre-explain* and *post-explain* combined)

Given that the tiers are linked with each other, an important step was to assess the difficulty of the items as the combination of their difficulty level in both tiers. This is visualized in Figure 1.6. Items are positioned along a two-axis coordinate system, with the x-axis representing the item difficulty in the 1st tier (*recognize*) and the y-axis depicting the item difficulty in the 2nd tier (*explain*). As can be seen here, there is a clear correlation between the item difficulty levels in the two tiers. Upon closer inspection it becomes clear that this item pool consists of three sets of items that differ in their difficulty level in both *recognize* and *explain*: a set of four easier items (*Woodpecker's beak*, *Mole's forefeet*, *Big flower*, and *Long tongue*), a set of four harder items (*Conifer needle*, *Fish's mouth*, *Squirrel's house* and *Mouse's tail*), and a set of eight items that are of medium difficulty (*Tadpole's tail*, *Turtle's shell*, *Flying seed*, *Jump legs*, *Rose's thorns*, *Dog's ears*, *Fly's mouth*, and *Duck's feet*).

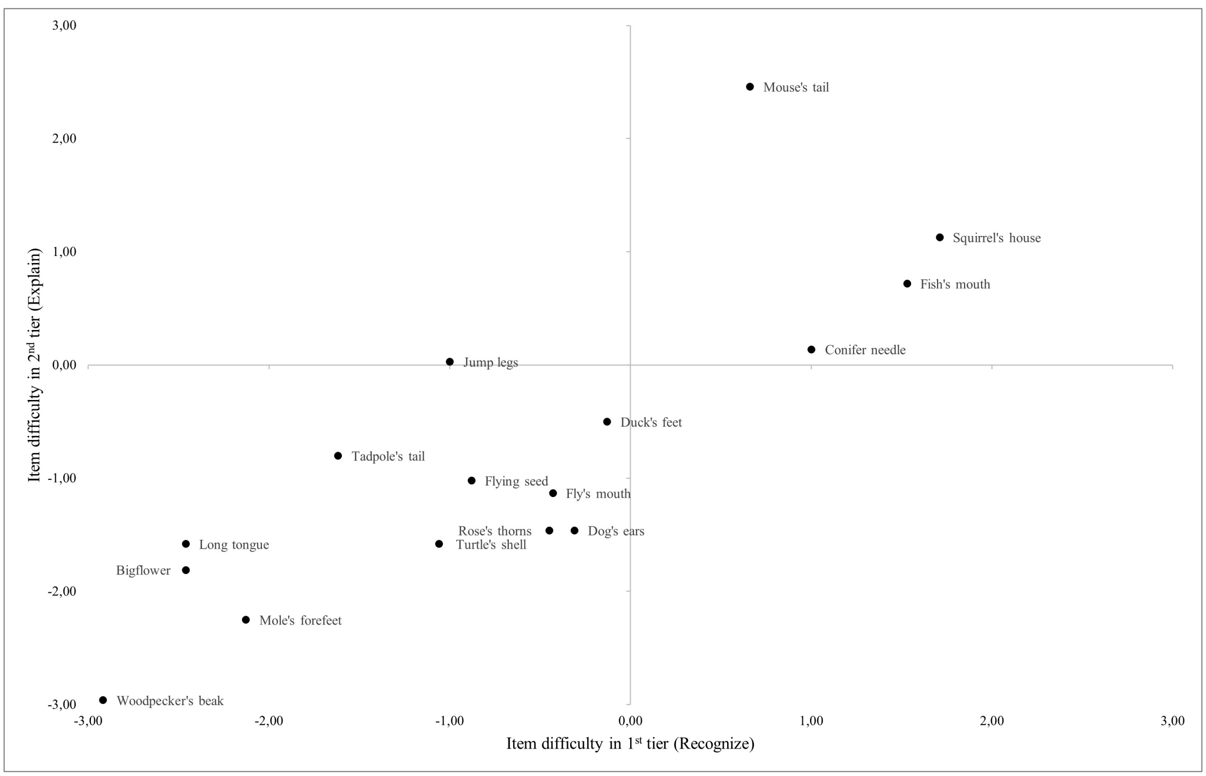


Figure 1.6: Two-axis coordinate system displaying all 16 items of the instrument according to their difficulty level in the 1st tier (x-axis) and 2nd tier (y-axis), with a clear correlation between the two axes

1.3.5 Anchor quality

Figure 1.5 also helps in assessing the quality of the anchor items. This shows a suboptimal distribution of the anchor items along the difficulty scale, both in the *recognize* and in the *explain* variables. The drift of the anchor items was assessed following the recommendations of Boone and Staver (2020, p. 173ff). According to J. Linacre (2021a), the difference between the item difficulty of each anchor item in one test form (corrected with the equating constant) and that in another test form should not be higher than 0.5 logit units. Table 1.6 shows for each anchor item the difference between the item difficulty in the pretest and the item difficulty in the post-test (corrected with the equating constant), in both *recognize* and *explain*. It demonstrates that in three of the six cases, the difference was not higher than 0.5 logit units.

With only three anchor items, an unequal distribution, a low degree of certainty due to a small sample size, and a large drift in three out of six cases, the anchor quality is unfortunately suboptimal to reliably assess changes in participants' performance across different test administrations (from pre- to post-test).

1.3.6 Correlation with language ability

Given the importance of language in the development of conceptual knowledge (Lemke, 1990), the evaluation of the instrument included calculating the correlation between the four variables and the respondent's language ability. As expected, there was a significant but not total correlation, as all values were below .65 (see Table 1.7). This indicates that this instrument is not merely capturing children's linguistic skills but is in fact assessing the different cognitive processes within their conceptual knowledge.

Table 1.6: Difference between the item difficulty of the anchor items in the pretest and the item difficulty of the anchor items in the post-test (corrected with the equating constant)

Anchor item	Recognize Item difficulty difference between pre-recognize and post-recognize	Explain Item difficulty difference between pre-explain and post-explain
Fly's mouth	0.26	0.51
Conifer needle	2.09	0.09
Jump legs	1.84	0.43

Table 1.7: Correlation between language ability and the variables *pre-recognize*, *pre-explain*, *post-recognize*, and *post-explain*

	Language ability
Pre-recognize	.57**
Pre-explain	.56**
Post-recognize	.56**
Post-explain	.62**

**$p < .01$

1.4 Discussion

Even before starting school, children possess basic ideas about diverse scientific concepts. These basic ideas are the starting point and prerequisite for further learning, as they represent the knowledge base upon which conceptual development and reconstruction takes place. Therefore, the correct assessment of children's level of conceptual knowledge as reflected by different cognitive processes is of great importance in the field of early science education.

The development and evaluation of an instrument that measures young children's knowledge of the biological concept of structure and function was presented here. The wide range of content, the assessment of two different cognitive processes, and the implementation of the Rasch technique represent the three benefits of this instrument in comparison to current assessment tools for preschool children that can be found in the literature (Ahi, 2017; J. L. Anderson et al., 2014; Samarapungavan et al., 2008, 2011). The content of the items covers a wide range of organisms, including plants, insects and various vertebrates. Through the two-tier item structure, it assesses two different cognitive processes within children's conceptual knowledge, i.e. their ability to match structures and functions (cognitive process called *recognize*), and their ability to explain these relationships in a logical manner (cognitive process labelled *explain*). To the best of my knowledge, this is the first instrument that makes use of a two-tier item structure to assess preschool children's reasoning behind their understanding of a scientific concept.

The results of the Rasch analysis demonstrate that the items are appropriate for assessing young children's conceptual knowledge, although the instrument revealed certain limitations that will be described in the following. How these limitations can be tackled in future implementations will be described in Part V.

The analysis of dimensionality revealed that all mean square values were within the acceptable range for small sample sizes and that the number of iterations required for all variables was within an acceptable range; all of this indicating that the data fits the model in a satisfactory way. All four variables analysed had an item reliability above .80, which is close to the value recommended by Malec et al. (2007). In contrast, the person reliabilities showed rather low values. As stated by Moeini et al. (2016), person reliability depends on the variance of sample ability, the length of the test, the number of categories per item and the sample-item targeting. The analysis demonstrated that the instrument shows a rather wide sample ability range and acceptable sample item targeting. Therefore, the low person ability values found here are presumably more related to the other two factors. Certainly, as the items are coded dichotomously in each tier, the number of categories per item in this instrument is inevitably low. The test forms that were used in this study consisted of 9 and 10 questions each, which could be considered rather too few items to provide high person reliabilities. This, however, was due to time constraints as these very young children had to be tested for a number of other traits and could therefore not be managed differently in the present study. In general, however, the high values of the item reliabilities still indicate that this instrument can reliably assess children's conceptual knowledge of structure and function. In addition, the evaluation of step ordering demonstrated the expected pattern in all items, as the average person measure of respondents that answered each item correctly was higher than the average of respondents that answered incorrectly.

The Wright maps allowed for further evaluation of the instrument functioning. The comparison between the range of item difficulty and that of person measures showed an acceptable coverage, and the test item targeting revealed that the items were neither too easy nor too difficult for the respondent's age group. The evaluation of the position of the items along the difficulty scale in each tier revealed a good distancing between the items despite the few exceptions stated above. Further, the results of the Rasch analysis allowed for the construction of a two-axis coordinate system, in which items are positioned according to the combination of their difficulty level in the 1st tier (*recognize*) and the 2nd tier (*explain*), with a clear correlation between the two axes.

This instrument allows for the assessment of young children's knowledge of the concept of structure and function as reflected by the cognitive processes *recognize* and *explain*. The wide range of person measures in both tiers demonstrate that there is a wide distribution in preschool-aged children's ability to match structures and functions (*recognize*), and to explain these relationships in a logical, concept-based manner (*explain*). Even though these cognitive processes represent discrete abilities, they also are inherently related to each other, as can be seen in the clear correlation between the two tiers in the two-axis representation of the item pool. The wide distribution can be partly explained by children's linguistic abilities, as a certain level of receptive and expressive language skills is necessary for participating in the communicative processes and social interactions in which learning often takes place (Akerson et al., 2000; Van Boxtel et al., 2000; Lemke, 1990; Vygotsky, 1978).

An important limitation of this instrument implementation lies on the rather low anchor quality, as revealed by the number, distribution, certainty, and drift of the anchor items. The limited availability of preschool groups for this study as well as the time constraints while testing young children did not allow for a bigger sample size or a higher amount of items in general. Consequently, there was not much room to include more anchors and, due to this, it was not possible to exclude malfunctioning items in order to improve the anchoring, as would be done in an optimal situation (Boone & Staver, 2020). Even though the items themselves seem to be effective in assessing children's knowledge of structure and function, the two forms used in this study cannot be considered optimal for identifying changes across different test administrations. Therefore, the results that will be presented in chapter 2 regarding preschool children's changes from pre- to post-test should be considered tentative.

Chapter 2

Study 2

2.1 Theoretical background

One of the most important goals of early science education is to foster children's development of a *basic* conceptual knowledge, i.e. an initial understanding of the scientific concepts they encounter in their everyday lives (Möller & Steffensky, 2010). This does not mean that children should completely transform their naïve conceptions into fully correct scientific knowledge, nor that they should learn in preschool what they are supposed to be taught at school. Rather, the idea behind this educational goal is for children to acquire an initial understanding of certain concepts that helps them make sense of the world around them and that can be built upon in later learning opportunities (Gelman & Brenneman, 2004; Möller & Steffensky, 2010; Samarapungavan et al., 2011; Steffensky, 2017). This basic conceptual understanding thus serves as an initial network of knowledge in which newly acquired knowledge elements can be integrated, for example after encounters with unfamiliar phenomena and later in science lessons at primary school.

Children's learning of concepts, however, is not the only important outcome of science education in preschool. Researchers and practitioners in the field argue that children's positive experiences with science are a valuable educational goal in and of themselves, independently of their knowledge gains. Andersson and Gullberg (2014), for example, analysed qualitatively the outcomes of a science activity on the topic of floating and sinking from two perspectives: focusing on children's development of conceptual understanding on one hand, and on their feelings of participation in a scientific context on the other. They concluded that, even though children did not gain conceptual knowledge, their participation in a scientific activity was still beneficial because it allowed them to engage as active agents in their own learning process.

In light of these educational goals, the question rises as to which instructional strategy and type of guidance are adequate and beneficial for preschool children. In the last years, practical recommendations for preschool teaching increasingly depict the inquiry-based science education approach as an appropriate strategy to engage preschool children with science (Eshach & Fried, 2005; Gerde et al., 2013). This is mainly based on the large body of research demonstrating the positive influence of this approach on older students (Alfieri et al., 2011; J. L. Anderson et al., 2014; Furtak, Seidel, et al., 2012; Lazonder & Harmsen, 2016; Minner et al., 2010). In the context of preschool, however, there is a scarcity of studies analysing its impact on preschoolers' learning experiences and outcomes and the ways in which the former influences the latter.

In the following, I will characterize conceptual knowledge and explore the biological concept of structure and function as an appropriate learning content for preschool children. Further, I will describe Laevers' construct of involvement for the quantitative assessment of preschoolers' experiences during a learning activity, and his experiential education (EXE) model as a framework to investigate the mediating effect of involvement on children's conceptual learning. Afterwards, I will characterize the inquiry-based approach within the context of preschool education and explore previous research on the effect of this instructional strategy on young children's acquisition of conceptual knowledge and their learning experiences.

2.1.1 Conceptual knowledge

De Jong and Ferguson-Hessler (1996) define conceptual knowledge as the "knowledge about facts, concepts and principles that apply within a certain domain" (p. 107). Within Bloom's revised taxonomy, conceptual knowledge is defined as the knowledge about interrelationships among specific facts or basic elements within a discipline, including the knowledge of principles and generalizations (Krathwohl, 2002). Based on Bloom's revised taxonomy and the knowledge matrix of De Jong and Ferguson-Hessler (1996), Förtsch et al. (2018) define conceptual knowledge as the knowledge about general principles and relations between single facts or elements within a specific domain, which is reflected in a person's ability to explain relationships, transfer and apply them to other contexts (Förtsch et al., 2018). Further, Krathwohl (2002) defines six cognitive processes that describe the range of cognitive activities in which a person can engage with this knowledge. In this study, the focus lies on the first two. The first process called *remember* refers to retrieving knowledge from long-term memory and includes the process called *recognize*, which involves identifying knowledge consistent to a given information. The second process called *understand* refers to constructing meaning and integrating new knowledge elements into already present mental schemas, and includes the process called *explain*, which involves expressing the meaning of a phenomenon by constructing and using a cause-effect model (Mayer, 2002).

In this study, Förtsch et al.'s (2018) definition of conceptual knowledge is adopted, as it is an integration of the different theoretical frameworks described above. Further, for the purpose of this study, the focus lies on how children's conceptual knowledge is reflected in the two cognitive processes *recognize* and *explain*.

Preschoolers' conceptual knowledge in biology

A domain that seems naturally appropriate for preschool children is the field of life sciences. Throughout their everyday life, young children gather various experiences with animals, plants, and processes in the human body, which allow them to slowly develop biological concepts even before starting school (Halldén & Caravita, 1994; Ghazali-Mohammed, 2016; Inagaki, 1990). As developmental research suggests, these concepts are the basis for children's emerging abilities to categorize living things, reason causally and make predictions about biological phenomena (Inagaki, 1990; Inagaki & Hatano, 2004).

In the domain of life sciences, one important concept is that of structure and function (Kultusministerkonferenz, 2004). This concept represents the relation that exists between the structures of an organism and the functions they fulfil (Kultusministerkonferenz, 2004; Standards, 2013), e.g. the relation between a bird's beak form and its eating habits, or between the distinctively shaped elements of a mammal's ear and their role in the hearing process. According to the German National Education Standards for the subject biology, students' knowledge of this concept is reflected in their ability to describe, compare and explain structural and functional relationships within different organisational levels, ranging from cells to ecosystems (Kultusministerkonferenz, 2004). Science education standards across the world designate this concept as one of the disciplinary core ideas that must be integrated in biology instruction, given that a concept-based science instruction is considered an important strategy to foster cumulative learning and the development of interconnected conceptual knowledge (Kultusministerkonferenz, 2004; Standards, 2013).

The concept of structure and function is especially important in early science education (Steffensky, 2017). Children's everyday contact with living organisms gives them plenty of opportunities to observe a variety of concrete examples of this relation (Staatsinstitut für Frühpädagogik München, 2006). They can observe, for example, that not only humans but also dogs, cats, fish and other pets use their mouths to eat, or that both turtles and snails use their shells to protect themselves. Further, a basic understanding of this relation is an important condition to understand more complex biological principles, such as the adaptation of animals and plants to different environments and their growth and development (Samarapungavan et al., 2008; Steffensky, 2017). Because of this, the biological concept of structure and function is considered an appropriate focus for engaging preschool children with scientific learning activities.

In light of this and based on the definitions of conceptual knowledge described above, in this study children's knowledge of the concept of structure and function is characterized as consisting of two dimensions, which represent two different cognitive processes. The first dimension represents the cognitive process called *recognize*; it reflects children's ability to match biological structures with their respective functions. The second dimension represents the cognitive process called *explain*; it reflects children's ability to describe and explain how the features of a specific biological structure allows it to fulfill its function.

2.1.2 Involvement

One approach to characterize young children's learning experiences is the "experiential education model" or "Belgian model", developed by Prof. Ferre Laevers for the identification of quality indicators in early childhood care and education (Laevers, 2000, 2003; Mayr & Ulich, 2003). The main premise of this approach states that the effects of an educational context, e.g. a science learning situation in preschool, shall be assessed not only through the observed outcomes, but also through children's learning experience. The latter is characterized by children's level of emotional well-being, i.e. "the degree to which children feel at ease, act spontaneously, and show vitality and self-confidence" (Laevers, 2000, p. 24), and involvement, i.e. a state of intense mental activity characterized by deep concentration, persistence in the task, and a feeling of satisfaction rooted in the fulfilment of one's exploratory drive (Laevers, 1993, 2003). According to Laevers' experiential education model, these indicators are believed to mediate the effect of the educational context on the learning outcomes (Laevers, 2000). In this study, the focus lies on the concept of involvement.

Involvement is related to the constructs of "flow" and intrinsic motivation (Laevers, 1993; Csikszentmihalyi & Csikszentmihalyi, 1992). Flow was first introduced to describe the state in which artists, athletes, and other professionals find themselves feeling completely absorbed in their respective activity, with such an intensity that their perception of time is distorted and feelings of hunger, fatigue or discomfort are disregarded, and can also be experienced by children during play situations (Laevers, 2003; Mayr & Ulich, 2003; Csikszentmihalyi & Csikszentmihalyi, 1992). Nakamura and Csikszentmihalyi (2009) describe flow as "the *subjective phenomenology* of intrinsically motivated activity" (p. 89). Intrinsic motivation is defined as "the inherent tendency to seek out novelty and challenges, to extend and exercise one's capacities, to explore, and to learn" (Ryan & Deci, 2000, p. 70). Both flow and intrinsic motivation stem from an individual's perception of an activity as rewarding in and of itself, independently from any external stimuli or beneficial consequences that may result from it (Mayr & Ulich, 2003; Nakamura & Csikszentmihalyi, 2009).

The concept of involvement is based on those of flow and intrinsic motivation, but can be distinguished from them by the fact that it does not only refer to an individual perception or tendency, but also to the expressed behaviour (Mayr & Ulich, 2003). As such, involvement can be identified and quantified through nine indicators of behaviour, which constitute the Leuven Involvement Scale: Concentration, i.e. the degree to which the child directs its attention to a specific task and cannot be distracted by external stimuli; energy, i.e. the physical expression of energy such as flushed cheeks when engaging in a physical activity; creativity, i.e. the degree to which the child draws on his or her own ideas for problem-solving; facial expressions, i.e. when the child's facial expression and general body language are directed towards the area in which the task is taking place; persistence, i.e. the degree to which the child is committed to remain focused on the task despite the difficulty; precision, which refers to the accuracy with which the action is carried out; reaction, i.e. the immediate readiness to, for example, follow instructions; verbal utterances, i.e. a child's verbal expressions of enthusiasm or the description of their own action; and general satisfaction with their learning process, expressed as positive or fascinated facial expressions or body posture (Laevers, Vandenbussche, Kog, & Depondt, 2009).

According to Laevers (2000), a person can only experience involvement when he or she is immersed in an activity in which the difficulty of the task appropriately matches their level of skill, that is, when the learning context falls within their “zone of proximal development” (Vygotsky, 1978). Thus, involvement is the result of the interaction between the learning context and the person’s characteristics (Laevers, 2000). Consequently, it is considered a fundamental condition for children’s development and learning (Laevers, 2000). Based on these considerations, Laevers developed the experiential education (EXE) model, also referred to as the deep-level-learning model (Klemm & Neuhaus, 2017). According to this model (see Figure 2.1), the characteristics of a learning context, such as the instructional approach, have an effect on children’s learning process, characterized by their experiences of involvement and their emotional well-being, which in turn influence the learning outcomes, such as the development of conceptual knowledge (Laevers, 2000, 2003).

Laevers’ construct of involvement and his EXE-model have been used in previous studies, for example to investigate gender-specific differences in children’s level of involvement in everyday situations at preschool (Mayr & Ulich, 2003), the relation between preschoolers’ emotional state and their ability to conduct scientific observations (Klemm & Neuhaus, 2017), the effect of an inquiry-based science project on the involvement of primary school students (Waldenmaier, Müller, Köster, & Körner, 2015), and the impact of involvement on children’s school grades (Pascal, Bertram, Mould, & Hall, 1998), amongst others (Aydoğan, Farran, & Sağsöz, 2015; Declercq et al., 2011). Thus, this theoretical framework has proven to be suitable to examine the effect of an educational approach on children’s acquisition of conceptual knowledge through the mediating effect of their level of involvement.

2.1.3 Inquiry-based science education

Research in both preschool and school have shown that there are three basic dimensions of instructional quality, whereby the used terminology may vary slightly according to different models. These basic dimensions are: classroom management, also called group organization; emotional support, also called supportive climate; and cognitive activation, also called instructional support (Baumert et al., 2010; Klieme, Schümer, & Knoll, 2001; Lipowsky et al., 2009; Pianta, La Paro, & Hamre, 2008; Pianta & Hamre, 2009). While

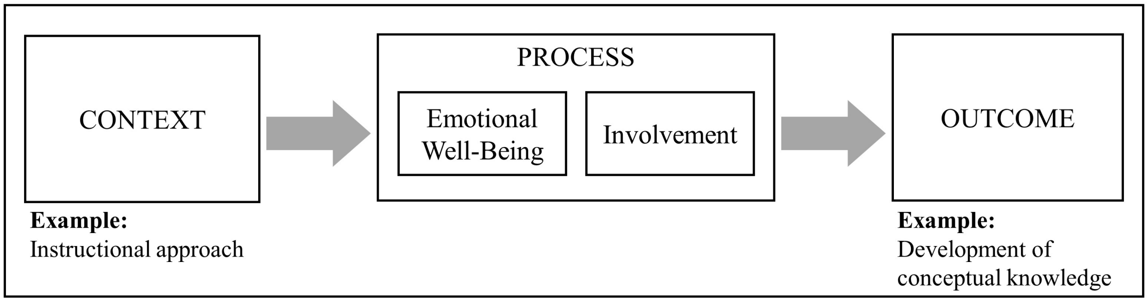


Figure 2.1: Laevers' (2020) experiential education (EXE) model. Adapted from —Forward to Basics! Deep-Level-Learning and the Experiential Approach by F. Laevers, 2000, *Early Year, 20(2)*, p. 24.

classroom management and emotional support are considered general, domain-independent features of instructional quality, the basic dimension of cognitive activation encompasses domain-specific characteristics of instruction that support students' use of higher order thinking skills with the aim of fostering conceptual development (Blazar, Braslow, Charalambous, & Hill, 2017; Dorfner, Förtsch, & Neuhaus, 2018; Seidel & Shavelson, 2007; Wüsten, Schmelzing, Sandmann, & Neuhaus, 2010). These domain-specific characteristics of instruction include strategies to set challenging tasks, confront students with diverse positions and ideas, take their previous knowledge into consideration, and enable thoughtful discourse during the lessons, amongst others (Förtsch et al., 2016; Förtsch, Werner, Dorfner, von Kotzebue, & Neuhaus, 2017; Klieme et al., 2001; Klieme, 2006; Lipowsky et al., 2009).

In the context of early science education, cognitive activation is centered around the verbal interactions between preschool teachers and children – as well as among children – that enable them to engage actively and deeply with a topic or phenomenon (Steffensky, 2017). This can be achieved by giving them opportunities to develop and express their own ideas and engage with the ideas of others, by asking them to formulate explanations, by illustrating thinking processes, and by guiding them through problem-solving strategies (Hopf, 2012; König, 2008; Steffensky, 2017; Vygotsky, 1962, 1978). An instructional approach that can be used to achieve cognitive activation in the preschool setting is the inquiry-based science education approach, as will be presented below.

The inquiry-based science education is a well-established instructional approach in which students actively engage in a process of scientific investigation in order to answer a research question (Abd-El-Khalick et al., 2004; R. D. Anderson, 2002; Bell, Smetana, & Binns, 2005; Decristan et al., 2015; Minner et al., 2010). It has been a crucial element of school and university education for several decades (Huber, 2014; Council et al., 1996, 2012) and, in the last years, this approach has also gained increasing attention in the field of early science education, as it is considered beneficial for preschool children (Eshach & Fried, 2005; Gerde et al., 2013). The inquiry-based approach is based on a constructivist view of learning, as it gives learners opportunities to construct knowledge by asking questions, generating evidence and drawing conclusions (Chinn & Malhotra, 2002; Schwab & Brandwein, 1962; Singer, Marx, Krajcik, & Clay Chambers, 2000; Zhang, 2016). As such, this instructional approach relies on the idea that students benefit the most when they are active participants in their own learning, when their interests and existing knowledge are the basis for new investigations and when teachers provide appropriate instructional support (R. D. Anderson, 2002; Furtak, Seidel, et al., 2012; Furtak, Shavelson, Shemwell, & Figueroa, 2012; Hackling, 2020).

The process of scientific investigation that takes place in inquiry-based learning opportunities can be defined as an inquiry cycle that consists of several interconnected phases (Pedaste et al., 2015). In the literature, these have been described using a wide variety of terminologies, thus leading to a lack of clarity regarding which and how many phases are actually part of the inquiry cycle and how they are connected with each other. Based on a review of existing definitions, Pedaste et al. (2015) proposed a framework describing five conceptually unique phases and various sub-phases that take place in inquiry-based science education: The first phase, Orientation, represents the activity of stimulating interest about a topic, for example through the statement of a problem. This is followed by Conceptualization, which is divided into two sub-phases, Questioning and Hypothesis Generation. The next phase, Investigation, is defined as the process of planning an exploration or experimentation and collecting and interpreting evidence. In the Conclusion phase, the results of the investigation are regarded in relation to the research question or hypothesis, thus leading to an answer or to the confirmation/refutation of the original hypothesis. Finally, the phase called Discussion contains the sub-phases Communication, defined as the discussion with others, and Reflection, which represents an internal evaluation. Communication and Reflection can take place both at any single phase and at the end of the inquiry cycle.

At the center of the inquiry cycle lie the scientific procedures that are executed by the students during the phase of Investigation. In the context of early science education, an important procedure is that of comparison. This procedure is particularly adequate for preschool children, given that throughout their everyday lives they gather a variety of experiences of comparing and categorizing different objects using criteria such as colours, forms and shapes (Steffensky, 2017). Comparison consists of an examination of two or more elements and the identification of their similarities and differences. The comparison of conceptually related elements is considered a powerful mechanism for learning, as it leads to a deeper understanding of the underlying principles or conceptual relations (Gentner, 2010; Rittle-Johnson & Star, 2011). Numerous studies have found a positive effect of comparison on conceptual learning across age groups and in various domains, including science (Alfieri, Nokes-Malach, & Schunn, 2013; Haglund, 2012). Regarding the age group of preschoolers specifically, Gentner and Namy (1999) have shown that 4-year-old children are able to recognize common conceptual properties between two different objects after comparing them. In line with this, several studies have found that prompting preschoolers to compare two examples of a category increases their ability to identify a new example of that category (Graham, Namy, Gentner, & Meagher, 2010; Namy & Gentner, 2002; Waxman & Klibanoff, 2000). Therefore, comparing different elements seems to be an appropriate scientific procedure to conduct during an inquiry-based learning activity with preschool children in order to foster their conceptual learning.

There is large consensus about the crucial role of guidance in inquiry-based science education (Alfieri et al., 2011; Decristan et al., 2015; Furtak, Shavelson, et al., 2012; Lazonder & Harmsen, 2016). As pointed out by Hmelo-Silver, Duncan, and Chinn (2007), a high level of guidance makes learning more manageable as it makes complex tasks more accessible, thus positioning them within student's zone of proximal development. According to Studhalter et al. (2021), instructors' scaffolding talk in the context of science learning fulfills two main functions: problematizing and structuring. The problematizing function refers to the activation of children's prior knowledge for the formulation of hypothesis and the support of children's knowledge construction through explanations, comparisons, reasoning, and cognitive conflicts (Studhalter et al., 2021). The structuring function includes the clarification of goals, tasks and scientific procedures for the investigation and the direction of student's attentions towards specific aspects of the phenomenon under investigation (Studhalter et al., 2021).

Within early childhood education, science learning activities commonly take the form of guided inquiry (Gerde et al., 2013; Howitt, Lewis, & Upson, 2011). In this type of guidance, teachers support students through all steps of the investigative process (Furtak, Shavelson, et al., 2012). An important first step of such guidance is to select topics that are relevant and interesting for young children (Peterson & French, 2008; Samarapungavan et al., 2008). Hereby it is not important whether the research question is originally formulated by the teacher or by the students, as long as it sparks their curiosity so that they can embrace it as their own (Steffensky, 2017). Throughout the investigative process, teacher's support consists of encouraging children to make predictions, helping them to formulate their ideas clearly, involving them in planning investigations and checking the results, helping them to compare their findings with their predictions, encouraging them to formulate their conclusions, and asking them to give reasons or explanations for what they found (Ergazaki & Zogza, 2013). While doing so, teachers take children's existing ideas, knowledge and capabilities into account, display scientific vocabulary and assist in the understanding of the phenomenon under investigation through hints, questions and clarifications (Samarapungavan et al., 2008). This way, teachers create a structured and collaborative learning experience while fulfilling both the problematizing and the structuring functions of guidance (Furtak, Seidel, et al., 2012; Peterson & French, 2008).

Effects of the inquiry-based approach on preschoolers' learning outcomes

Despite the increasing acceptance of inquiry-based science education in preschool, only few studies have investigated the influence of this approach on preschool children's learning of scientific concepts. Samarapungavan et al. (2008, 2011) evaluated the influence of guided inquiry units about the life cycle of the monarch butterfly on kindergarteners' acquisition of conceptual knowledge. In both studies, the findings show that participants were able to develop an understanding of important biological concepts, such as adaptation, growth and development, and the relation between structure and function. A study conducted in German preschools compared the learning approaches "experiments", in which inquiry took place, and "discussion on the relevance of the natural sciences in daily life" on the topic of water properties (Steffensky et al., 2012). The results demonstrated that when kindergarteners participated in a combination of both approaches, they were able to learn significantly more than by engaging in either one or the other.

The development of conceptual knowledge through inquiry places high demands on children's linguistic abilities, as a certain level of receptive and expressive language skills are necessary for participating in collaborative and communicative processes, e.g. for understanding tasks given by an instructor and for discussing science concepts (Akerson et al., 2000; Van Boxtel et al., 2000). At the same time, engaging with science can contribute to the development of language skills. Within the context of scientific investigations, children take part in a variety of language-related activities, such as asking questions and describing observations, which are accompanied by authentic and meaningful conversational exchanges with instructors (Gerde et al., 2013). Adult's use of language throughout the investigative process thus plays a crucial role in supporting children's science-related linguistic development; it provides the vocabulary and models the discourse formats that are necessary to describe and explain observations and scientific concepts (Dickinson & Porche, 2011; French, 2004). The inquiry-based approach thus provides children with ample opportunities to develop a rich knowledge base that supports their acquisition of science-related vocabulary and discourse skills. For example, in an evaluation of the ScienceStart! Curriculum, French (2004) measured kindergarteners' learning in the areas of colour, shadow and air through narrative assessments. Here, the author found statistically significant increases from pre- to post-test, demonstrating that this approach leads to a better understanding of science content while supporting the development in the areas of language and early literacy. This is consistent with the results of Peterson and French (2008), who analysed three- and four-year old children's explanatory language after participating in a five-week inquiry unit on the topic of colour mixing. They found that with appropriate adult support, which included modelling the conventions of explanatory language in inquiry and a repeated observation-prediction discourse format, young children developed explanatory language abilities, as they increased their use of colour terms, colour mixing verbs and casual connectives in their explanations. These findings demonstrate that the inquiry-based approach can contribute to preschool children's development of basic conceptual knowledge, including the appropriate formulation of conceptually based explanations.

Effects of the inquiry-based approach on preschoolers' learning experiences

A small body of qualitative research has investigated the relation between inquiry-based science education and preschool children's learning experiences. Howitt et al. (2011) presented a case study about an activity in which children engaged in scientific inquiry to find out "who left behind the (bear) footprints" (p. 1). Here, the authors described that children were highly concentrated and enthusiastic when applying their scientific skills in order to solve the mystery. In the previously described study on the experiences of kindergarteners during a floating and sinking activity, Andersson and Gullberg (2014) stated that by engaging in different phases of the inquiry cycle, children engaged as active participants in their own learning process, which allowed them to develop feelings of empowerment and personal satisfaction. This perspective is reinforced by studies on the Scientific Literacy Project, which show that children who engaged in guided inquiry throughout the preschool year reported considerable interest and enjoyment in science and viewed themselves as competent in learning about science (Mantzicopoulos, Patrick, & Samarapungavan, 2008; Patrick, Mantzicopoulos, & Samarapungavan, 2009; Samarapungavan et al., 2011). In a study with older students, Waldenmaier et al. (2015) described how the educational approach of an extracurricular science course for 1st-4th graders was changed from a traditional direct instruction to an inquiry-based one. The authors assessed participants' levels of involvement before and after the change and discovered that the latter approach resulted in higher involvement levels.

Taken together, these studies suggest that the inquiry-based approach elicits positive learning experiences for preschool children, as it allows them to actively engage in the process of scientific investigation in order to answer an interesting question. However, to the best of my knowledge, no study has quantitatively analysed the effect of an inquiry-based science activity on preschool children's level of involvement, let alone the influence of this involvement on their development of conceptual knowledge.

2.2 Research aims and Hypotheses

This study aims at investigating the effect of an inquiry-based science learning activity on preschoolers' involvement during the conducted activity (learning experience) and on their conceptual knowledge of structure and function (learning outcome), as well as the way in which the former relates to and influences the latter.

Following hypotheses were formulated:

H1) An inquiry-based learning activity has a positive effect on preschooler's involvement

(Andersson & Gullberg, 2014; Howitt et al., 2011; Mantzicopoulos et al., 2008; Patrick et al., 2009; Samarapungavan et al., 2011; Waldenmaier et al., 2015)

H2) An inquiry-based learning activity has a positive effect on preschooler's knowledge of the biological concept of structure and function, reflected in:

a) their ability to match structures and functions, i.e. the ability to recognize specific relationships

b) their ability to explain these relationships

(Dickinson & Porche, 2011; French, 2004; Peterson & French, 2008; Samarapungavan et al., 2008, 2011; Steffensky et al., 2012)

H3) Preschoolers' involvement mediates the effect of the inquiry-based learning activity on their conceptual knowledge

(Laevers, 2000, 2003; Pascal et al., 1998; Waldenmaier et al., 2015)

2.3 Materials and Methods

2.3.1 Sample and procedure

The sample of this study consisted of 59 preschool children. Twenty-eight (47%) of the children were female. The mean age was 6 years and 3 months (*SD* = 0.44). The children belonged to four German preschools, of which one was located in a rural area and three in an urban environment. Informed consent and child assent were obtained for all children.

Within each preschool, both inquiry-based and control learning activities were conducted with randomly assigned small groups (subgroups) of three to five children. In total there were 16 subgroups. Nine subgroups took part in an inquiry-based learning activity, thus together the participating children conform the "inquiry group" (n = 32). The other seven subgroups participated in a control learning activity, thus conforming the "control group" (n = 27). The study was conducted in the facilities of the participating preschools. Children participated in three consecutive sessions (see Figure 2.2).

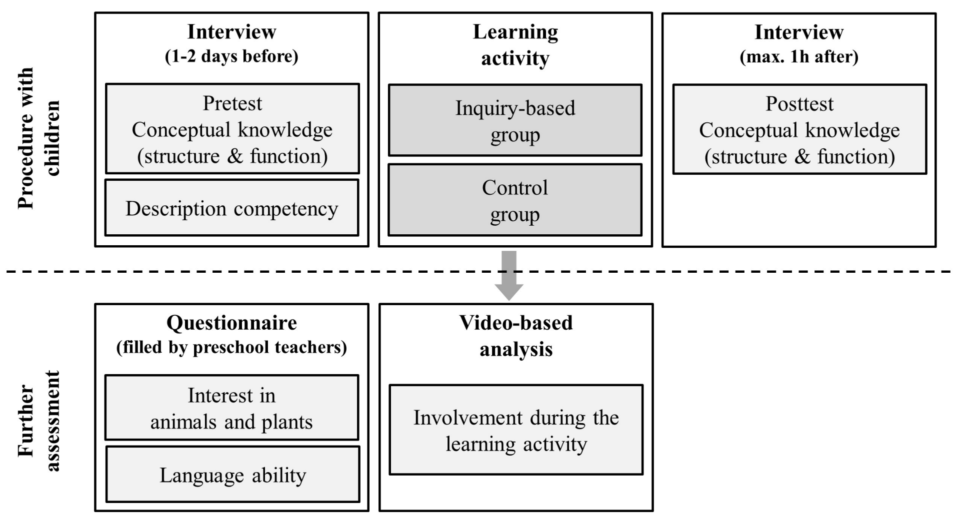


Figure 2.2: Study design of study 1

The first session consisted of one-on-one interviews, in which children's prior knowledge of the concept of structure and function as well as their description competency were tested. The tests lasted on average 14.5 min (*SD* = 2.5) and 3.3 min (*SD* = 0.8) respectively. The interviews were recorded on audiotape and later transcribed. The second session took place one or two days after the first one. In this session, the learning activities were performed. All 16 subgroups were instructed by the same person in order to avoid influences of different instructors. The inquiry-based activities lasted on average 55.8 min ($SD = 5.7$), whereas the control activities had a mean length of 39.4 min ($SD = 3.9$). All activities were recorded on video. The third session was conducted immediately after the second one. It consisted of one-on-one interviews to assess children's conceptual knowledge after the learning activity. The interviews lasted on average 10.4 min ($SD = 2.1$), were recorded on audiotape and later transcribed. In addition, children's interest in animals and plants and their language ability were assessed through questionnaires that were filled in by preschool teachers. Further, the video recordings of the learning activities were used for the assessment of children's involvement.

2.3.2 Learning activities

Materials of the learning activities

The materials used in this study consist of self-constructed models that were developed to represent the biological concept of structure and function in animals and plants living in the forest. The materials consist of eight different stations that display how four distinct behaviours (= functions) are performed by several forest habitants, who possess different anatomies (= structures). Table 2.1 shows which forest habitant and behaviour are represented in each station.

For every station, two different models were developed: One that represents the real structure and is therefore able to fulfil a given function, and one that possesses another

Table 2.1: Stations of the learning activities

Station	Behaviour	Forest habitant
1	Moving	Woodpecker
2	Moving	Ant
3	Sensing	Squirrel
4	Sensing	Owl
5	Protecting	Snail
6	Protecting	Spruce
7	Feeding	Ant
8	Feeding	Snail

structure that does not fulfil the function and thus serves as comparison. For example, in station 1 (the moving behaviour of woodpeckers) the materials consisted of a model that simulates the foot structure of a woodpecker and is therefore able to hang on to a piece of tree-trunk, and a second model that represents the webbed foot of a duck, which cannot fulfil that function (see Figure 2.3 and 2.4). The materials were validated by conducting pilot learning activities with preschool children of one kindergarten under the supervision of eight preschool teachers. These teachers then filled out a questionnaire regarding whether the materials are age-appropriate, appeal to the interest of young children, and are equally engaging for boys and girls.

Figure 2.3: Close-up of the foot of a woodpecker

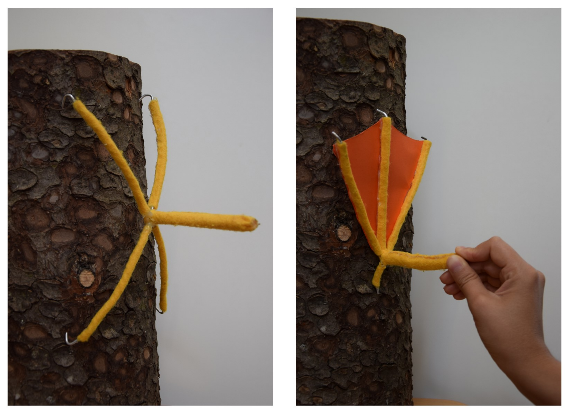


Figure 2.4: Models representing the foot of a woodpecker (left) and of a duck (right)

Procedure of the learning activities

In order to assess the effects of the inquiry-based approach, two types of learning activities were developed: One learning activity was based only on the implementation of the disciplinary core idea of structure and function in the instruction; this served as control. The other learning activity included, besides the use of this core idea, the implementation of the guided inquiry approach, and thus represented the treatment. In both learning environments, children were guided by the instructor through all eight stations. For this, the instructor was provided with a script that indicated the procedure he had to follow in each station.

Inquiry-based learning activity

In each station of the inquiry-based learning activity, children were guided through four of Pedaste et al.'s (2015) (sub-)phases of the inquiry cycle:

1. Questioning: In each station, the instructor first posed a question about the presented behaviour and forest habitant. In the example of the moving behaviour of woodpeckers, children were asked how these animals climb trees, specifically with which foot structure they are able to do so.
2. Hypothesis Generation: Each child then generated a hypothesis by observing the two models and predicting which one was the best to serve the given function. In our example, children predicted whether the model of the woodpecker's foot or the one of the duck's foot would be able to hang on to the piece of tree-trunk.
3. Investigation: They collected evidence by trying both models out. Given that this was a group activity, children were able to observe their own handling of the models as well as the other participants'. They then were guided by the instructor to summarize what they observed and compare the two models regarding their capacity to fulfil the given function. For this, he asked them what they saw happened with each of the models and which of the models was able to fulfil the given function. In station 1, children approached the models to the tree-trunk and observed that only the model of the woodpecker's foot was able to hang on to the tree-trunk. In this context, the models were thus used as a tool for hypothesis-testing.
4. Conclusion: Finally, children were guided to discuss their findings in relation to the original question and their own hypotheses. Here, the instructor asked them to remember which model they first thought was better and to compare their first ideas with their observations. Further, he encouraged them to give reasons why one model was better than the other. Regarding the moving behaviour of woodpeckers, the instructor asked the children why one model held better on to the tree trunk than the other. To this, children for example stated that it was because one model had bent claws which helped it hold on to the tree. Further, the instructor added any information that was missed by the children, for example that the model had two claws at the front and two at the back so that it could hold even tighter. This way, children learned that woodpeckers are able to climb trees due to the structural characteristics of their feet.

Control learning activity

The control learning activity was designed for participants to learn about the concept of structure and function without engaging in the afore mentioned steps of the scientific method. The models were thus used to merely illustrate the relation between structure and function but not for hypothesis-testing through comparison. Because of this, each of the eight stations contained only the one model that represented the correct structure.

Each station started with a brief introduction about the presented behaviour and forest habitant. Children were then encouraged to observe, describe and interact with the presented model. In station 1, children observed and described the model representing the woodpecker's foot structure. After this, each participant approached it to the piece of tree-trunk and observed that it was able to hang on to it. They then learned with the guidance of the instructor that the characteristics of the structure served the given function.

2.3.3 Instruments

Test on children's conceptual knowledge of structure and function

Children's conceptual knowledge was assessed before and after the learning activity using the pre-test and post-test described in detail in chapter 1. The pre-test consists of nine items, whereas the post-test contains ten. Three of these items are identical in both tests and are thus used as anchors in the Rasch analysis.

The tests were conducted as one-on-one interviews, in which children were inquired about the structure and function of different organisms that are generally familiar to young children. The interviews were conducted with the help of drawings in order to facilitate children's responses. The items have a two-tier item structure; that is, each item consist of two questions. In two-tier instruments, the 1st tier questions are multiple-choice or true/false content knowledge questions, and the 2nd tier questions require respondents to explain their reasoning behind their 1st-tier answers (Liu et al., 2011; Treagust, 1988; Treagust & Mann, 1998).

Here, all items were introduced following the same format: Embedded in an interesting context, children were presented with the behaviour of an animal or a plant suitable to represent the relation between structure and function. For example, the item called *Mosquito's mouth* started by mentioning that mosquitoes drink blood from animals and humans, but in order to do so they must first go through their skin.

After introducing the behaviour, the interviewer posed children the 1st tier question about the corresponding structural and functional relationship and asked them to answer by choosing one out of three options. In some cases, the function was given, and children had to choose a structure. In other cases, the structure was given, and they were required to choose a function. In the example of the mosquito, the function (go through the skin of an animal) was given and children were shown three different forms of mouths (see Figure 2.5). They were asked to choose which one of the three images best represented the mouth of a mosquito. If they selected the correct option, they received 1 point for the variable *recognize*. Thus, this variable represents the first dimension of children's conceptual knowledge, i.e. their ability to match a biological structure with its function.

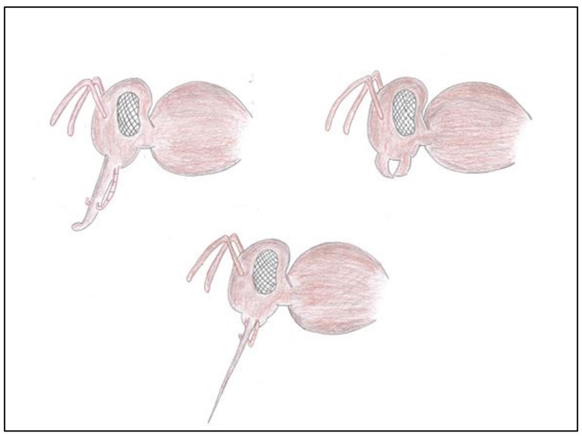


Figure 2.5: Pictures of the item *Mosquito's mouth*

Afterwards, in the 2nd tier questions, all children were asked to explain their reasoning, independently of their 1st tier answers. Their explanations were transcribed. For the coding, eight categories were defined to which the answers could be assigned (see Table 2.2). The first three categories represented answers in which children mentioned a relevant structure, function, or relation between them. Categories 4-7 represented statements in which children do not refer to structures or functions to justify their 1st tier answers. Further, one category was included for the cases in which children's explanations revealed a certain level of understanding of the structure-function relation even though their 1st tier answer was wrong, but in reality no answer provided by any child of the sample could be assigned to this last category.

Answers that belonged to any of the first three categories scored 1 point for the variable *explain*, whereas answers that belonged to the other categories did not. In the case of the item called *Mosquito's mouth*, answers such as "because this one can go through the skin", were coded in the category 2 and thus scored with 1 point, whereas answers such as "because I've seen it on TV" were coded in the category 4 so they did not get a point. The variable *explain* thus represents the second dimension of children's conceptual knowledge, which is their ability to describe and explain which characteristics of the structure allow it to fulfil its function.

Table 2.2: Coding categories for children's 2nd-tier responses

Category Nr.	Content of children's response
1	Structure
2	Function
3	Structure & Function
4	Previous experiences (e.g. seen it on TV)
5	Fantasy
6	No relation to question/ incomprehensible answer
7	No answer/ "Don't know"
8	Structure & Function but wrong 1st-tier answer

To ensure objectivity, a second rater coded the explanations of 11 children (17%) in both pre- and post-tests. The analysis of inter-rater reliability showed very good values for both the pre-test (K = 0.87, 95% CI [0.78, 0.97], $p < .001$) and the post-test (K = 0.75, 95% CI [0.62, 0.89], $p < .001$).

Involvement

Children's involvement during the learning activity was evaluated via video-based analysis. For this, the observation form of the Leuven Involvement Scale was adapted from Laevers and Schlömer (2006). The analysis was limited to five aspects of involvement that could be observed in the learning situation: concentration, facial expression and body language, reaction, verbal utterances, and satisfaction. A 3-level scale was used in order to rate the degree of manifestation of the observed aspects. A low degree of manifestation occurs, for example, when a child seems to be mentally absent and shows little drive to engage with the learning materials. The medium degree of manifestation is present in children who are often but not completely focused on the task at hand, i.e. shows interest but is easily distracted.

The high degree of manifestation occurs when children work in a very concentrated way and can ignore stimuli from the environment (Laevers et al., 2009). For each indicator of behaviour, different exemplary signals were defined to distinguish between the three degrees of manifestation that could be recognized during the observation situation. This way, the levels could be distinguished from each other more precisely. Table 2.3 shows the signals for each level of manifestation of the aspect "concentration".

Children's involvement was assessed separately for each station by rating the level of manifestation for each of the aspects of involvement. Due to some difficulties in the observation, stations 3 and 4 (the sensing behaviour of squirrels and owls) were excluded from the analysis. Thus, the mean value of involvement was calculated using the other 6 stations.

To test the validity of the adapted scale, the videos of a previous version of the learning activity were first used to analyse children's involvement with both the original Leuven Involvement Scale and the adapted version. Here, a significant high correlation was found between the two scales ($n = 15$, $r = .75$, $p < .001$). With the videos of this study, a second rater coded the involvement of 17 children (29%), which demonstrated a high objectivity ($K = 0.73$, 95% CI [0.68, 0.78], $p < .001$). These values, together with the results of the Rasch analysis (see below), demonstrate that the adapted scale is a valid instrument for analysing the involvement of preschool children during a science activity.

Table 2.3: Levels of manifestation of the aspect "concentration" of the involvement scale. The scale used in this study was formulated in German and adapted from Laevers and Schlömer (2006)

Level 1 (low manifestation)	Level 2 (medium manifestation)	Level 3 (high manifestation)
The eyes are briefly directed at the instructor or materials for short periods of time, the eyes wander aimlessly	The eyes are predominantly directed at the instructor or materials (more than half of the time)	The eyes are almost uninterruptedly directed at the instructor or materials
Stimulants from the environment are perceived by the child and distract him/her from the activity for a longer period of time	Stimulants from the environment are perceived by the child and distract him/her from the activity for a short period of time	Stimulants from the environment are perceived by the child but do not distract him/her from the activity

Description competency

Participant's description competency was assessed using an ad-hoc developed oral test based on Kohlhauf's observation competency instrument (Kohlhauf et al., 2011). Children were presented with a stuffed squirrel and asked to describe it as detailed as possible. Points were given for the body parts mentioned and the number of adjectives that were used to objectively describe the animal.

Language ability and interest in animals and plants

In order to assess children's language ability and interest in animals and plants, preschool teachers were required to complete a questionnaire based on their every-day observations of the children. The questionnaire was rated using a 5-point Likert scale ranging from one (strongly disagree) to five (strongly agree). Children's language ability was assessed using the section "speaking and comprehension" of the KOMPIK Observation Form (Mayr et al., 2011), which includes items such as "The child answers questions appropriately regarding the content" and "The child actively participates in group conversations and discussions". For the assessment of interest, a new scale was developed that contains four items regarding to children's interest in animals and plants, including items such as "The child has a great interest in animals and often asks questions about them".

2.3.4 Data analysis

The instruments implemented in this study were evaluated with the Rasch analysis using the program Winsteps (J. Linacre, 2021b). This includes but is not limited to the evaluation of dimensionality, item and person reliability, and step ordering (for further details on these aspects of Rasch analysis, see section 1.2.3). The dimensionality was evaluated by the infit and outfit mean-square values (MNSQ Infit & MNSQ Outfit). Here, the ideal values are close to 1, and in small sample sizes the range of 0.5-1.5 is considered satisfactory (J. M. Linacre, 2002; Wright et al., 1994). To verify the reliability of the instruments, the values of item and person reliability were checked. For item reliability, values of .90 or higher are considered satisfactory, whereas for person reliability, values of .80 or higher are considered satisfactory (Malec et al., 2007). The assessment of step ordering consists of comparing, for each item, the average measure of respondents who answered that item correctly and the average measure of respondents who didn't. In a well-functioning instrument, the former measure should always be higher than the latter. The person measures obtained through the Rasch analysis for each variable were used for further statistical analysis.

Descriptive analysis was conducted to describe both groups (inquiry and control group). To test for significant differences between the 16 subgroups regarding the control variables, one-way analyses of variance (ANOVAs) were conducted. To test for significant differences between the two groups (inquiry and control) regarding the control variables, independent t-tests were calculated. Further, correlations were calculated between the three dependent variables – *post-recognize*, *post-explain*, and *involvement* – and between them and the control variables.

The inference-statistical analysis consisted of several steps. First, the influence of the inquiry-based approach on children's conceptual knowledge was analysed. Given that the assessment of conceptual knowledge consisted of two separate but interrelated dimensions (*recognize* and *explain*), a multivariate analysis of covariance (MANCOVA) was conducted with *post-recognize* and *post-explain* as the two dependent variables, the group (i.e. the type of learning activity) as the independent variable, and *pre-recognize*, *pre-explain*, *language ability*, *description competency* and *interest in animals and plants* as covariates. This was followed by the examination of the discriminant function coefficients, which represent the relative weight of each dependent variable within the multivariate combination, as well as Bonferroni-adjusted univariate analyses, as recommended by Grice and Iwasaki (2008) and Field (2017). Second, in order to address the impact of the inquiry-based approach on children's involvement during the learning activity, an ANCOVA was conducted with *involvement* as the dependent variable, the group (i.e. the type of learning activity) as the independent variable, and the same covariates as in the MANCOVA. Third, in order to assess the indirect effect of the inquiry-based approach on children's conceptual knowledge through their level of involvement, mediation analyses were conducted using the program PROCESS (Hayes, 2017) and following the recommendations of Zhao, Lynch Jr, and Chen (2010). Here, the analysis started by conducting simple mediation analyses based on Laevers' EXE-model, which included the learning group as the independent variable, *involvement* as the mediator and *post-recognize* and *post-explain* as the outcome variable respectively. Following this, the model was extended in order to include the covariates that were shown in the previous ANCOVAs to have a significant relation with both the mediator and the outcome variable.

2.4 Results

2.4.1 Psychometric results

The following provides a summary of the psychometric results regarding the dependent variables, namely *pre-recognize*, *pre-explain*, *post-recognize*, *post-explain*, and *involvement* (for further detail on the psychometric results regarding the variables *pre-recognize*, *pre-explain*, *post-recognize*, and *post-explain*, see section 1.3).

Given the small sample size, the range of 0.5-1.5 was considered satisfactory for the analysis of dimensionality (J. M. Linacre, 2002; Wright et al., 1994). All Infit and Outfit MNSQ values were located within the range of 0.5-1.5, which indicates a good model fit for all dependent variables. The values of item and person reliability for each variable can be found in Table 2.4. All variables show an item reliability higher than .80, which is close to the values considered satisfactory (Malec et al., 2007), and indicates a high variance in item difficulty. The instrument assessing involvement shows a satisfactory value of person reliability. In contrast to this, the person reliabilities of the other dependent variables are rather low. This is believed to be a result of the length of the test (too few items in total) and of the low number of categories per item, as these were coded dichotomously (Malec et al., 2007; Moeini et al., 2016). Nevertheless, the high values of the item reliabilities still indicate satisfactory reliabilities for all the instruments.

Table 2.4: Item reliability and person reliability of the variables *pre-recognize*, *pre-explain*, *post-recognize*, *post-explain*, and *involvement*

	Item reliability	Person reliability
Pre-recognize	.92	.41
Pre-explain	.81	.13
Post-recognize	.91	.59
Post-explain	.83	.66
Involvement	.90	.85

2.4.2 Descriptive results

The descriptive results depicted in Table 2.5 show that children in both groups achieved a higher Rasch-scaled score in the conceptual knowledge test after participating in the learning activity compared to their scores before their participation; the average increase from *pre-* to *post-recognize* in the control group was of .26 and in the inquiry group of .04, and the average increase from *pre-* to *post-explain* was of .04 in the control group and of .51 in the inquiry group. Further, the inquiry group achieved a higher average score in *involvement* (1.58) compared to the control group (.90).

Table 2.5: Rasch-scaled means (*M*) and standard deviations (*SD*) of all variables in the control and the inquiry groups

	Control group		Inquiry group	
	Before activity	During/after activity	Before activity	During/after activity
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
Age (months)	74.70 (5.33)	-	76.41 (5.20)	-
Language ability	3.70 (2.78)	-	5.27 (2.94)	-
Interest in animals and plants	-0.11 (4.16)	-	0.93 (3.93)	-
Description competency	-2.38 (0.90)	-	-2.49 (0.91)	-
Recognize	0.67 (1.41)	0.93 (1.48)	1.05 (1.09)	1.54 (1.48)
Explain	-1.38 (1.92)	-1.34 (2.03)	-0.60 (1.66)	0.11 (1.39)
Involvement	-	0.90 (0.97)	-	1.58 (1.14)

2.4.3 Inferential results

One-way ANOVAs showed that there was no significant difference regarding the control variables between the 16 subgroups that participated in this study (see Table 2.6). Independent t-tests for all control variables showed that children in the inquiry group had a significantly higher language ability than those in the control group ($t(57)$ = -2.11, p <

.05, $d = .55$), which represented a medium-sized effect (Cohen, 1988). No other significant differences between the two groups were found (see Table 2.6).

The calculated correlations are depicted in Table 2.7. All control variables were significantly correlated with all three dependent variables, except for *age*, which showed no significant correlation, and *description competency*, which was not significantly correlated with *post-recognize*. Further, all three dependent variables were significantly correlated with each other.

Table 2.6: Results of the one-way ANOVA for all 16 subgroups (left) and of the independent t-test for the control and the inquiry group (right)

	One-way ANOVA (16 subgroups)			Independent t-test (2 groups)		
	F-value	p-value	η^2	F-value	p-value	η^2
Age	$F(15,43) = 1.82$	.063	.388	$t(57) = -1.24$	.221	.323
Language ability	$F(15,43) = 1.24$	.285	.301	$t(57) = -2.11$	.040	.551
Interest in animals and plants	$F(15,43) = 1.19$	.318	.293	$t(57) = -0.98$	.330	.256
Description competency	$F(15,38) = 0.77$	.703	.232	$t(52) = 0.44$	.663	.120
Pre-recognize	$F(15,43) = 1.35$	.215	.321	$t(57) = -1.16$	.252	.299
Pre-explain	$F(15,43) = 1.87$	.055	.395	$t(57) = -1.68$	.098	.436

Effect of the inquiry-based activity on preschoolers' conceptual knowledge

Results of the MANCOVA showed that there was a significant omnibus effect of the inquiry-based approach on the multivariate combination of both dimensions of conceptual knowledge after controlling for all covariates ($F(2,46) = 3.75$, $p < .05$, $\eta^2 = .14$). Nevertheless, the discriminant function coefficient of the variable *post-recognize* was close to zero ($w_s = -0.08$), whereas that of *post-explain* was close to one ($w_s = 1.03$). This indicates that the inquiry and the control groups could only be differentiated by the second dimension of conceptual knowledge and not by a combination of both dimensions, thus a multivariate composite was ruled out. Follow-up Bonferroni-adjusted ANCOVAs confirmed that the

Table 2.7: Correlations between the dependent and the control variables

	Dependent variables		
	Post-recognize	Post-explain	Involvement
Control variables			
Age	.10	.06	.18
Language ability	.56**	.62**	.45**
Interest in animals and plants	.39**	.34**	.31*
Description competency	.24	.34*	.35**
Pre-recognize	.69**	.65**	.27*
Pre-explain	.64**	.76**	.28*
Dependent variables			
Post-recognize	-	.74**	.29*
Post-explain	-	-	.40**

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

inquiry-based approach had no effect on *post-recognize* (F(1,47) = 1.17, p = .284, η^2 = .024), but it had a significant effect on *post-explain* (F(1,47) = 7.62, p = .008, η^2 = .140). The value of partial eta square (η^2) suggests that this effect on children's explanations represents a large effect size (Cohen, 1988). These analyses also showed that *post-explain* had a significant relation with the covariates *pre-explain*, *language ability* and *description competency* (see Table 2.8). In summary, these results indicate that there was no significant difference between the children of the inquiry and the control group regarding their recognition of correct structures and functions in the post-test, but there was a significant difference in terms of their ability to describe and explain the relationship between biological structures and functions, as they made more references to this relation when giving their explanations.

Effect of the inquiry-based activity on preschoolers' involvement

Results of the ANCOVA with *involvement* showed a significant effect of inquiry on the involvement of children during the learning activity with an intermediate effect size (F(1,47) = 4.41, p < .05, η^2 = .09). Further, the covariates *language ability* and *description compe-*

tency showed a significant relation with *involvement* (see Table 2.8). These results indicate that children of the inquiry group achieved higher levels of involvement during the learning activity compared to the control group even after controlling for the covariates.

Table 2.8: Significant relations between the dependent variables and the covariates

Dependent variable (test)	Covariate	F-value	p-value	η^2
Post-explain	Pre-explain	$F(1{,}47) = 23.88$	<.001	.337
(Follow-up ANCOVA)	Language ability	$F(1{,}47) = 4.38$	.042	.085
	Description competency	$F(1{,}47) = 7.41$	.009	.136
Involvement	Language ability	$F(1{,}47) = 5.31$	.026	.101
(ANCOVA)	Description competency	$F(1{,}47) = 4.85$	.033	.093

Mediation analysis

In the mediation analysis regarding *post-recognize*, no significant indirect effect through involvement could be found, as the bootstrapped 95% confidence interval (CI) included zero (see Figure 2.6). In the mediation analysis regarding *post-explain*, results show that there is a significant indirect effect through involvement, since the 95% CI does not include zero (see Figure 2.7a). Nevertheless, the direct effect of the inquiry-based learning activity on children's conceptually based explanations remained significant ($p < .05$). This could possibly be due to other unmeasured mediators or potential confounding variables affecting both the mediator and the dependent variable. To address this, the model was extended in order to include the covariates *language ability* and *description competency*. Here, the results show that after including these covariates in the model, the indirect effect of involvement disappeared, as it was merely the inquiry-based learning context and the characteristics of the children that had a significant effect on children's conceptually based explanations (see Figure 2.7b).

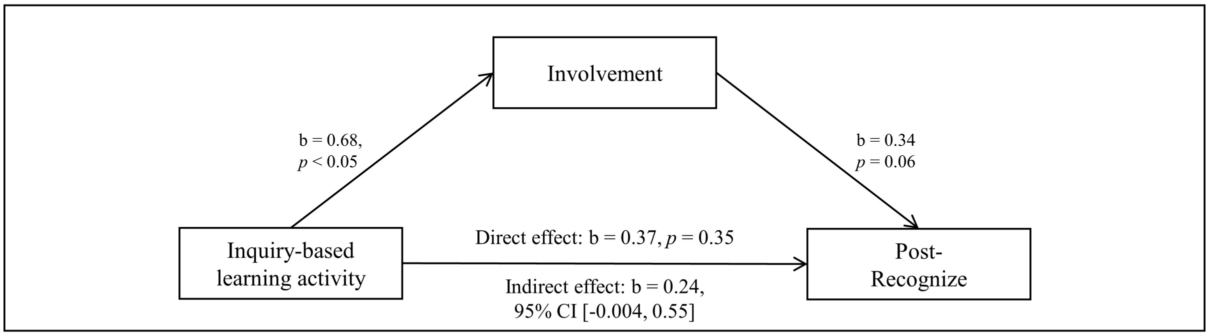


Figure 2.6: Mediation analysis of the indirect effect of the inquiry-based learning activity on children's selection of correct structures and functions through involvement

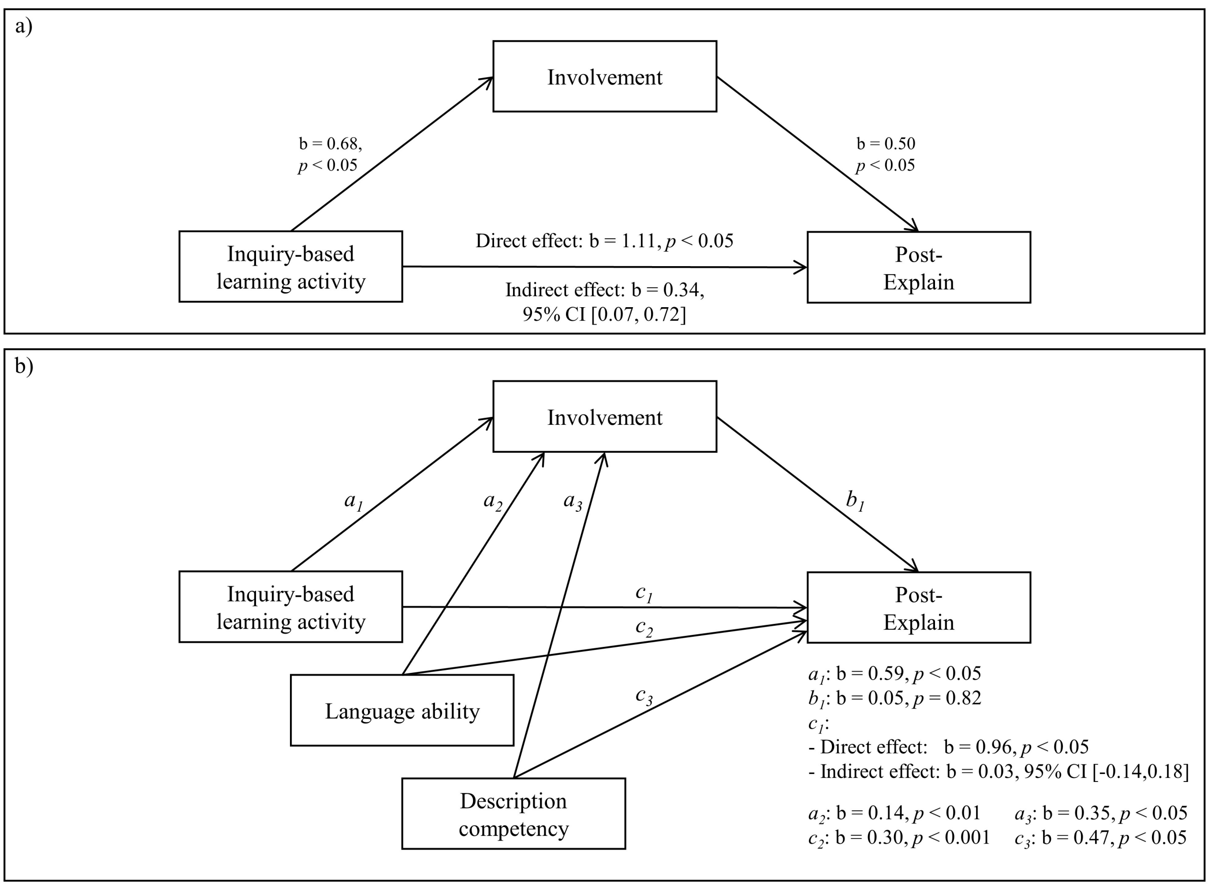


Figure 2.7: Mediation analysis of the indirect effect of the inquiry-based learning activity on children's conceptually based explanations through involvement: a) without covariates, b) with covariates language ability and description competency

2.5 Discussion

This study intended to (a) analyse the effect of an inquiry-based science activity on preschoolers' learning outcome, i.e. their conceptual knowledge, (b) analyse the effect of an inquiry-based science activity on preschoolers' learning experience during the learning situation, characterized by their level of involvement, and (c) understand the role of children's involvement as a mediator for their conceptual learning.

These investigative aims are important for several reasons. Even though the inquiry-based approach is increasingly depicted as a suitable strategy to engage young children with science (Eshach & Fried, 2005; Gerde et al., 2013), there is a scarcity of studies analysing the impact of this approach on preschool children. The lack of attention towards this age group is reflected in several meta-analyses about inquiry-based science education conducted in the last years. Furtak, Seidel, et al. (2012), for example, included 37 experimental and quasi-experimental studies in a meta-analysis on the effects on student learning. Even though the literature search covered K-12 classrooms, none of the included studies focused on preschool children; in fact, the youngest students that were investigated were 3rd graders (Hardy, Jonen, Möller, & Stern, 2006). Lazonder and Harmsen (2016) presented a meta-analysis on the effects of different types of inquiry guidance, and only 2 out of the 68 studies comprised in the analysis were conducted with preschoolers (Baroody, Eiland, Purpura, & Reid, 2012; Steffensky et al., 2012). Surely, these reports do not include some studies mentioned above that do focus on preschool children. Nevertheless, they do reflect that without a sound body of research, the extent to which this approach is truly beneficial for young children remains unclear. In addition, to the best of my knowledge, there is no study that specifically addresses the mediating role of children's experiences on their learning outcome in an inquiry-based science activity.

The most prominent difference between the inquiry-based and the control learning context in this study refers to the type and range of activities children engaged in. In each station of the inquiry-based context, children aimed at answering a question by engaging in several phases of the inquiry cycle, which included the scientific procedure of comparison, under the guidance of an instructor, whereas in the control activity they did not engage in an investigative process. As previous research has demonstrated, the more inquiry phases students engage in during a science lesson, the higher is their gain of content knowledge (Dorfner, Förtsch, Germ, & Neuhaus, 2018). Therefore, children of the inquiry group were expected to learn more about the relation between biological structures and functions through their own investigation (French, 2004; Peterson & French, 2008; Samarapungavan et al., 2011; Steffensky et al., 2012). Hereby it's important to highlight that the questions of the post-test did not directly relate to the content of the learning activity. Therefore, the idea of the post-test was not to evaluate whether children remembered the structural and functional relations learned during the inquiry-based activity, but to assess whether the inquiry group was better at *recognizing* and *explaining* relations between biological structures and their functions in comparison to the control group after participating in the learning activity. Unfortunately, the results of the Rasch analysis presented above (see section 1.3) showed that, even though the items proved to be successful in assessing children's ability to recognize and explain structural and functional relationships, the anchoring did not achieve the required quality to confidently rely on the changes between pre- and post-test. Therefore, the findings presented here should be considered tentative.

The results of this study demonstrate that the inquiry group was not better than the control group in their recognition of correct structures or functions of different organisms, but they were better at giving conceptually based justifications for their selections. This indicates that the inquiry-based approach did not have an influence on children's ability to *recognize* relations between biological structures and their function (i.e. cognitive process *recognize*), but it did influence children's ability to *explain* those relations that they did recognize by referring to certain characteristics of those structures and functions (i.e. cognitive process *explain*).

The fact that children did not improve in their selections of correct structures and functions is consistent with the idea that the knowledge enrichment that would be necessary to successfully achieve this is a long process that requires several exposures to a given topic (Ghazali-Mohammed, 2016; Halldén & Caravita, 1994). This goes in line with Samarapungavan et al. (2011), who compared children that participated in guided inquiry in a 5-week period with those taking part in a 10-week period and showed that participants of the longer treatment had a greater acquisition of knowledge regarding important biological concepts.

The effect found on children's conceptually based explanations, however, indicates that even a one-time inquiry-based learning event can have a positive impact on their ability to describe and explain structural and functional similarities and differences of organisms, even after controlling for previous conceptual knowledge, language ability and description competency. This effect relies in the way the instructor interacted with the children. The inquiry-based approach represents a language-rich environment in which teachers' guidance can fulfil both its problematizing and its structuring function (Studhalter et al., 2021). The scientific procedure of comparison that was conducted within the inquiry cycle plays an important role within the problematizing function of teacher scaffolding talk, as stated by Studhalter et al. (2021). Several studies indicate that adult's use of language within an investigative process supports children's development of science-related vocabulary and discourse skills (e.g., Dickinson & Porche, 2011; French, 2004). Due to the inquiry context with a focus on comparison, the instructor provided children with a problematizing and structuring guidance. He helped them recognize the differences between the structural models and deduce the relation with the function, thus creating an expectation of conceptually based arguments. At the same time, he encouraged them to answer the initial questions by referring to their own observations about the different models. This way, he offered children several opportunities to formulate evidence-based explanations, which are considered a strong predictor of student learning (McNeill & Krajcik, 2008; Songer & Gotwals, 2012). This is similar to the findings of Peterson and French (2008), who recognized that teachers' use of a repeated observation-prediction discourse format elicited an improvement in young children's scientific explanatory language. Further, the fact that the conducted learning activity had an influence on children's conceptual explanations in contexts that were not the subject of study suggests that the inquiry-based approach is an appropriate strategy to foster children's ability to transfer their conceptual knowledge beyond the learned content. Hereby it's important to keep in mind that children of the inquiry group had a significantly higher language ability compared to those of the control group. Given the importance of linguistic skills in the participation of collaborative inquiry processes (Akerson et al., 2000; Van Boxtel et al., 2000), it is possible that children of the inquiry group were in an advantage to profit from the instructor's guidance.

The video-based analysis showed that, even after controlling for previous conceptual knowledge, language ability and description competency, the inquiry-based activity led to higher levels of involvement in the participants. Here again, the present guidance played a crucial role. In the inquiry-based learning activities, the instructor posed questions that challenged the children and stimulated their motivation to engage in the investigation. This kind of support, together with the fulfilment of their exploratory drive, are key to understand the higher involvement levels found in the inquiry group. To the best of my knowledge, the few studies that have investigated the relation between an inquiry-based approach and preschoolers' experiences during the learning activities have reported qualitative assessments of children's active participation in their own learning and developing feelings of participation and enjoyment in science (Andersson & Gullberg, 2014; Conezio & French, 2002; Howitt et al., 2011). Thus, the findings presented here represent a quantitative confirmation of previously only qualitatively described effects of this type of instruction.

No significant indirect effect of the inquiry-based activity on children's outcomes through involvement could be found after including children's language ability and description competency as covariates. These results suggest that in the case of inquiry-based learning contexts, the mediating role of involvement is not as straight forward as Laevers' EXE-model assumes. Rather, the knowledge and capabilities that children bring to the table seem to have a greater impact on their conceptual learning. This does not take away the importance of involvement as a relevant goal of early science education. An important characteristic of this measurement is the fact that it gives immediate feedback about the quality of an educational context, unlike learning outcomes, which often come to light only after a long period of time (Laevers, 2000). As Andersson and Gullberg (2014) point out, children's "learning" in science is not only related to the acquisition of scientific content knowledge, but also to the knowledge of the social practices of science, and their experience as active agents in their own learning process. An example of this can be found in a study comparing a student-driven and a teacher-led learning design with 5th graders on the topic of mathematics (Sengupta-Irving & Enyedy, 2015). Here, the authors found that despite equal gains in knowledge, participants reported liking the student-driven approach better than the teacher-led design and were more positive about learning, and video-based analyses revealed that these differences were partly because this group engaged more frequently in using data and different inquiry phases. Thus, children's positive experiences with science are important even independently of other cognitive learning outcomes. In this case, the existing correlation between children's involvement and their conceptual explanations in the post-test suggests that even though the former may not play a mediating role on the latter, they certainly go hand in hand as two important outcomes of an inquiry-based learning situation.

2.5.1 Limitations

As stated before, an important limitation of this study is the low quality of the anchor items of the instrument assessing children's conceptual knowledge, which unfortunately does not allow for a fully reliable identification of changes from pre- to post-test. The main issue that led to such unsatisfactory quality is the small amount of anchors, as it did not leave room to discard malfunctioning items. Given that this issue stems from the limited time that can be invested in interviewing young children, future instrument implementations should keep this in consideration, especially those aiming at addressing changes over time.

Children of the inquiry group possessed a significantly higher language ability than those of the control group. Given this, all analyses of covariance present an overlap between the effect of inquiry and the effect of language ability, which means that part of the variance found in each dependent variable was explained by both the inquiry-based learning context and children's language ability (Field, 2017). This translates into a reduction of the effect of inquiry (Field, 2017), which means that in these cases, the effect of the inquiry-based learning context on children's *post-recognize*, *post-explain*, and *involvement* is underestimated. Similarly, the effects found in the mediation analysis could be understated. It may very well be that, without a pre-existing difference between the groups, a significant mediating role of involvement could have been found.

The differentiation between the experimental and the control learning environment relied on the implementation of the inquiry-based approach. Hereby, a decision had to be made on the scientific procedure that was to be implemented. Given that comparing objects is considered an appropriate process to integrate in early science education and that, from an everyday-perspective, young children are rather familiar with this way of engaging with the world around them, the decision was made on choosing the process of comparison as the scientific procedure to be conducted in the experimental learning activity. Although this decision was driven by theory, it led to a confounding between the effect of the inquiry-based approach and the provided materials. It's possible that the mere presence of another model could have an impact on children's learning experiences and outcomes. Nevertheless, the act of comparing objects and, with that, the presence of a second model, was viable only in the experimental learning activity as it was the central procedure in which the scientific inquiry took place.

As it often happens in experimental intervention studies, the inquiry-based learning activity took in average 16 minutes longer than the control activity. This difference was inevitable due to the nature of the tasks involved. One could argue that a difference in instruction time could partly explain the learning outcomes. Nevertheless, several characteristics of this study indicate that this is not the case: Both the inquiry-based and the control activity consisted of the same amount of stations, each of which represented a learning opportunity. Thus, in this case, a longer instruction time did not mean that children had more learning opportunities, but merely that each one of them took longer to complete. Further, the results show that children of the inquiry group did not improve in their selection of correct structures and functions compared to the control group. Instead, in the questions in which they selected the correct structures and functions, the children of the inquiry group were better at referring to the structural and functional relationship when justifying their selections. As stated before, the questions of this instrument did not directly relate to the learned content, so the post-test required children to transfer their conceptual knowledge into new contexts. Thus, participants of the inquiry group did not learn more than those of the control group. Rather, their improvement was of a qualitative nature, as the main difference between the two groups lied in their conceptually based (and transferred) explanations. Moreover, the results regarding involvement can only be explained by the instructional context and not by the instruction time, as this measurement was observational. If anything, the difference in instruction time further accentuates the importance of these results, as it could be expected that preschoolers' level of involvement would decline over time, so that any significant difference between groups would disappear. Nevertheless, in this study this was not the case.

Chapter 3

Study 3

3.1 Theoretical background

Early education, i.e. the education of young children before starting school around the age of six, has experienced great changes in the last years. While for a long time the focus lied mainly on children's development of language and social skills, science has now become a crucial element of this field (Eshach, 2006; Fthenakis et al., 2009; Gelman & Brenneman, 2004; Scheiwe & Willekens, 2009; Staatsinstitut für Frühpädagogik München, 2006; Standards, 2013). This development is reflected in current guidelines and standards for early science education, which state that preschool children should receive varied opportunities to engage in scientific inquiry activities (Council et al., 2012; Staatsinstitut für Frühpädagogik München, 2006). In Bavaria, for example, the education and development plan for preschool mentions that children should be enabled to observe, compare, and describe short- and long-term changes in nature, conduct experiments, form hypotheses and test them using appropriate methods (Staatsinstitut für Frühpädagogik München, 2006).

The responsibility for this lies on the shoulders of early childhood education professionals. They are now expected to recognize relevant everyday situations and children's questions and interests that can be used to develop and implement science learning opportunities (Steffensky, 2017). To successfully achieve this, preschool teachers should possess not only knowledge of science and how to teach science to young children, but also the motivation, interest, and self-efficacy to do so (Anders et al., 2018). Given that for a long time, the priority of preschool teachers has been to foster children's language and social skills (Copley, 2004; Greenfield et al., 2009; Scheiwe & Willekens, 2009), this development entails new professional expectations for which preschool teachers are often not sufficiently equipped. It is thus not surprising that, as several studies have demonstrated, both the quantity and the quality of science-related learning opportunities in preschool generally leave much to be desired (Connor, Morrison, & Slominski, 2006; Early et al., 2010; Gerde et al., 2013; Greenfield et al., 2009; Hollingsworth & Vandermaas-Peeler, 2017; Kauertz & Gierl, 2014; Piasta, Pelatti, & Miller, 2014; Roehrig, Dubosarsky, Mason, Carlson, & Murphy, 2011; Tu, 2006). Connor et al. (2006), for example, found that preschoolers spend on average barely 8 minutes of their day in activities related to math and science, whereas Piasta et al. (2014) found a large variability ranging from 0 to 102 minutes with an average of 26 minutes dedicated to science. In terms of quality, a study in Germany found great variance regarding the cognitive activation within science learning opportunities in preschool (Kauertz & Gierl, 2014). Furthermore, Hollingsworth and Vandermaas-Peeler (2017) discovered that, even though preschool teachers were able to identify science-related topics and activities, they were not able to implement complete cycles of inquiry, as their science activities often included only the beginning steps of inquiry, i.e. observing and questioning, but not the subsequent and more complex steps, i.e. making predictions and evaluating evidence. Similar findings were presented by Inan (2010), who showed that pre-service preschool teachers made use of different scientific process skills in varying frequencies, e.g. observing was the most used skill, whereas the least used skills were predicting and data gathering.

Several reasons may account for this gap between expectation and reality. Preschool teachers may still be influenced by Piaget's assumptions that preschool-aged children are not yet cognitively able to learn science (e.g., Piaget, 1978), hold negative attitudes towards science education in general (Baroody, Lai, & Mix, 2006; Copley & Padron, 1998; Koballa Jr & Crawley, 1985; Sutton, Watson, Parke, & Thomson, 1993; Tosun, 2000), or consider it less important than other educational fields and thus allocate less time to it (Copley, 2004; Greenfield et al., 2009). Further, several studies have shown that preschool teachers lack self-efficacy in teaching science (Copley, 2004; Greenfield et al., 2009; Olgan, 2015; Spektor-Levy, Baruch, & Mevarech, 2013), and have not been properly trained for this task (Isenberg, 2000; Lobman, Ryan, & McLaughlin, 2005; Özbey & Alisinanoğlu, 2008). Barenthien, Oppermann, Anders, and Steffensky (2020), for example, found that the majority of German preschool teachers have never participated in any science-related course, neither during their pre-service training nor during their employment as early childhood education professionals.

Most important are the findings demonstrating that preschool teachers' knowledge of science concepts and phenomena and knowledge of how to teach science to young children is rather limited, and widely heterogeneous at best (Appleton, 2008; Barenthien, Lindner, Ziegler, & Steffensky, 2020; Björklund & Barendregt, 2016; Bose & Seetso, 2016; Chee, Mariani, Othman, & Mashitah, 2017; Dunekacke et al., 2015; Garbett, 2003; Gropen et al., 2017; Isenberg, 2000; Kallery & Psillos, 2001; Kutluca, 2021; Leavy & Hourigan, 2018). Other studies have shown that preschool teachers often hold – and therefore also teach – conceptions that are not scientifically correct (Kallery & Psillos, 2001) and have insufficient knowledge about the steps of the inquiry process (Hollingsworth & Vandermaas-Peeler, 2017). This situation has led to an ongoing debate about the competences that preschool teachers need in order to successfully fulfill their new professional expectations (e.g., Andersson & Gullberg, 2014; Viernickel, 2009).

Before diving into the following section, it's important to mention that current theoretical assumptions about the competence of early childhood professionals are heavily based on research with primary and secondary school teachers, given that not many studies have centered specifically around preschool teachers (Anders, 2012; Anders et al., 2018). A special focus on them is nevertheless necessary due to the fundamental differences in the working conditions of school and preschool teachers (Dunekacke et al., 2015, 2016).

3.1.1 Teachers' professional competence

Current conceptualizations of what teachers need in order to fulfill the demands of their profession are based on Weinert's (1999, 2001) definition of competence. According to Weinert (1999, 2001), competence encompasses the cognitive abilities and skills that are available in individuals or can be learned by them for solving specific problems, as well as the associated motivational, volitional and social willingness and skills necessary to solve problems successfully and responsibly in variable situations. Based on this, professional competence is understood as a multidimensional construct, a complex set of cognitive and affect-motivational dispositions that underlie a person's performance in a particular professional field (Blömeke et al., 2015). Moreover, professional competence is regarded as a horizontal continuum, a process in which dispositions are integrated and transformed into an observable performance through the mediation of situation-specific skills (Blömeke et al., 2015).

Blömeke et al.'s (2015) competence model has been widely used as a theoretical framework to investigate primary and secondary teachers' professional competence. In this context, teachers' dispositions consist of their professional knowledge, motivational orientations, beliefs, and self-regulation, as defined by the COACTIV competence model (Kunter, Baumert, & Blum, 2011), whereas teachers' situation-specific skills include the perception and interpretation of a particular situation as well as the consequent decision-making (Blömeke et al., 2015). Teachers' performance, on the other hand, refers to the observable instructional practice that takes place during a learning situation, which includes, for example, the implementation of a relevant instructional strategy (Kunter et al., 2013).

Regarding early education, Fröhlich-Gildhoff et al. (2011) construed a professional competence model with a focus on preschool teachers, which distinguishes between the foundations for action, the willingness to act, and the acting in a particular situation. Regardless of the terminology used to describe this model, important parallels can be found between this and the conceptualizations of school teachers' competence presented above. Therefore, in the following, I will describe the elements of Fröhlich-Gildhoff et al.'s (2011) model and, in parenthesis, I will name the equivalent elements of Blömeke et al. (2015) and the COACTIV competence model (see also Figure 3.1).

According to Fröhlich-Gildhoff et al. (2011), the foundations for action are characterized as an interplay between theoretical and experiential knowledge and skills (disposition: professional knowledge), motivation (disposition: motivational orientation), and the perception and analysis of a given situation (situation-specific skills: perception and interpretation). These aspects thus have an effect on the action planning and willingness to act (situation-specific skill: decision-making). These, in turn, influence the acting in the particular situation (performance), which can then be evaluated and, as a consequence, shape the foundations for further action. Further, all these aspects are influenced by the self-reflection and professional attitude, which encompasses a person's action-guiding orientations, values, and beliefs (disposition: beliefs and self-regulation).

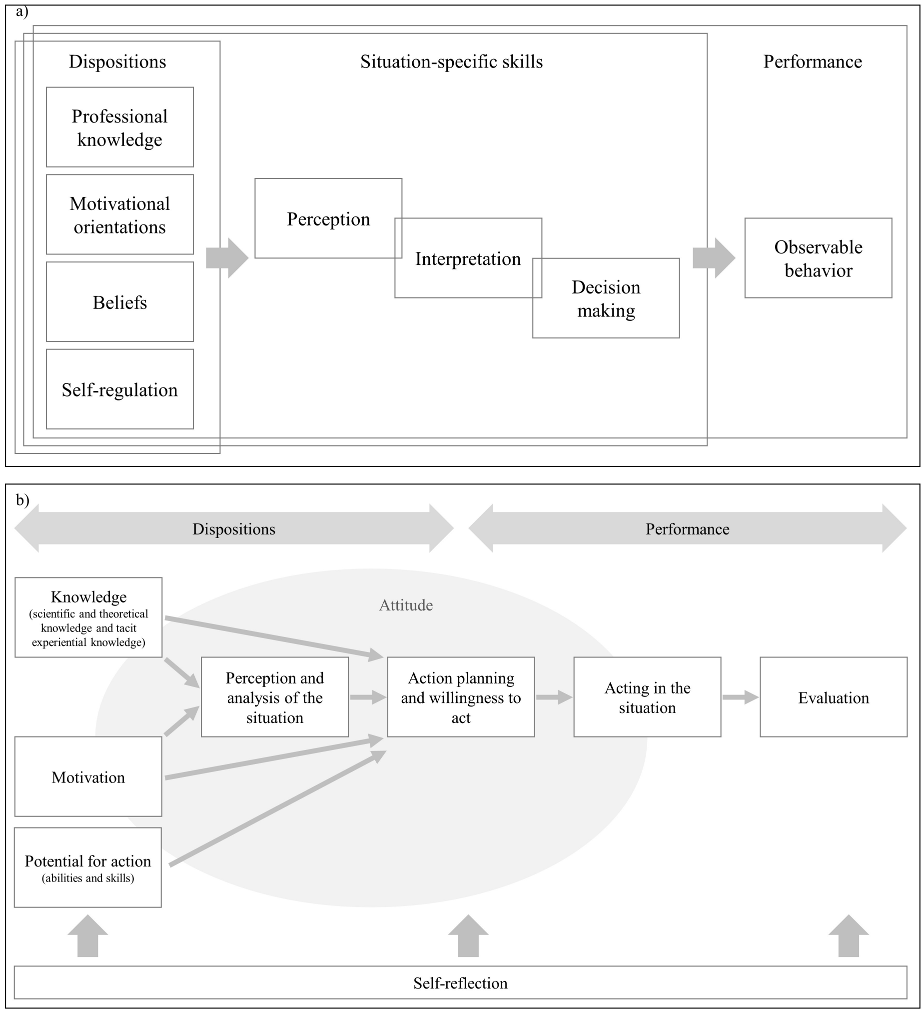


Figure 3.1: a) Teachers' professional competence model, adapted from Blömeke et al. (2015) and Kunter et al. (2011). b) Preschool teachers' professional competence model, adapted from Fröhlich-Gildhoff et al. (2011)

This competence model can thus be used as a theoretical framework to investigate the relation between preschool teachers' dispositions, i.e. foundations for action, and certain elements of their performance, i.e. acting in the situation. In this study, the focus lies on the relation between preschool teachers' domain-specific professional knowledge and their instructional practice during a science learning situation with preschool children. Thus, in the following, I will present the topology of teachers' professional knowledge and the relevance of each facet within the context of early science education, explore the dimensions of science-related instructional practices in preschool, and finally discuss the current state of research regarding the role of preschool teachers' professional knowledge on their instructional practices.

Professional knowledge

Modern conceptualizations of teachers' professional knowledge are based on L. S. Shulman's (1986; 1987) topology, which originally differentiated between content knowledge, pedagogical knowledge, pedagogical content knowledge, curriculum knowledge, knowledge of learners and their characteristics, knowledge of educational contexts, and knowledge of educational ends, purposes and values. This model has since then been modified and simplified by several authors; currently, there is broad consensus that the three main facets of teachers' professional knowledge are content knowledge (CK), pedagogical content knowledge (PCK), and pedagogical knowledge (PK) (Baumert et al., 2010; Baumert & Kunter, 2013; Borko, 2004; Brunner, Anders, Hachfeld, & Krauss, 2013; Darling-Hammond, 2010; Park & Oliver, 2008; L. S. Shulman, 1986; L. Shulman, 1987). In the last years, this tripartite categorization has increasingly been transferred to professionals in early childhood education (Anders, 2012; Anders et al., 2018; Barenthien, Lindner, et al., 2020; Blömeke, Jenßen, Grassmann, Dunekacke, & Wedekind, 2017; Dunekacke & Barenthien, 2021; Dunekacke et al., 2015, 2016; Fröhlich-Gildhoff et al., 2011; McCray & Chen, 2012). Given that CK and PCK are the two domain-specific knowledge facets and are considered the most important for high-quality education (Krauss, Baumert, & Blum, 2008), they will be in the focus of this dissertation.

Content knowledge (CK), also known as subject matter knowledge, is defined as the in-depth understanding of a particular subject (Baumert et al., 2010). This includes the knowledge about phenomena, concepts, principles and theories of the domain or discipline and the ability to apply this knowledge in different contexts (Großschedl, Harms, Kleickmann, & Glowinski, 2015; Steffensky, 2017). In the field of early science education, there is not yet an established consensus on the CK that preschool teachers need in order to support children's learning, although it is generally accepted that teachers should possess a level of CK that is more advanced than the one they teach, i.e. that corresponds to the subsequent level of education (Anders et al., 2018; Barenthien, Lindner, et al., 2020; Garbett, 2003). For early childhood professionals, this means that they should possess a level of knowledge that corresponds, at least, to the learning goals of primary education. In general, preschool teachers' CK should allow them to recognize science content in everyday situations and identify children's misconceptions; it should include an understanding of basic yet scientifically correct concepts that are appropriate for children's everyday life and that are connectable to the basic core concepts addressed in primary school (Anders et al., 2018; Barenthien, Oppermann, et al., 2020; Kallery & Psillos, 2001; Oppermann et al., 2016; Osborne & Simon, 1996). In the field of life science in particular, this means that preschool teachers should possess an understanding of concepts such as structure and function, growth and development, and adaptation, as these represent the basic core ideas that structure science lessons later in school (Kultusministerkonferenz, 2004; Steffensky, 2017).

Pedagogical content knowledge (PCK) was first defined as "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learning, and presented for instruction" (L. Shulman, 1987, p. 8). PCK is thus understood as the knowledge that is necessary to make a particular topic comprehensible to a particular group of students in a particular learning context (Chan & Hume, 2019).

Although PCK has been conceptualized in various ways by different authors (e.g., Abell, Appleton, & Hanuscin, 2013; Baumert et al., 2010; Baxter & Lederman, 1999; Berry, Loughran, & van Driel, 2008; Chan & Hume, 2019; Magnusson, Krajcik, & Borko, 1999), there is general agreement that it consists of two main components: knowledge of students' understanding, which comprises the knowledge about what students find difficult to learn and the previous knowledge necessary for learning specific scientific topics, and knowledge of instructional strategies, that is, teachers' knowledge of specific activities and representations to support students understanding of a given topic (Depaepe, Verschaffel, & Kelchtermans, 2013; Großschedl et al., 2015; Hill et al., 2008; E. Lee & Luft, 2008; Magnusson et al., 1999; Park & Oliver, 2008; L. S. Shulman, 1986). In the context of science instruction, knowledge of instructional strategies incorporates two aspects: knowledge of experiments and knowledge of models (Jüttner, Boone, Park, & Neuhaus, 2013; Tepner et al., 2012).

This theoretical understanding of PCK, originally defined for primary and secondary school teachers, has also been applied to preschool teachers, although the corresponding empirical research is still in its infancy (Anders et al., 2018; Barenthien, Lindner, et al., 2020; Dunekacke et al., 2015, 2016; Ginsburg & Ertle, 2008; J. Lee, 2010; Sarama & Clements, 2009). Considering the goals of early science education, preschool teachers must possess knowledge about children's cognitions and knowledge about suitable scientific inquiry activities, both of which enable them to recognize and make use of everyday situations to create structured learning environments in which children can gain positive experiences with science and develop basic conceptual knowledge (Andersson & Gullberg, 2014; Barenthien, Lindner, et al., 2020). This requires an understanding of the type of support children need when engaging with science. Following the conceptualization of the two components of knowledge of instructional strategy – knowledge of experiments and of models – this includes, on one hand, an understanding of what topics are of interest to the children, what type of scientific questions are age-appropriate and answerable through available means, and how to support children in the formulation of their own hypotheses as well as in the description and interpretation of their own observations. On the other hand, it encompasses an understanding on how models can be constructed and/or used as hands-on materials to foster children's learning of certain scientific concepts, and which aspects of the models should be compared to the real objects and critically reflected upon.

Instructional practice

In light of the increasing importance of science in early education, preschool teachers are confronted with two important questions. The first one refers to what type of content should be explored with preschool children. Steffensky (2017) mentions different criteria for the selection of suitable content for early science education. These include choosing topics that originate from children's questions or that can spark their curiosity, finding connections between the topic and children's everyday life, and embedding these topics within basic core concepts that children can use to make sense of the world around them and that can be built upon in later learning opportunities (Möller & Steffensky, 2010; Steffensky, 2017). In this study, the focus lies on the topic of animals of the forest, such as woodpeckers and owls, and the concept of structure and function. This concept represents the relation that exists between certain structures of an organism and the purpose they serve, e.g. the relation between a duck's webbed feet and its ability to swim (Kultusministerkonferenz, 2004; Standards, 2013). Given that this relation is the basis for understanding more complex biological phenomena, and that young children already encounter many examples of this relation in their everyday experiences with animals, plants and their own body, this concept is considered appropriate for the context of early science education (Staatsinstitut für Frühpädagogik München, 2006; Steffensky, 2017).

The second question refers to which type of guidance is adequate and beneficial for preschool children. In the last years, practical recommendations for preschool teaching increasingly depict the guided inquiry approach as a suitable strategy to engage kindergarteners with science (Eshach & Fried, 2005; Gerde et al., 2013). This approach is based on the scientific inquiry process, which is defined as a cycle consisting of several interconnected inquiry activities that include questioning, generating an hypothesis, collecting and interpreting evidence and drawing conclusions (Pedaste et al., 2015). As such, preschool teachers can make use of the scientific inquiry process as a structuring framework to allow children to actively engage in an investigation in order to answer a research question (Abd-El-Khalick et al., 2004; R. D. Anderson, 2002; Bell et al., 2005; Decristan et al., 2015; Furtak, Shavelson, et al., 2012; Minner et al., 2010).

Against this background, in the study presented here, the instructional practice is operationalized as consisting of two dimensions: the content dimension, that relates to the topics and concepts addressed during the learning situation, and the inquiry dimension, that refers to the extent to which preschool teachers implement scientific inquiry activities during the learning situation.

Relation between content knowledge, pedagogical content knowledge, and instructional practice

Several empirical studies on school teachers have demonstrated that the CK and PCK dimensions are unique and separable, but correlated to each other (e.g., Blömeke & Suhl, 2010; Großschedl et al., 2015; Jenßen et al., 2015; Kleickmann et al., 2017; Krauss et al., 2008; Riese & Reinhold, 2012), whereby the strength of this correlation seems to depend on the degree to which the operationalization of PCK is related to the content (Buchholtz, Kaiser, & Blömeke, 2014). Kleickmann et al. (2017) investigated the role of prior CK and PK for the development of PCK of science teachers. They found that training in both a combination of CK and PK as well as CK alone could account for a certain degree of PCK development, although training in PCK alone as well as a combination of CK and PCK proved to be more effective. This indicates that "explicitly addressing the knowledge of students, learning and teaching in concrete content domains, whether with or without antecedent CK instruction, appeared to be the most effective pathway" (Kleickmann et al., 2017, p. 126).

The last decade has seen a surge of studies investigating the role of school teachers' professional knowledge on different features of their instructional practice in mathematics, physics, and biology lessons. These studies show a relation between teachers' PCK and the instructional quality in terms of different indicators, such as the cognitive activation (Baumert et al., 2010; Förtsch et al., 2016; Kunter et al., 2013), and the quality of teachers' explanations (Kulgemeyer & Riese, 2018); although there are some contradictory findings that indicate that PCK does not always correlate with the quality of instruction (Cauet, Liepertz, Borowski, & Fischer, 2015; Delaney, 2012; Ergönenç, Neumann, & Fischer, 2014). In general, it is agreed that CK is a necessary but not sufficient condition to conduct effective teaching; rather, CK is considered a precursor of PCK (Abell et al., 2013; Ball, 1988; Ball, Hill, & Bass, 2005; Baumert et al., 2010; Kulgemeyer & Riese, 2018).

Here again, there is little empirical evidence regarding early childhood professionals. The few studies that have addressed this on preschool teachers indicate that in this case too, preschool teachers' PCK is indicative of their instructional practices (Gropen et al., 2017; J. Lee et al., 2003; J. Lee, 2005). Gropen et al. (2017) investigated the relation between preschool teachers' physics-related PCK and instructional quality. Here, the conceptualization of PCK included teachers' understanding of relevant science concepts, i.e. their CK, whereas the quality of instruction was assessed in terms of their ability to plan science learning environments and conduct high quality science-related interactions with children, and can thus also be regarded as cognitive activation or instructional support (Steffensky, 2017). The results showed a significant correlation between PCK and high-quality science teaching (Gropen et al., 2017). These findings go in line with those of early mathematics education. J. Lee et al. (2003) and J. Lee (2005) showed that preschool teachers with higher mathematics PCK (MPCK) conducted high-quality mathematics instructions more frequently, and McCray and Chen (2012) found a positive relation between preschool teachers' MPCK and the quality of math teaching in terms of the frequency of math-related language. Further, CK seems to act as a precursor of PCK, at least in the field of early mathematics. Oppermann et al. (2016) found that preschool teachers' mathematics CK (MCK) predicts their ability to recognize mathematical contents in children's play. Dunekacke et al. (2016) studied the effect of preschool teachers' MCK and MPCK on their ability to perceive relevant learning situations and plan adequate educational activities to foster children's learning. They found no direct effect of MCK, but discovered that it acted as a predictor of MPCK, which in turn predicted preschool teachers' perception and planning skills (Dunekacke et al., 2016).

These studies represent an important starting point in the research field of early mathematics and science education. However, there is still a dire need of empirical evidence regarding the relation between preschool teachers' professional knowledge and instructional practices, as several questions remain unanswered. Especially in the context of preschool, in which the co-constructivist perspective of learning plays a significant role, there is an ongoing debate about the importance of the different knowledge facets (Anders, 2012; Anders et al., 2018). Regarding PCK, the question arises as to whether preschool teachers need specific science-related PCK – e.g. knowledge of the guided inquiry approach – in order to engage children with scientific learning opportunities or if, in their case, they can compensate using their existing CK, following the views that PCK can develop from teachers' prior CK alone or from an amalgamation of their CK and PK (see Kleickmann et al., 2017). Regarding the importance of CK, two opposing views can be found: One view states that an in-depth CK is necessary to accompany young children's science learning process, just as it is necessary for teaching older students, whereas the opposing view considers CK to be far less relevant compared to PCK, assuming that a preschool teachers' PCK can compensate for the lack of CK in specific learning situations (see Anders, 2012; Anders et al., 2018; Steffensky, 2017). The latter perspective thus considers that, in the case of science instruction, it is more important to know how to structure a science learning episode than to have an understanding of the specific content that is being addressed. In other words, preschool teachers should be able to engage in scientific inquiry processes with children, i.e. using children's questions and interests as a starting point of an investigation and guiding them through the different inquiry phases, even when they do not know what the outcome of this investigation will be. Considering that preschool teachers often do not feel confident in teaching science due to a lack of CK, this perspective is an important focus of investigation.

3.1.2 Effect of training

Teachers' professional competence is believed to be learnable; it can be trained and modified through formal and informal education and it develops continuously throughout a teachers' professional journey (Epstein & Hundert, 2002; Koeppen, Hartig, Klieme, & Leutner, 2008; Shavelson, 2010; Sternberg & Grigorenko, 2003; Weinert, 2001). Professional development (PD) is considered the most effective approach to successfully foster teachers' competence and, in turn, improve instructional practices and student outcomes (Ball & Cohen, 1999; Buysse, Winton, & Rous, 2009; Darling-Hammond & McLaughlin, 1995; Desimone, 2009; Little, 1993). In general, PD is defined as all types of "facilitated teaching and learning experiences that are transactional and designed to support the acquisition of professional knowledge, skills, and dispositions as well as the application of this knowledge in practice" (Buysse et al., 2009, p. 239). In this context, "dispositions" are understood as the motivational orientation and beliefs a teacher holds (Sheridan, Edwards, Marvin, & Knoche, 2009). Teachers' PD takes place not only prior to their employment, e.g. through formal education in an university, but also when they are already active practitioners. This kind of in-service PD can take the form of specialized training, including workshops, conferences, and lectures; coaching interactions and communities of practice (Little, 1993; Sheridan et al., 2009).

Desimone (2009) defined five critical features that determine the effectiveness of PD. These include (a) a content focus, based on the evidence that PD with a focus on CK and PCK increases teacher's knowledge, skills and practice; (b) active learning, i.e. teachers have opportunities to be actively involved in their learning process, for example, by being observed during their own practice and receiving interactive feedback; (c) coherence, i.e. the consistency between what is being taught and relevant teaching reforms and policies; (d) duration, based on the evidence that both the span of time and the number of hours in which the PD takes place are factors that play a role in its effectiveness; and (e) collective participation, as the participation of teachers from the same school or grade can foster fruitful interactions and knowledge exchange between colleagues. Similarly, Buysse et al. (2009) described characteristics of effective PD that go in line with Desimone's (2009) critical features. According to Buysse et al. (2009), effective PD opportunities are "focused on professional practices and consist of content-specific rather than general instruction" (p.240), i.e. content focus; "aligned with instructional goals, learning standards and the curriculum materials that practitioners use in practice" (p.240), i.e. coherence; "intensive [and] sustained over time" (p.240), i.e. duration; and "include guidance and feedback on how to apply specific practices through methods such as coaching, consultation, or facilitated collaboration (e.g., communities of practice, teacher study groups)" (p.240), i.e. active learning and collective participation.

Further, different models of effective PD (Desimone, 2009; Fishman, Marx, Best, & Tal, 2003; Garet, Porter, Desimone, Birman, & Yoon, 2001; Guskey & Sparks, 2004; Kunter et al., 2011; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007) agree that the process by which PD influences teacher and student outcome consists of following steps: First, teachers participate in an effective PD opportunity, which encompasses the critical features described above. This leads to an improvement in teachers' dispositions, i.e. their CK, PCK, motivational orientations, and beliefs. Teachers then make use of these new dispositions to improve their instructional practices with students. Finally, these improved instructional practices have a positive impact on student learning experiences and outcomes.

The crucial features of PD effectiveness and the conceptual framework describing how PD affects teachers and student outcomes have also been applied to the field of early science education (Steffensky, 2017). In the last years there has been an increase in science-related PD opportunities for preschool teachers across the world, such as the Project ASTER (Active Science Teaching Encourages Reform) and the ScienceStart! Curriculum in the USA (Duran, Ballone-Duran, Haney, & Beltyukova, 2009; French, 2004), the Little Scientists project in Australia (MacDonald, Huser, Sikder, & Danaia, 2020) and the offers of the Little Scientists' House and the Klaus Tschira Competence Centre for Early Science Education in Germany (Anders et al., 2018; Zimmermann, 2013).

Research in this field has also been growing, so that there are now first insights into the effects of such science-related PD opportunities on preschool teachers' beliefs, knowledge and instructional practices. Duran et al. (2009) demonstrated the positive effects of the PD Program ASTER, which focuses on inquiry-based science teaching through exhibit-based hands-on/minds-on investigations at a science museum, on early childhood teachers' self-efficacy and perceptions about inquiry-based science teaching. Barenthien, Oppermann, et al. (2020) found a positive relation between the amount of PD courses preschool teachers attended to and their self-efficacy beliefs, enthusiasm for teaching science, and science-related CK. Roehrig et al. (2011) found that a sustained PD program within the Head Start project improved early childhood teachers attitudes toward science. Further, they found that after 2 years their instructional practices were increasingly inquiry-based and contained higher levels of instructional support, i.e. cognitive activation (Roehrig et al., 2011). Similarly, Atiles, Jones, and Anderson (2013) found a positive impact of a science-focused PD on preschool teachers' self-efficacy beliefs and science-related PCK, reflected in participants' creation of concept maps that illustrated their knowledge of teaching science. Further, Gropen et al. (2017) assessed the effect of a PD program regarding physical science topics on preschool teachers' PCK and instructional quality. The findings showed that preschool teachers that participated in the PD program showed significantly greater PCK and higher quality science teaching compared to the control group (Gropen et al., 2017). Piasta, Logan, Pelatti, Capps, and Petrill (2015) showed that science PD had a positive impact on preschool teachers' provision of science learning opportunities, whereas a large variability could be found in the amount of learning opportunities provided by these teachers. In the study of Vick Whittaker, Kinzie, Williford, and DeCoster (2015), a group of preschool teachers received a special curricula and didactic materials oriented towards improving their CK, PK, and PCK on the topics of life science, earth science, and physics and with a focus on inquiry-based activities. Compared to the "business-as-usual" control group, the teachers who received the PD showed higher levels of instructional support, i.e. cognitive activation, and greater support of children's science thinking and reasoning in their instructional practices (Vick Whittaker et al., 2015).

These studies provide first evidence regarding the impact of science-related PD on early childhood teachers' dispositions and instructional practices by assessing the development over time, comparing treatment groups with "business-as-usual" control groups, or assessing the effect of additional online resources or coaching (e.g., Vick Whittaker et al., 2015). Nevertheless, to the best of my knowledge, no study has aimed at comparing PD opportunities with different content foci in regards to their impact on teachers' knowledge and instructional practices, especially in the field of life sciences.

3.2 Research aims and Hypotheses

This study aimed at exploring the role of preschool teachers' professional knowledge on their instructional practice in the field of life sciences. For this, participants' professional knowledge was manipulated through PD trainings that focused on improving either their CK, PCK, or both knowledge facets. Participants then conducted an instructional practice with small groups of preschool children using learning materials about forest animals that center around the concept of structure and function. Their instructional practice was conceptualized as consisting of two dimensions, which in turn consists of different subdimensions. The content dimension represents the extent to which preschool teachers and children explored the specific facts and relations that were the focus of the learning activity, and thus consists of two subdimensions labeled *single facts* and *relations*. The inquiry dimension represents the extent to which preschool teachers implemented scientific inquiry activities during the instructional practice, which in this study consists of the following five subdimensions: *questioning*, *hypothesizing*, *testing*, *describing*, and *interpreting*.

Following hypotheses were formulated:

> H1) Preschool teachers' CK has an influence on the content dimension and the inquiry dimension of their instructional practice
>
> (Abell et al., 2013; Ball, 1988; Ball et al., 2005; Baumert et al., 2010; Carlson et al., 2019; Dunekacke et al., 2016; Kulgemeyer & Riese, 2018; Oppermann et al., 2016).
>
> This refers to the question as to whether CK is necessary: Do preschool teachers need specific CK in order to engage children in science learning situations, or are they able to make use of their existing PCK in contexts in which they don't possess CK? To address this, a comparison was conducted between preschool teachers that received training only in PCK and those that received training in both CK and PCK.
>
> H2) Preschool teachers' PCK has an influence on the content dimension and the inquiry dimension of their instructional practice
>
> (Baumert et al., 2010; Carlson et al., 2019; Cauet et al., 2015; Delaney, 2012; Ergönenç et al., 2014; Förtsch et al., 2016; Gropen et al., 2017; Kulgemeyer &

Riese, 2018; Kunter et al., 2013; J. Lee et al., 2003; J. Lee, 2005; McCray & Chen, 2012).

This refers to the question as to whether PCK is necessary: Do preschool teachers need PCK in order to engage children in science learning situations, or are they able to develop counteract their lack of PCK with their existing CK? To address this, a comparison was conducted between preschool teachers that received training only in CK and those that received training in both CK and PCK.

Further, following two aspects were evaluated in an exploratory manner: The relation between all subdimensions of the instructional practice and the differences in the instructional practices of preschool teachers that are native German speakers and those that are non-native German speakers.

3.3 Materials and Methods

3.3.1 Sample and Procedure

This study was conducted with teachers from five preschools. Two preschool teams participated in a PD training with a focus on CK (CK-training), two teams participated in a PD training with a focus on PCK (PCK-training), and one team participated in a PD training with a focus on both CK and PCK (CK+PCK-training). Out of all training participants, a total of 27 subjects conducted the instructional practice and thus constitute the sample of this study (13 participants of the CK-training, 7 participants of the PCK-training and 7 participants of the CK+PCK-training). These subjects were on average 45.4 years old (*SD* = 11.3 , age range of 23-63 years) and had been working in their profession for a mean of 11 years (*SD* = 8.8, ranging between 0-34 years). Fourteen participants (51.9%) never took prat in a science PD training before, five (18.5%) took part in one, six (22.2%) took part in 2-5 PD trainings, and two (7.4%) assisted more than 5 times in a science PD training before this study. Out of these 27 participants, nine subjects (33.3%) indicated that German is not their first language: Five of the CK-training (38.5%), two of the PCK-training (28.6%), and two of the CK+PCK-training (28.6%).

The procedure consisted of four sessions that took place in the facilities of the participating preschools (see Figure 3.2). The first session consisted of a paper-and-pencil test, in which participants' professional knowledge and further demographical information were assessed. This test lasted 30 minutes. No aids or consultation with other participants was allowed. Non-native German speakers were allowed to use the PONS translator and were given 10 more minutes to complete the test.

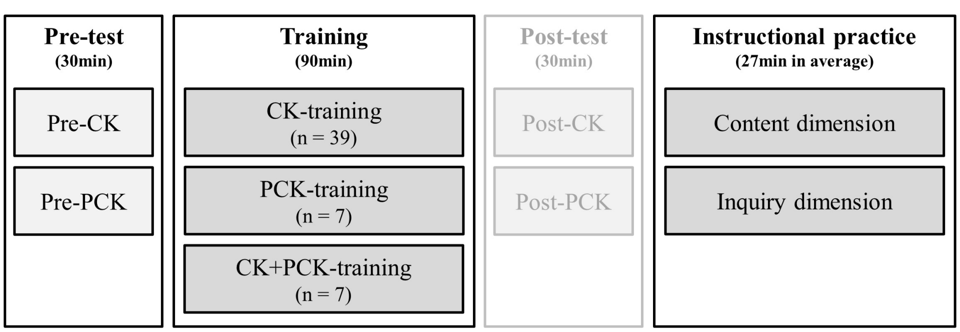


Figure 3.2: Study design of study 3

In the second session, the complete team of each participating preschool took part in a PD training of approx. 90 min that focused either on CK (CK-training), PCK (PCK-training), or a combination of both professional knowledge dimensions (CK+PCK-training). Immediately afterwards, participants took part in the third session, i.e. the post-test assessing participants' CK and PCK. Due to a low participation rate, however, this post-test could not be further analyzed. The fourth session took place in a consecutive day. Here, teachers conducted an instructional practice with small groups of 2-3 preschool children using a selection of the learning materials. This included following four stations: the moving behavior of woodpeckers, the feeding behavior of ants, the sensing behavior of owls, and the protecting behavior of snails. For this session, participants were given as much time as they needed. The instructional practices lasted in average 27 minutes (SD = 9.6; time range of 13-46 minutes). Two raters conducted observations of the instructional practice, assessing its content and inquiry dimensions.

3.3.2 Professional development training

Three types of PD trainings that focused on different domains of professional knowledge were developed: One training focused on improving participants' CK (CK-training), one on improving their PCK (PCK-training), and one on improving both knowledge facets (CK+PCK-training). Each PD training consisted of three phases: introduction, elaboration, and closure. Table 3.1 presents a summary of the focus and the phases of the three types of training. In the following, further details on each training will be presented.

Table 3.1: Summary of the three types of PD training

	CK-Training	PCK-Training	CK+PCK-Training
Focus	4 behaviors x 4 animals (in total 16 structure and function relations), Concept of S&F	Scientific reasoning activities, Inquiry-based learning, Working with models	CK: 4 behaviors + 4 animals (4 stations present in the instructional practice), Concept of S&F PCK: Scientific reasoning activities, Inquiry-based learning, Working with models
Introduction	Activation of previous knowledge about forest animals	Analogy of "children as little scientists", short film about foxes	Analogy of "children as little scientists"
Elaboration	Input: Basic concept of S&F Work in groups: Production of a poster about 1 behaviour x 4 animals	Alternating input and work in groups: Steps of the scientific inquiry process using the example of the fox's structures and functions	Input: Basic concept of S&F (CK), Steps of the scientific inquiry process (PCK) Work in groups: Production of a poster about 1 behaviour and 1 animal (CK) and worksheet (PCK)
Closure	Group puzzle: Presentation of the poster in new groups	Poster with the steps of the scientific inquiry process using the example of the fox's structures and functions	Group puzzle: Presentation of the S&F model, including poster (CK) and worksheet (PCK)

Content Knowledge Training

The focus of the CK-training lied on the scientific facts and concepts that are part of the instructional practice that participants were required to conduct after the training. This constitutes the biological concept of structure and function, specifically in regards to the four selected forest habitants (woodpecker, ant, snail, and owl) and the four selected behaviors (moving, feeding, protecting and sensing).

Following learning goals were formulated for the CK-training:

> Preschool teachers should be able to...
> ...illustrate the complexity of the interrelations between forest animals by means of a food network.
> ...summarize the relation between structure and function using the examples of the selected forest animals (woodpecker, ant, snail, and owl) and behaviors (moving, feeding, protecting and sensing) with the help of the provided information.
> ...explain the behavior assigned to their work group (moving, feeding, protecting or sensing) with reference to the respective structure and function of the forest animals (woodpecker, ant, snail, and owl) with the help of the created poster and the living or stuffed animals.

During the introduction phase, participants' previous knowledge about forest animals was activated. The materials used for this part consisted of small magnetic figures of the most common forest animals and a magnetic bord with the picture of a forest. Participants were asked to name any forest animal that came to their minds. Each time an animal was mentioned, the training instructor discussed with the participants in which part of the forest this animal can usually be found and placed the magnetic figure on the board accordingly. Then, the instructor and participants discussed the feeding dynamics between the forest animals and created a food web by spanning wool between the small magnetic figures.

The elaboration phase started with a short lecture on the biological concept of structure and function. Following this, participants were divided in four groups; each group was assigned one of the four selected behaviors (moving, feeding, sensing, protecting) and received the instruction to create a poster about the assigned behavior presenting the examples of all four selected animals (ant, snail, owl, woodpecker). For this, they received a text with all the necessary content summarized for each animal and several pictures of the four animals that illustrated the relevant structural-functional relation, which they could use in their posters. Further, they had the opportunity to observe living snails, a stuffed owl and woodpecker to gain a more detailed insight into the respective structure and function relations.

The closure phase was conducted using the group puzzle method. New groups were formed that consisted of one representative of each of the former groups. Each person had the task to present and explain the behavior they had worked on to the members of the new group using the posters they created and the living or stuffed animals. This way, all training participants could learn about the structural and functional relations present in all four behaviors and all four animals.

Pedagogical Content Knowledge Training

The idea behind the PCK-training was for participants to acquire the pedagogical content knowledge, but not the specific content knowledge, that was relevant for the instructional practice. Therefore, participants of this training learned about the role of models in science instruction, the scientific inquiry activities and the inquiry-based approach using the example of a forest animal that was not part of the instructional practice: The fox. This animal was chosen as the content aspect of this training because it possesses several structure and function relations that could be used to illustrate an inquiry-based learning situation. The two structures that were chosen were the fox's paw pads and its whiskers. Foxes' paws are softly padded, which does not only protect the paws while walking, but can also absorb the impact and muffle sounds. Due to this, foxes can walk very quietly, which allows them to sneak up on their prey without being noticed. Foxes' whiskers, also called "mystacial vibrissae", are long and stiff hairs that grow from special hair follicles that are innervated by sensory nerves, so they serve as sensory receptors of the environment. They are located on the side of the snout and extend beyond the width of the fox's skull and body. Due to this, foxes can perceive obstacles and recognize, even in complete darkness, whether their body can fit through a gap. Thus, the content in which the pedagogical content knowledge was embedded centered around the structure and function relations within the moving behavior and the sensing behavior of foxes.

Following learning goals were formulated for the PCK-training:

Preschool teachers should be able to...
... set the steps of the scientific inquiry method in the correct order
... describe the steps of the scientific inquiry method
... match the steps of the scientific inquiry method with the examples provided in the training
... describe the use of models in science instruction and the aspects of critical reflection of models
... construct a model using the craft supplies provided in the training and conduct a critical reflection of the model

This training was introduced with the analogy of "children as little scientists" (Elschenbroich, 2005). Participants were encouraged to consider, based on their everyday experiences and observations as preschool teachers, all the ways in which children act as scientists. For example, they share an innate curiosity about the world and an interest in natural phenomena, they like to ask questions and make observations. This comparison highlighted the fact that young children, unlike scientists, usually do not have a structured or systematic approach in their search for answers, which lead to the focus question that guided the rest of the training: "How can we support children's exploratory drive?"

During the elaboration of this training, participants learned step-by-step all phases of the scientific inquiry method and discovered how the inquiry-based approach can be used to provide a structure in science learning opportunities with preschool children. At the beginning, participants watched a short film about foxes (Wie schlau ist der Fuchs? (Doku) — Reportage für Kinder — Paula und die wilden Tiere). They were divided in three groups that received different tasks. One group was asked to merely watch the film and write down any observations that they found new or interesting. Another group was asked to specifically observe and make annotations about the whiskers of the fox, including their color, their position in the fox's head, and their length in comparison to the fox's fur. The third group was required to specifically observe and write down three characteristics of the fox's paw pads that could be recognized during the film. Upon this, participants worked through the steps of the scientific inquiry method in small groups under the guidance of the instructors using the examples of the moving and sensing behavior of foxes, as will be described in the following.

Posing a scientific question. Instructors discussed with participants what a scientific question is and what type of questions and topics are appropriate for preschool children. This includes preferably questions that stem from children's everyday observations and encounters with nature and that are answerable through available means. Instructors then introduced the structure and function relation as a concept that can be the focus of scientific questions with young children, given that they already possess experiences with this concept in animals and their own bodies. Upon this, participants were divided in small groups that received the task to formulate a scientific question about either the fox's paw pads or their whiskers, such as "what is the function of a fox's paw pads?".

Formulating an hypothesis. Instructors then defined what an hypothesis is and explained its important role within the investigative process. This was followed by a discussion about how preschool teachers can support children in their formulation of hypotheses. For example, when children have difficulties posing their own hypothesis, adults can help them by providing different options from which children can choose. In the same small groups, participants were first asked to write down what hypotheses children would typically pose to the questions formulated before, and then to pose a hypothesis based on what they observed in the film about foxes.

Planning an investigation. The next step included a discussion on how preschool teachers can plan an investigation in order to test previously formulated hypotheses. Here, the entire group mentioned different possibilities of observing live organisms in the preschool facilities using animals that can be found in the garden, and listed the pros and cons of such observations. Instructors then explained how 3D-models can be constructed and used to illustrate certain biological structures and the relation to their functions that cannot be easily observed in living animals. This lead to the next task. Participants were provided with further written information about the structure and function relation of either the fox's paw pads or whiskers, depending on the assignment of their group, and a box of diverse craft supplies. They were asked to use these materials to construct a 3D-model in which the assigned structure and function relation could be illustrated.

Conducting an investigation. This step consists of conducting observations with the previously created models. Groups that constructed models of the fox's paw pads were required to test the fox's whiskers models and vice versa. Participants were instructed to try the models out and describe their observations. For this, they were encouraged to conduct a detailed and objective description of what they could observe by focusing on specific characteristics, and avoiding further interpretation at this point. For example, the groups working with the models of the paw pads could observe that the models allowed them to walk silently.

Interpreting. In the last part, instructors highlighted the importance of comparing the previously formulated hypotheses with the conducted observations in order to reach a valid interpretation. Groups were thus asked to recall the hypotheses they formulated at the beginning and to compare them with the observations they made with the models. Based on this, they were required to write down their interpretation of the fox's structure and function relation. Instructors gave further recommendations for supporting children's interpretations, such as seeing previously made "incorrect" hypotheses as learning opportunities, and using the findings of an investigation to generate new scientific questions.

Regarding the work with models, instructors and participants discussed several aspects that should be reflected on with the children. This includes comparing the model with the real object in terms of the structures that are represented as well as adjoining structures that are absent in the model, the size, the colors, the materials, and a reflection on what can be done with the model that would not be possible with the real object. At the end of the elaboration phase, participants conducted such a reflection on the models created in this training.

At the closure phase, participants were asked to create a poster in which they could summarize the lessons learned in this training. For this, they were given word cards with the labels of every step of the scientific inquiry process and were asked to put them in the correct order and to illustrate each step using the example of the fox's structure and function relations used during the training.

Content Knowledge and Pedagogical Content Knowledge Training

The CK+PCK-training provided participants with the content knowledge as well as the pedagogical content knowledge relevant for the instructional practice. Regarding the content knowledge, this training focused specifically on the four stations present in the instructional practice; participants learned about the structure and function relations within the moving behavior of woodpeckers, the feeding behavior of ants, the sensing behavior of owls and the protecting behavior of snails. Thus, in comparison to the CK-training, the CK+PCK-training provided a more narrow focus of the content. What the pedagogical content knowledge concerns, the CK+PCK-training was similar to the PCK-training in that it focused on the role of models in science instruction, the scientific inquiry activities and all steps of the inquiry-based learning approach. Participants of this training thus received the same background information and the same teaching recommendations for each step of the scientific inquiry method as participants of the PCK-training, such as the definition of what a scientific question is and how to support children in formulating their own hypotheses. In this case, however, participants were not required to construct a model but worked using the models that were part of the instructional practice, and received a worksheet where they could follow all steps of the scientific method and write down their questions, hypotheses, observations and interpretations.

Following learning goals were formulated for the CK+PCK-training:

> Preschool teachers should be able to...
> ...illustrate the relation between structure and function of one station with the help of the created poster
> ...explain the adaptation of the presented animal to the forest habitat with the help of the created poster
> ...describe the steps of the scientific inquiry method
> ...describe the use of models in science instruction and the aspects of critical reflection of models
> ...conduct a critical reflection of the assigned model

Just as in the PCK-training, the introductory part of this training started with the analogy of "children as little scientists", which lead to the focus question "How can we support children's exploratory drive?".

In the elaboration part, participants discovered step-by-step all phases of the scientific method. Before diving into this, there was a short discussion about biology concepts that are appropriate for preschool children, such as the concepts of growth or structure and function, as well as animals and plants that children encounter in their everyday life, like certain birds, spiders, squirrels, etc. Participants were then divided into four groups, each of which was assigned one of the four animals present in the instructional practice; the woodpecker, the ant, the owl and the snail. Each group received the corresponding model, the stuffed or living animal, and the worksheet to follow the steps of the scientific inquiry method. As stated before, participants of this training received the same information and teaching recommendations for all steps of the scientific inquiry method and for working with models as participants of the PCK-training. Therefore, in the following I will merely illustrate the aspects of each step that were different from the PCK-training.

Posing a scientific question. First, each group was encouraged to familiarize themselves with the assigned model to discover what structure it represented. They then received the task to formulate a scientific question that could be answered using that model. For example, the group that was assigned to the snail could pose the question "How does the snail protect itself?".

Formulating an hypothesis. After receiving the corresponding teaching recommendations for conducting this step with young children, participants were asked to formulate an hypothesis for their previously posed scientific question.

Planning an investigation. Unlike in the PCK-training, participants did not need to create a 3D-model to plan the investigation; they merely had to plan how they could use the given models to test their hypothesis. They were asked to create a poster in which their assigned structure and function relation could be illustrated. For this, they were provided with further written information so that they could acquire the necessary content knowledge.

Conducting an investigation. After receiving the same information and recommendations as the PCK-training about the importance of conducting objective observations, participants were asked to try the models out and write down a detailed and objective description of their observations. In the case of the snail's shell, for example, they could describe that the shell is a hard structure, whereas the body is soft and can fit into the shell.

Interpreting. Here again, groups were asked to recall the hypotheses they formulated at the beginning and to compare them with the observations they made with the models, and finally to write down their interpretation of the structure and function relation.

Similar to the CK-training, the closure phase of this training consisted of the group puzzle method. The new groups consisted of one representative of each of the former groups, so that in each group there was one expert for each of the stations present in the instructional practice. Participants received the task to present their assigned structure and function relation and explain the steps of the scientific method using the models and the posters they created. This way, all training participants could acquire the CK and PCK necessary for all four stations of the instructional practice.

3.3.3 Participants' instructional practice with preschool children

Participants were invited to conduct an instructional practice with small groups of 2-3 preschool children using the following four stations of the learning materials: the moving behavior of woodpeckers, the feeding behavior of ants, the sensing behavior of owls, and the protecting behavior of snails (for more information on these learning materials, see section 2.3.2). The general layout of the stations was positioned in the same order in every participating preschool.

Participants were given 10 minutes to familiarize themselves with the layout and the learning materials before children were invited in, and were given as much time as they needed for the instructional practice. Two raters - the same two instructors of the trainings - conducted observations on teachers' interactions with the children and the materials using a self-developed observation sheet, in which they recorded aspects of teachers' instructional practice, specifically its content dimension and inquiry dimension. The observation sheet will be described in detail below.

3.3.4 Instruments

Professional Knowledge Test

The professional knowledge test consisted of two parts: The CK and the PCK tests. These were developed following the four steps recommended by Jüttner et al. (2013): Conceptualization of a variable, topic selection, instrument blueprint, and item structure and rubric. Blueprints are used to communicate the structure and organization of a test by providing a summary of the type and number of items that correspond to each aspect of the variable assessed by the instrument. The blueprints developed for the CK and the PCK tests are depicted in Table 3.2 and 3.3 respectively. The knowledge dimensions are presented along the vertical axis in an order that mirrors the sequence in which the corresponding questions were presented to participants in the test. Therefore, this order does not represent any cognitive hierarchy that may exist within the different knowledge types.

Content knowledge test

As this study aimed at assessing preschool teachers' instructional practice using the provided learning materials, the topics for the CK test were focused on animals and plants living in the forest, specifically the relations between structure and function that can be found in these organisms. As in Jüttner et al. (2013), CK knowledge was conceptualized based on three knowledge types: declarative knowledge, necessary for declaring and explaining facts; procedural knowledge, described as knowledge about how biology processes work and everyday life situations of natural phenomena; and conditional knowledge, defined as knowledge regarding biological concepts and principles. As can be seen in Table 3.2, the CK test consisted of three short answer questions and two multiple choice questions for declarative knowledge, one multiple choice question for procedural knowledge, and one open-ended answer question for conditional knowledge. Therefore, a total of seven question were developed for the CK test.

Table 3.2: Blueprint for the CK test

Knowledge dimension	Question	Type of answer
Declarative knowledge	CK_D1	short answer
	CK_D2	multiple choice (1 correct item out of 3 items)
	CK_D3	short answer
	CK_D4	short answer
	CK_D5	multiple choice (5 correct items out of 8 items)
Procedural knowledge	CK_P1	multiple choice (3 correct items out of 5 items)
Conditional knowledge	CK_C1	open-ended answer

Note. The acronyms of the test questions are: CK = content knowledge; D = declarative knowledge, P = procedural knowledge, C = conditional knowledge.

Pedagogical content knowledge test

The focus of the PCK test lied on the two aspects of knowledge about instructional strategies. The first aspect refers to subjects' knowledge about the scientific inquiry activities (equivalent to Jüttner et al.'s (2013) "knowledge about experiments"). This is assessed in the test by questions that reflect participants' knowledge about biology-related situations in preschool everyday life that could be used to engage young children with scientific inquiry activities. The other aspect refers to participants' knowledge about models. Here, the PCK test assesses participants' knowledge about the advantages and disadvantages of a certain biology model and their knowledge about how models can be constructed and/or used to engage children with biology topics. In summary, the goal of the PCK test was to assess participants' knowledge about how to recognize and make use of situations in preschool everyday life to engage young children with biological topics by conducting scientific inquiry activities or by creating and/or using models. Regarding the knowledge about scientific inquiry activities, this instrument contains 3 questions for the procedural knowledge and one for the declarative knowledge. Regarding the knowledge about models, it contains two questions for the procedural knowledge and one for the declarative knowledge. The answers to these questions were expected to stem not only from participants' theoretical knowledge about instructional strategies in science, but also from their creativity and wide experience working with young children. Therefore, for many questions there were no limitations to the possible answers, so they were conceived as open-ended questions (see blueprint in Table 3.3). As stated before, the order of the knowledge dimension in Table 3.3 reflects the sequence in which the questions were presented in the test.

Table 3.3: Blueprint of the PCK test

Knowledge aspect & dimension	Question	Type of answer
Knowledge about scientific inquiry activities		
Procedural knowledge	PCK_SIA_P1	short answer
	PCK_SIA_P2	open-ended answer
	PCK_SIA_P3	open-ended answer
Declarative knowledge	PCK_SIA_D1	short answer
Knowledge about models		
Procedural knowledge	PCK_MOD_P1	short answer
	PCK_MOD_P2	open-ended answer
Declarative knowledge	PCK_MOD_D1	open-ended answer

Note. The acronyms of the test questions are: PCK = pedagogical content knowledge; SIA = scientific inquiry activities, MOD = models, D = declarative knowledge, P = procedural knowledge.

Observation sheet for the assessment of participants' instructional practice

The observation sheet was developed to assess participants' instructional practice. The instructional practice was conceptualized as consisting of two dimensions, namely the content and the inquiry dimensions. The content dimension represents the extent to which preschool teachers and children mentioned the specific facts and relations that were the focus of the learning activity and consists of following two subdimensions: *single facts* and *relations*. The inquiry dimension represents the extent to which preschool teachers implemented scientific inquiry activities during the instructional practice, and thus consists of following five subdimensions: *questioning*, *hypothesizing*, *testing*, *describing*, and *interpreting*.

The developed observation sheet was first piloted using the videos produced in study 2. These videos show the instructor interacting with small groups of preschool children using eight stations of the learning materials. The piloting was conducted by the same two raters that conducted the observation of the instructional practices and thus also served as practice. In case of discrepancies, the different perspectives were discussed and the two raters came to an agreement. The observation sheet was then piloted a second time with a first team of preschool teachers that took part in a PCK-training and then conducted the instructional practice, which was not included in the sample analyzed. This resulted in slight modifications of the original observation sheet.

For each of the four stations of the learning activity (the moving behavior of woodpeckers, the feeding behavior of ants, the sensing behavior of owls and the protecting behavior of snails), the observation sheet consisted of two sections that assess the two dimensions of participants' instructional practice. In the following, a detailed description of the two sections will be presented.

Content dimension section

The content dimension section of the observation sheet is structured in the same way for all four stations. It is divided into following subsections:

- Identification of the animal (subdimension *single facts*)
- Mention of characteristics (subdimension *single facts*)
- Mention of specific structures (subdimension *single facts*)
- Mention of specific functions (subdimension *single facts*)
- Mention of specific relation between structure and function (subdimension *relations*)
- Mention of relation to other biological phenomena (subdimension *relations*)

The first four subsections register the single facts mentioned by both the preschool teacher and children during the instructional practice, thus together they represent the subdimension labeled *single facts*. The remaining two subsections register the extent to which the preschool teachers and children mentioned relations between specific structures and functions as well as between the content that they were exploring and other biological phenomena, thus together they represent the subdimension labeled *relations*.

In each station, the specific facts and relations that could be mentioned varied according to the animal and behavior that were represented (see Table 3.4 for the example of the station "moving behavior of woodpeckers"). For each element mentioned by the preschool teacher or the children, participants received 1 point. In the subsection "Mention of characteristics", every trait that was mentioned correctly was counted by 1 point, so there was no maximal amount of points that could be achieved in this subsection. For the analysis, the points scored in the four subsections that represent the subdimension *single facts* were added across stations (variable called *single facts*), and the points scored in the subsections that represent the subdimension *relations* were added across stations (variable called *relations*).

Table 3.4: Observation sheet – Content dimension section for the station "moving behavior of woodpeckers"

Subsection	Coded elements	Range of points
Identification of the animal (single facts)	- Bird - Woodpecker - Great spotted woodpecker	0-3
Mention of characteristics (single facts)	*Every trait mentioned correctly*	no maximum
Mention of specific structures (single facts)	- Foot/Feet - Claws - Muscle/ Muscle strength - Toe alignment - Webbed feet (comparison model)	0-5
Mention of specific functions (single facts)	- Climbing - Holding on/Clawing - Swimming (comparison model)	0-3
Mention of specific relation (relations)	- Relation between toes/ claws and climbing/clawing - Relation between webbed feet and swimming	0-2
Mention of a relation to other biological phenomena (relations)	- Relation to other types of moving behaviour	0-1

Inquiry dimension section

The inquiry dimension section was structured in the same way for all stations. It is divided into following five subsections, which represent the homonymous five subdimensions (see also Table 3.5):

- Questioning (subdimension *questioning*)
- Hypothesizing (subdimension *hypothesizing*)
- Testing (subdimension *testing*)
- Describing (subdimension *describing*)
- Interpreting (subdimension *interpreting*)

The subsection "Questioning" assesses whether the subject formulates a scientific question (1 point) and whether this question refers to the learning materials presented in the stations (2 points). "Hypothesizing" refers to whether the subject encourages children to pose an hypothesis about the previously formulated question (1 point). In the subsection "Testing" is reported whether the teacher is the one using the models (1 point), and whether he/she encourages some (2 points) or all children (3 points) to use the models. "Describing" refers to whether he/she describes the action of the model him/herself (1 point) or whether he/she allows children to describe what they observe (2 points). Finally, the subsection "Interpreting" assesses whether he/she interprets the findings by him/herself (1 point) or if he/she does it together with the children (2 points) (see Table 3.5).

For the analysis, the mean score of each subsection was calculated across all four stations. Thus, subjects received five scores that corresponded to each subdimension and that were used as dependent variables for further analysis (variables *questioning*, *hypothesizing*, *testing*, *describing*, and *interpreting*).

Following aspects were also assessed in each station but not further analyzed because the means and standard deviations were not reliable: Critical reflection of the models, Dealing with "incorrect" hypotheses, Dealing with errors, Comparing, Scaffolding, Introduction to the station (e.g. activation of previous knowledge), and Closure of the station (e.g. reflection).

Table 3.5: Observation sheet – Inquiry dimension section for all stations

Subsection	Coded elements	Range of points
Questioning	- Formulates a scientific question	0-2
	- Formulates a scientific question referring to the models	
Hypothesizing	- Asks children to pose an hypothesis	0-1
Testing	- Uses the model him/herself	0-3
	- Encourages some children to use the model	
	- Encourages all children to use the model	
Describing	- Describes the process him/herself	0-2
	- Encourages children to describe the process	
Interpreting	- Interprets him/herself	0-2
	- Encourages children to interpret / Interprets together with the children	

3.3.5 Data analysis

The analysis was conducted using the data of the 27 participants that performed the instructional practice. Given that this constitutes a very small sample size, it was not possible to conduct Rasch analysis, so all analyses were performed using the raw data.

Descriptive analysis was conducted to describe the three groups (CK-group, PCK-group and CK+PCK-group) regarding the mean values and standard deviations of all dependent variables, i.e. all subdimensions of the instructional practice (content dimension: *single facts* and *relations*; inquiry dimension: *questioning*, *hypothesizing*, *testing*, *describing*, and *interpreting*).

The small sample size raised concerns about two assumptions of parametric tests, namely the normal distribution and the homogeneity of variance. Because of this, the decision was made to use the bootstrap method to calculate bias corrected and accelerated (BCa) 95% confidence intervals (using 1000 bootstrap samples), as this is considered a robust method for analysing data that lacks normality (Field, 2017, p. 265, 456). Regarding the concern about the homogeneity of variance, different robust methods were used following the recommendations of (Field, 2017): When independent t-tests were implemented, the results were interpreted under the assumption that the variance in the groups were not equal (Field, 2017, p. 456). When ANOVAs were implemented, the Welch's F was interpreted instead of the usual F-statistic (Field, 2017, p. 535-537). In the case of

ANCOVAs, the results were confirmed using the HC4 method, which provides parameter estimates with heteroscedasticity robust standard errors (Field, 2017, p. 590).

Before investigating the differences between groups regarding their instructional practice, two steps were conducted. First, a bootstrapped ANOVA was conducted to check for differences in the control variables (*pre-CK* and *pre-PCK*) between the three groups. Second, the correlations between the control variables (*pre-CK* and *pre-PCK*) and the dependent variables (content dimension: *single facts* and *relations*; inquiry dimension: *questioning*, *hypothesizing*, *testing*, *describing*, and *interpreting*) were calculated in order to define in which cases should *pre-CK* and *pre-PCK* be included as covariates in the further analyses of (co)variance. To address the effect of CK on participants' instructional practice, a comparison was conducted between the CK+PCK-group and the PCK-group, whereas the effect of PCK was assessed by comparing the CK+PCK-group and the CK-group. These comparisons were conducted as one-way ANOVAs or ANCOVAs, depending on whether significant correlations were found between the control variables and the addressed dependent variable.

Further exploratory analyses were conducted to investigate the correlations between all subdimensions of the instructional practice as well as the difference between native and non-native German speaking participants in their instructional practice. Given that participants' 1^{st} language was coded dichotomously (native German speaker/ non-native German speaker), independent t-tests were conducted to check for significant differences in the dependent variables.

3.4 Results

3.4.1 Descriptive results

Table 3.6 shows the means and standard deviations of the content subdimensions (*single facts* and *relations*) and the inquiry subdimensions (*questioning*, *hypothesizing*, *testing*, *describing*, and *interpreting*) of the instructional practice, for each group and for the complete sample. As can be seen here, the CK+PCK-group reached the highest values in the two content subdimensions as well as in the inquiry subdimensions *hypothesizing* and *interpreting*, followed by the PCK-group. In the subdimensions *questioning*, *testing*, and *describing*, the mean values of the PCK-group were the highest among the three groups, although the values were very close to those of the CK+PCK-group.

Table 3.6: Means and Standard Deviations of the dependent variables for each group and for the complete sample

	CK-group	PCK-group	CK+PCK-group	Total sample
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
Content dimension				
Single facts	28.00 (6.15)	28.57 (8.26)	37.00 (4.76)	30.48 (7.35)
Relations	2.54 (1.61)	4.00 (1.29)	4.43 (1.27)	3.41 (1.65)
Inquiry dimension				
Questioning	1.58 (0.41)	1.86 (0.20)	1.82 (0.19)	1.71 (0.34)
Hypothesizing	0.46 (0.22)	0.79 (0.27)	0.93 (0.12)	0.67 (0.29)
Testing	2.63 (0.42)	2.86 (0.20)	2.82 (0.31)	2.74 (0.35)
Describing	1.06 (0.62)	1.75 (0.32)	1.71 (0.39)	1.41 (0.60)
Interpreting	0.90 (0.45)	1.39 (0.56)	1.54 (0.44)	1.19 (0.54)

3.4.2 Effect of the CK+PCK-training on the instructional practice

Before investigating the differences between groups regarding their instructional practice, two steps were conducted. First, a bootstrapped ANOVA was conducted to check for differences in the control variables between the three groups. There were no significant differences between groups in either *pre-CK* or *pre-PCK* (see Table 3.7).

Second, the correlations between participants' previous knowledge (*pre-CK* and *pre-PCK*) and the dependent variables were calculated in order to define in which cases should *pre-CK* and *pre-PCK* be included as covariates in the further analyses of (co)variance. Table 3.8 shows the calculated Spearman rho correlations (r_s). Here, in case of disagreement between the p-value and the bootstrapped 95% confidence interval, the correlation was considered significant based on the confidence interval. Participants' previous CK did not correlate with any of the assessed subsections of instructional practice. Previous PCK correlated positively with the inquiry subdimensions *hypothesizing*, *testing*, and *describing*. Therefore, in the subsequent analyses of covariance conducted with these three dependent variables, *pre-PCK* was included as a covariate.

Table 3.7: Results of the one-way ANOVA for the comparison of control variables between the three groups

	CK-group *M (SD)*	PCK-group *M (SD)*	CK+PCK-group *M (SD)*	F-value (p-value)	η^2
Pre-CK	16.58 (3.42)	16.17 (1.84)	14.14 (2.67)	F(2,22) = 1.60 (.225)	.127
Pre-PCK	12.00 (6.09)	15.00 (6.20)	18.14 (8.34)	F(2,22) = 1.83 (.184)	.143

Table 3.8: Spearman's rho correlations (r_s) between the control variables and the dependent variables

	Pre-CK	Pre-PCK
	r_s [BCa 95% CI]	r_s [BCa 95% CI]
Content dimension		
Single facts	-.05 [-.46, .36]	-.01 [-.46, .36]
Relations	-.17 [-.55, .24]	.10 [-.38, .55]
Inquiry dimension		
Questioning	.04 [-.35, .41]	.11 [-.30, .51]
Hypothesizing	-.07 [-.50, .37]	.39 [.04, .68]
Testing	.30 [-.12, .65]	.64** [.38, .81]
Describing	.18 [-.27, .56]	.45* [.15, .70]
Interpreting	.12 [-.32, .54]	.37 [-.001, .66]

*$p < .05$, **$p < .01$

Effect of the CK+PCK-training in comparison to the PCK-training on the instructional practice

Table 3.9 shows the results of the ANOVAs and ANCOVAs for the comparison between the CK+PCK-group and the PCK-group regarding all subdimensions of the instructional practice. As can be seen here, the CK+PCK-group achieved a significantly higher score than the PCK-group in the content subdimension *single facts*. There were no other significant differences between the two groups.

Effect of the CK+PCK-training in comparison to the CK-training on the instructional practice

As can be seen in Table 3.10, the conducted ANOVAs and ANCOVAs revealed that the CK+PCK-group achieved significantly higher scores than the CK-group in both content subdimensions as well as in the inquiry subdimensions *hypothesizing* and *interpreting*. There were no significant differences between the CK- and the CK+PCK-group regarding the inquiry subdimensions *questioning*, *testing*, and *describing*.

Table 3.9: Results of the ANOVAs/ANCOVAs for the comparison between the CK+PCK-group and the PCK-group of all subdimensions of the instructional practice

	F-value	p-value	η^2
Content dimension			
Single facts[a]	$F(1,10) = 5.47$	.042	.313
Relations[a]	$F(1,12) = 0.39$	.543	.032
Inquiry dimension			
Questioning[a]	$F(1,12) = 0.12$	.735	.010
Hypothesizing[b]	$F(1,10) = 1.30$	.281	.115
Testing[b]	$F(1,10) = 0.49$	.502	.046
Describing[b]	$F(1,10) = 0.01$	.942	.001
Interpreting[a]	$F(1,12) = 0.28$	.605	.023

[a] = ANOVA with group as independent variable
[b] = ANCOVA with group as independent variable and *pre-PCK* as covariate

Table 3.10: Results of the ANOVAs/ANCOVAs for the comparison between the CK+PCK-group and the CK-group of all subdimensions of the instructional practice

	F-value	p-value	η^2
Content dimension			
Single facts[a]	$F(1,15) = 13.17$	.002	.384
Relations[a]	$F(1,16) = 8.28$	.011	.284
Inquiry dimension			
Questioning[a]	$F(1,18) = 3.28$	.087	.107
Hypothesizing[b]	$F(1,16) = 17.68$	$<.001$	.525
Testing[b]	$F(1,16) = 0.01$	.938	.000
Describing[b]	$F(1,16) = 3.02$	.101	.159
Interpreting[a]	$F(1,13) = 9.13$	.010	.334

[a] = ANOVA with group as independent variable
[b] = ANCOVA with group as independent variable and *pre-PCK* as covariate

Figure 3.3 presents a summary of the comparisons between the CK+PCK-group and the PCK-group on one hand, and between the CK+ PCK-group and the CK-group on the other.

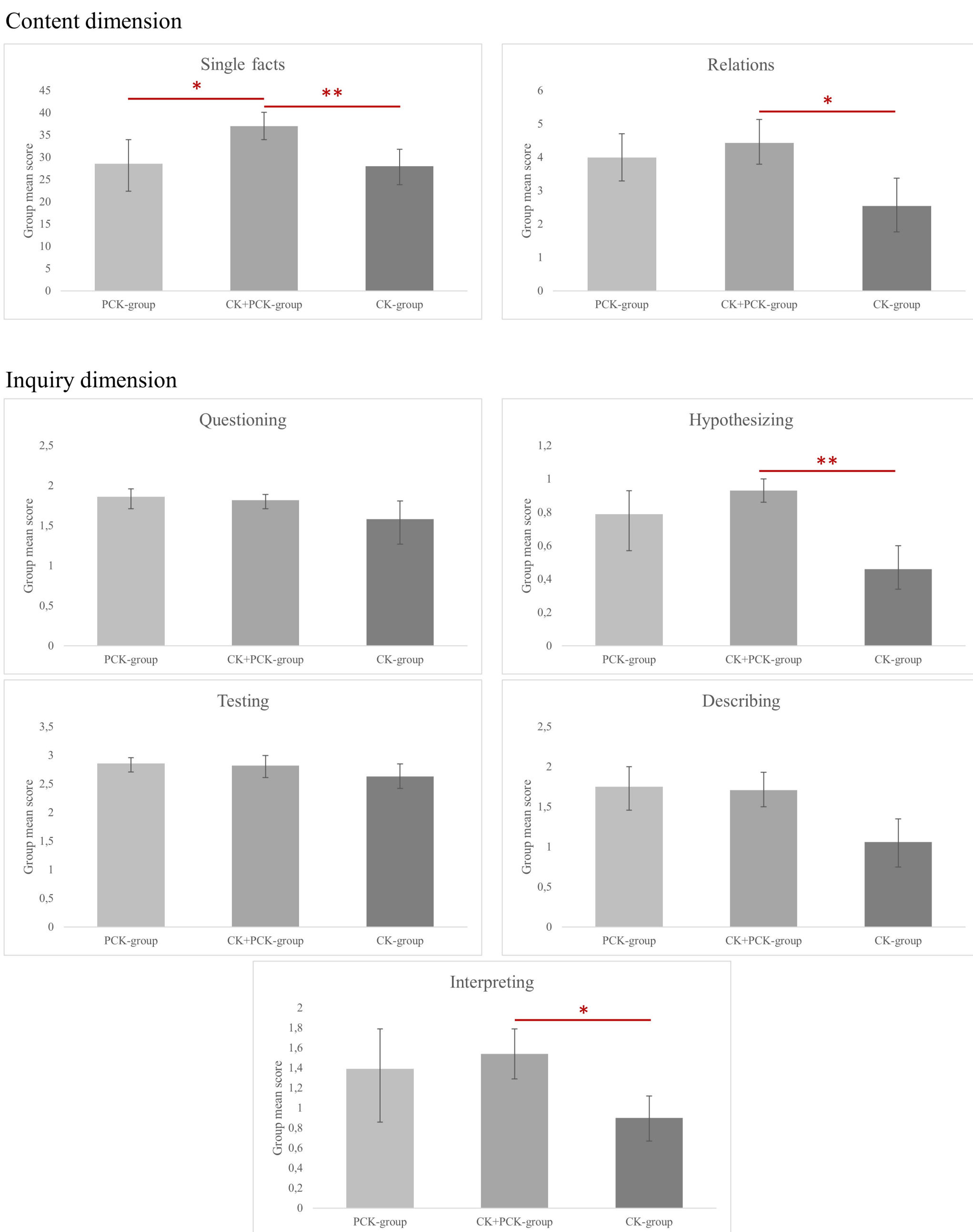


Figure 3.3: Summary of the comparison between groups regarding all subdimensions of the instructional practice

3.4.3 Exploratory results

Correlations between all subdimensions of the instructional practices

Table 3.11 depicts the Spearman rho (r_s) correlations between all subdimensions of the instructional practices. Here, the cases in which the p-value and the bootstrapped 95% confidence interval disagreed, the correlation was considered significant based on the confidence interval.

The two content subdimensions correlated positively with each other and with the inquiry subdimensions *questioning*, *hypothesizing*, and *interpreting*. Further, *relations* also correlated significantly with *describing*. There was a positive significant correlation in all combinations of the inquiry subdimensions except between *testing* and *questioning* and between *testing* and *hypothesizing*.

Table 3.11: Spearman rho correlations (r_s) between the content subdimensions and the inquiry subdimensions of the instructional practice

	Content dimension	Inquiry dimension				
	Relations	Questioning	Hypothesizing	Testing	Describing	Interpreting
Content dimension						
Single facts	.38	.43*	.57**	-.19	.10	.39
	[.03, .66]	[.04, .74]	[.24, .80]	[-.60, .21]	[-.32, .51]	[.03, .71]
Relations	-	.55**	.57**	.06	.41*	.49*
		[.20, .78]	[.26, .81]	[-.33, .45]	[.02, .72]	[.16, .75]
Inquiry dimension						
Questioning	-	-	.58**	.09	.45*	.56**
			[.22, .83]	[-.37, .49]	[.08, .73]	[.23, .81]
Hypothesizing	-	-	-	.37	.59**	.73**
				[-.12, .71]	[.21, .85]	[.51, .87]
Testing	-	-	-	-	.68**	.43*
					[.39, .85]	[.08, .70]
Describing	-	-	-	-	-	.84**
						[.61, .94]

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

Differences between native and non-native German speakers in their instructional practices

Table 3.12 reveals that participants that were native speakers achieved consistently higher values than non-native speakers in all subdimensions of the instructional practice. Independent t-tests revealed no significant difference between both groups regarding the two content subdimension and the inquiry subdimensions *questioning* and *hypothesizing*, but native German speakers were significantly better than non-native speakers in the inquiry subdimensions *testing*, *describing*, and *interpreting*, and the corresponding values of Cohen's d indicate a large effect size in all of them (see Table 3.12).

Table 3.12: Results of the independent t-tests for the comparison between native German speakers and non-native German speakers of the dependent variables

	Native German speakers *M (SD)*	Non-native German speakers *M (SD)*	t-value (p-value)	[BCa 95% CI]	Cohen's d
Content dimension					
Single facts	31.81 (6.25)	28.89 (9.61)	$t(12) = 0.82$ (.428)	[-4.10, 9.68]	.323
Relations	3.75 (1.73)	2.78 (1.39)	$t(20) = 1.53$ (.142)	[-0.19, 2.29]	.585
Inquiry dimension					
Questioning	1.81 (0.27)	1.53 (0.42)	$t(12) = 1.83$ (.093)	[-0.03, 0.61]	.878
Hypothesizing	0.77 (0.23)	0.50 (0.35)	$t(12) = 2.02$ (.066)	[-0.02, 0.51]	.913
Testing	2.89 (0.22)	2.44 (0.39)	$t(11) = 3.15$ (.009)	[0.15, 0.72]	1.571
Describing	1.70 (0.33)	0.81 (0.57)	$t(11) = 4.33$ (.001)	[0.53, 1.26]	2.157
Interpreting	1.41 (0.45)	0.72 (0.44)	$t(17) = 3.71$ (.002)	[0.32, 1.00]	1.641

3.5 Discussion

As stated before, this study was conducted as a pilot study and the findings must thus be considered tentative. They are, however, an interesting first insight into preschool teachers' professional competence, specifically the relation between their professional knowledge related to life science and the quality of their instructional practices.

This study aimed at exploring the role of preschool teachers' CK and PCK on their instructional practice, specifically the mention of single facts and relations regarding the explored animals (content dimension of the instructional practice) and the implementation of scientific inquiry activities (inquiry dimension of the instructional practice). Further, in an exploratory manner, this study investigated the relation among the two dimensions of the instructional practice and the difference in the instructional practice between preschool teachers that are native German speakers and those that are not.

This focus of investigation is needed for several reasons. Currently, there is a major gap between expectations and reality regarding the presence of science in the preschool setting; preschool teachers are expected to engage children with science but in reality the quality and quantity of science learning opportunities provided in early childhood are still unsatisfactory (Connor et al., 2006; Early et al., 2010; Gerde et al., 2013; Greenfield et al., 2009; Hollingsworth & Vandermaas-Peeler, 2017; Kauertz & Gierl, 2014; Piasta et al., 2014; Roehrig et al., 2011; Tu, 2006). To close this gap, it is necessary to understand the type of knowledge that preschool teachers need in order to fulfill their new professional expectations. Current assumptions about this are heavily based on research on primary and secondary school teachers, so a special focus on this group of professionals is essential (Blömeke et al., 2015; Fröhlich-Gildhoff et al., 2011; Kunter et al., 2011). As demonstrated by the review of Dunekacke and Barenthien (2021), there are still very few studies investigating early childhood professional knowledge related to science, less so focusing on the effect of the different knowledge facets on preschool teachers' instructional practices, and even less so centered in content related of life science.

The first hypothesis tested in this study refers to the debate on the importance of CK for the instructional practice (Abell et al., 2013; Ball, 1988; Ball et al., 2005; Baumert et al., 2010; Carlson et al., 2019; Dunekacke et al., 2016; Kulgemeyer & Riese, 2018; Oppermann et al., 2016). It is hypothesized that preschool teachers' CK (manipulated by the training) has an effect on the content dimension and the inquiry dimension of their instructional practice with preschool children. This was tested by comparing the group of teachers that received PCK-training and the group that received CK+PCK-training.

The results show that the CK+PCK-group was significantly better than the PCK-group in the content subdimension *single facts*, i.e. the mention of specific characteristics of the animal, but not in the subdimension *relations*, i.e. the mention of relations between specific structures and functions and relations to other biological phenomena. As described in section 3.3.2, the content aspect of the CK+PCK-training focused on the four animals that were present in the instructional practice, so participants learned about these specific structures and functions, whereas the content aspect of the PCK-training centered around a forest animal that was not part of the instructional practice. The results thus indicate that participants that possessed the relevant CK were better able to successfully implement this factual knowledge during the instructional practice. Nevertheless, given that both groups achieved rather low scores in the subdimension *relations*, the training seems to not have been efficient for participants to achieve a higher level of relational knowledge.

There was no significant difference between the CK+PCK-group and the PCK-group regarding any of the assessed scientific inquiry activities during the instructional practice. This goes in line with Kleickmann et al. (2017), who found no difference between the PCK development of physics teachers that received training in only PCK and that of those who received training in both CK and PCK. Considering that the CK+PCK-group was significantly better than the PCK-group in the content dimension of their instructional practice (*single facts*), the nonexistent difference in the elements of the inquiry dimension indicates that teachers that possess science-related PCK can engage in the scientific inquiry process with children even when they lack the relevant CK. This seems to support the co-constructive view that in the context of preschool, the knowledge on how to structure a science learning opportunity is more important than the knowledge about the specific content being addressed, and preschool teachers should be encouraged to engage children with scientific investigations even when they themselves do not know what the outcome of such investigations will be (Anders et al., 2018). However, the question rises as to how meaningful it is for children to engage in such activities if the instructor's knowledge of the content may be lacking. Considering that preschool teachers often hold scientifically incorrect conceptions (Kallery & Psillos, 2001), it remains questionable whether they are able to conduct scientific inquiry with children without introducing and teaching these misconceptions. To achieve this, teachers would have to have an in-depth understanding of not only the process of scientific inquiry, that is, the procedural knowledge, but also an epistemological understanding about how knowledge is created as well as an awareness of one own's knowledge limitations. During a science activity, they would need to be able to create strong, conclusive evidence and rely on it instead of on their own conceptions when interpreting the findings. In other words, the less content knowledge a teacher possesses, the more they would have to make use of their procedural and epistemological knowledge in order to successfully support children's conceptual learning through inquiry. Given the wide-held view that teachers should possess a higher level of content knowledge than the one they teach (Anders et al., 2018; Barenthien, Lindner, et al., 2020; Garbett, 2003), it seems more attainable and effective for preschool teachers to develop a CK that allows them to support children in formulating relevant hypotheses and describing and interpreting the findings of an investigation.

The second hypothesis refers to the role of PCK in preschool teachers' instructional practice, i.e. the question as to whether preschool teachers need specific PCK in order to engage children in a scientific learning situation or if they can compensate a lack of PCK using their existing CK, following the idea that PCK can develop from a teachers' previous CK (and PK) (Baumert et al., 2010; Carlson et al., 2019; Cauet et al., 2015; Delaney, 2012; Ergönenç et al., 2014; Förtsch et al., 2016; Gropen et al., 2017; Kleickmann et al., 2017; Kulgemeyer & Riese, 2018; Kunter et al., 2013; J. Lee et al., 2003; J. Lee, 2005; McCray & Chen, 2012). To address this, the CK-group and the CK+PCK group were compared. The descriptive analysis shows that the CK+PCK-group achieved higher scores than the CK-group in all the inquiry subdimensions. The inferential statistical analysis indicated that no significant difference was found in the subdimensions *questioning*, *testing*, and *describing*, whereas there were significant differences in the subdimensions *hypothesizing* and *interpreting*.

Questioning and describing are common practices in kindergarten, they has been shown to be activities that preschool teachers conduct very often and are therefore part of preschool teachers' repertoire of pedagogical strategies that go beyond the field of early science (Hollingsworth & Vandermaas-Peeler, 2017; Inan, 2010). Therefore, it is not surprising that no difference was found between the two groups. In the context of the conducted learning activity, *testing* was originally intended to refer to the testing of a previously formulated hypothesis by using the models in a hands-on manner. Nevertheless, during the observation it was only possible to assess if the participants encouraged children to interact with the models, but it was not always possible to assess whether the testing was conducted in the inquiry sense, given that many preschool teachers did not always follow the "linear" path of the scientific inquiry method. Therefore in the end the subdimension called *testing* refers to the hands-on activity of interacting with the models. This is also a common practice in kindergarten so here again, it is comprehensible that *testing*, in the sense of a hands-on action, did not differ between groups.

The inquiry subdimensions *hypothesizing* and *interpreting* were significantly different between the participants of the CK-training and those of the CK+PCK-training. In contrast to questioning, describing and the hands-on use of the learning materials (i.e. *testing*), these activities are considered the more complex steps of the scientific inquiry method and are more specific to the field of science (Hollingsworth & Vandermaas-Peeler, 2017; Inan, 2010). Hollingsworth and Vandermaas-Peeler (2017) and Inan (2010) showed that preschool teachers rarely report implementing the inquiry steps of making predictions (i.e. *hypothesizing*) and evaluating evidence (i.e. *interpreting*). This, together with the findings of this study, indicate that specific science-related PCK is necessary for preschool teachers to implement more complex inquiry activities in a learning situation.

Due to the procedural nature of scientific inquiry, all inquiry phases are related to and, to a certain degree, dependent on each other (Pedaste et al., 2015). The formulation of an hypothesis, for example, is based upon the formulation of a research question, just like the interpretation of the findings of an investigation depend on the execution of the investigation itself. It is therefore especially interesting that no difference was found in *questioning* but it was found in *hypothesizing*, and no difference in *testing* but in *interpreting*. The difference in *hypothesizing* suggests that children of PCK-trained teachers (the CK+PCK-group) received more opportunities to formulate their own ideas and assumptions. Further, the fact that *interpreting*, but not *testing*, was significantly different means that participants without PCK training (CK-group) only conducted a hands-on activity, whereas those with PCK training (the CK+PCK-group) created a hands-on and minds-on activity. Only with the PCK-trained teachers (the CK+PCK-group) did children not only do something but they also were enabled to reflect on what they were doing and what they could observe. All of this suggests that PCK allows preschool teachers to conduct inquiry in a deeper and more complex manner, which goes in line with recent research studies that reported a significant relation between PCK and instructional quality in the fields of early physics and mathematics (Dunekacke et al., 2016; Gropen et al., 2017; J. Lee et al., 2003;

J. Lee, 2005; McCray & Chen, 2012).

Interestingly, the CK+PCK-group was significantly better than the CK-group in both content subdimensions of the instructional practice (*single facts* and *relations*). As described in section 3.3.2, the CK+PCK-training provided a more narrow focus of the content compared to the CK-training, given that the former focused only on the four structure and function relations that were present in the instructional practice. Therefore, one possible explanation for the significant difference in the content dimension may be that participants of the CK+PCK-group were better able to retain the learned content because they were not overloaded with new information about the content, as may have been the case with the CK-group. Another explanation is that through the implementation of scientific inquiry activities, which was consistently better in the CK+PCK-group, preschool teachers created an adequate framework in which they could explore the content with the participating children. This is also reflected in the correlations found between the content subdimensions and the inquiry subdimensions.

The exploratory analysis also revealed interesting findings about the role of participants' German language skills in their instructional practice. The descriptive results showed that preschool teachers that were native German speakers were better than the non-native German speakers in all subdimensions of the instructional practice, and independent *t*-tests showed significant differences between native and non-native German speakers in the inquiry subdimensions *testing*, *describing*, and *interpreting*. Of course, it is not surprising that the quality of instructional practice is related to preschool teachers' language skills, but these findings indicate that science-related PD-training may be especially beneficial for non-native speakers, as they do not only learn about science content and instructional strategies, but also acquire the relevant vocabulary and ways of communicating. This is reflected in the following statement of one of the participants of the CK+PCK-training: "This workshop was very helpful for me. I come from a different country; I have a different first language. I learned many new German terms and that is good for me." Considering that the percentage of early childhood professionals that have a migration background has been increasing in Germany in the last years (Fachkräftebarometer, 2021), it is important to take this group into consideration in PD programs in order to support their development of professional competence in the field of early science education.

3.5.1 Limitations

This study contains several limitations that need to be addressed. As stated earlier, this study was originally planned as a pilot study with a small sample size, given that it was not originally intended to conduct conclusive statistical analyses. The small sample size entails several constraints. First, it does not allow for a Rasch analysis of the data, so it was necessary to use the raw data for conducting the analysis. Therefore, it was not possible to account for the unequal difficulties of the different items that were assessed in the tests and in the observations. Second, it raises concerns about the normal distribution and homogeneity of variance. To counteract this, every analysis was conducted using robust methods following the recommendations of (Field, 2017). Third, it reduces the statistical power of the study, as it increases the likelihood of a Type II error (false negative). This means that due to the small sample size, the analyses conducted here may have not been able to detect effects that may, in reality, actually exist. Fourth, due to the small sample size it was not always possible to conduct the type of analysis that would have been the most appropriate. For example, due to the interdependence among the different dependent variables, MANOVAs/MANCOVAs would have been the best option for analyzing the effect of the PD trainings on the instructional practice. However, the small sample size made such complex analyses unfeasible and ANOVAs/ANCOVAs were conducted instead. With this decision, the two main benefits of MANOVAs/MANCOVAs were lost. On one hand, they protect against inflated type I errors (false positive); on the other, they accounts for the interrelation between dependent variables by using the cross-products, which allows it to detect whether groups differ along a combination of dimensions, thus having a higher power to detect significant effects, compared to ANOVAs/ANCOVAs (Field, 2017).

Consistent with research on PD effectiveness (Buysse et al., 2009; Desimone, 2009), the PD trainings (a) were focused on improving participants' CK and/or PCK, (b) encouraged active participation, given that teachers had several opportunities to acquire and share knowledge with their peers in a competent and autonomous way, (c) were consistent with current teaching recommendations, given the increasing attention that science has been gaining in the field of early childhood education, and (d) were conceived as team trainings, thus encouraged the collective participation of all teachers of the same preschool. The only aspect of the PD trainings that was not consistent with Desimone's (2009) critical features was the duration. Being one-time courses with a duration of only 90 minutes, these PD trainings clearly do not align with neither the span of time nor the number of hours that are considered necessary to produce a sustainable effect on participants' learning (Desimone, 2009; Gropen et al., 2017; Piasta et al., 2015). Such short courses have been often criticized for being fragmented and noncumulative (Ball & Cohen, 1999). They are, however, often the only possibility preschool teachers have to participate in learning opportunities. In Germany, for example, preschool teachers usually only take part in one-day PD trainings (Beher & Walter, 2012). This is the reason behind the short duration of the PD trainings conducted in this pilot study, even though a longer time span would have been desirable.

Another important limitation is the fact that the post-tests could not be included in the analyses because more often than not, participants did not fill them out properly. When asked about the whole experience after participating in the study, they expressed being too tired to conduct the post-test. This is understandable, given that the pre-test, the PD training, and the post-test were all conducted one after the other at the end of participants' whole working day. Because of this, it was not possible to assess the direct effect of the PD trainings on their CK and PCK, so it cannot be stated with certainty that they acquired the knowledge addressed in their respective trainings. Therefore, the data of this study only allows for the assessment of the effect of the PD training on participants' instructional practices. This would have been unproblematic if an observation of the instructional practice would have taken place before the PD trainings, but given that the original design of the study relied on the post-tests, this previous observation was not considered necessary. Even though the pre-tests demonstrated that the groups did not differ from each other in terms of their previous CK and PCK, the lack of previous observation makes it impossible to fully assume that the differences found in the instructional practices are only due to the PD trainings.

For the purpose of this investigation it was necessary to assess participants' instructional practices by conducting live observations. A video documentation, as was planned for the following study, would have allowed for a more precise assessment, but unfortunately it was not feasible during the pilot study due to data protection issues with the participating children. Even though observations are considered an appropriate approach to achieve comprehensive and objective measurements of performance (Desimone, 2009), they also entail several challenges. First, they are very time-consuming, which has an effect on the sample size that can be achieved (Desimone, 2009). This is further accentuated by the fact that at least three observations are required to achieve a reliable and valid measure of one stable observation (Taylor, Pearson, Clark, & Walpole, 1999). In this case, this was achieved given that the complete assessment of participants' instructional practice consisted of four independent observations in the four different learning stations. Second, given the complex nature of performance situations, a certain degree of measurement error is unavoidable, especially compared to surveys with clearly-defined items (Blömeke et al., 2015), which was further complicated by the fact that the observations were conducted in real time and not via video analysis. To circumvent this, two raters conducted the observations simultaneously and their ratings were combined. Third, the different elements that are assessed during a performance task are often dependent of each other, as is the case of the scientific inquiry activities assessed in this study, which has important implications regarding the statistical analysis that must be conducted (Blömeke et al., 2015). In this case, as stated above, a multiple analysis of (co)variance would have been the optimal approach but was unfeasible due to the small sample size.

In summary, most of the limitations are related to organizational issues due to the pilot nature of this study. Therefore, they serve as an insightful source of information upon which several potential improvements can be made in future research endeavors.

Part IV

Outreach

Chapter 4

Outreach

4.1 Theoretical background

In the last decades, there have been several attempts to classify research projects according to their goals and motivations. One approach that has gained wide acceptance is Stokes's (1997) Quadrant Model of Scientific Research (see Figure 4.1). This model characterizes research in terms of two dimensions: a) the degree to which it is inspired by a quest for fundamental understanding, and b) the degree to which it is guided by considerations of use. As Stokes (1997) points out, these dimensions are in reality continuous, but for practical reasons they are described as two dichotomies. As a result, the model consists of four quadrants. In the upper left quadrant the pure basic research is located. This type of research "is guided solely by the quest for understanding without thought of practical use" (Stokes, 1997, p. 73). The lower right quadrant contains the pure applied research, i.e. "research that is guided solely by applied goals without seeking a more general understanding of the phenomena" (Stokes, 1997, p. 74). The upper right quadrant contains the so-called use-inspired basic research, which is defined as "basic research that seeks to extend the frontiers of understanding but is also inspired by considerations of use" (Stokes, 1997, p. 74). It is also described as "Pasteur's quadrant" due to "how clearly Pasteur's drive toward understanding and use illustrates this combination of goals" (Stokes, 1997, p. 74). This quadrant thus exemplifies how the goals of basic research (quest of understanding) and applied research (applicability) are not inherently opposed to each other.

This model was originally created to contribute to the then ongoing debate about the relationship between basic science and technological innovation. Threrefore, it is presented

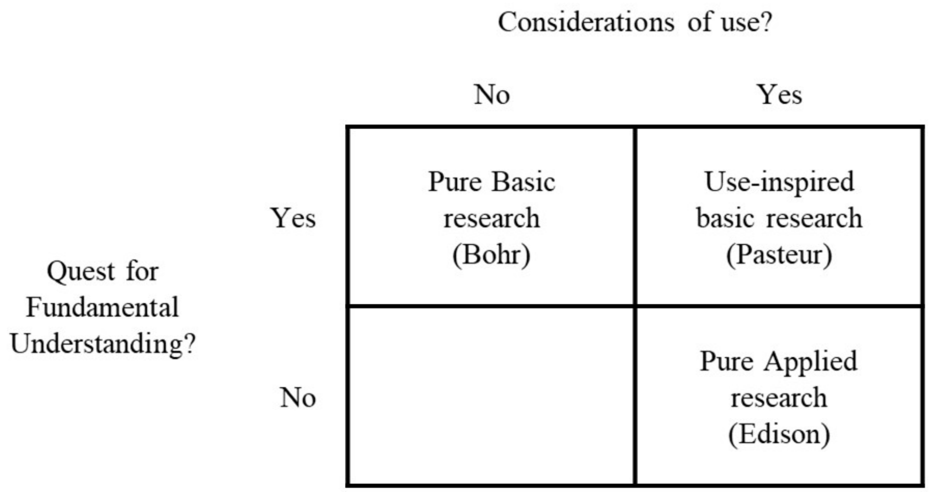


Figure 4.1: Quadrant Model of Scientific Research. Adapted from Stokes (1997)

using examples from research in natural sciences, such as physics and biology, as well as research in innovative fields such as biomedicine, engineering and technology. Nevertheless, other fields of research, such as psychology or education, can also be observed through the lens of this categorization system.

The research field of domain-specific didactics ("Fachdidaktik" in German), to which this dissertation pertains, deals with the science of domain-specific teaching and learning. It aims at understanding the processes of teaching and learning with the ultimate goal of improving science instruction in all educational levels. Historically, this field has not only conducted investigations, but also strongly influenced educational policies and the training of pre-service teachers; didactics professionals often consider it part of their job to developed educational resources, teaching recommendations, and provide a variety of PD opportunities for teachers. As such, the field of domain-specific science didactics can be described as use-inspired research, given that it is guided by both a quest for understanding and considerations of use in real-life education.

When giving examples of use-inspired research, Stokes (1997) states that "Pasteur wanted to understand *and to control* the microbiological processes he discovered. Keynes wanted to understand *and to improve* the workings of modern economies. The physicists of the Manhattan Project wanted to understand *and to harness* nuclear fission. Langmuir wanted to understand *and to exploit* the surface physics of electronic components. The molecular biologists have wanted to understand *and to alter* the genetic codes in DNA material" (Stokes, 1997, p. 79-80). To this, one can add that researchers in the field of subject-specific science didactics want to understand *and to improve* science education. This illustrates the idea that use-inspired research is not complete until it has been actually put to use. In the case of science didactics, research is not really complete until it is used to improve science education. One way to achieve this is to conduct outreach initiatives oriented towards students and teachers, in which findings about best practices are either directly put to use in educational activities with students or shared with educators so that they can implement these best practices in their own science lessons.

Based on these considerations, this doctoral project aimed at complementing the conducted research studies with concrete outreach activities oriented towards preschool teachers and children with the goal of contributing to the improvement of early science education. To embed this within the context of current science communication research, in the following I will elucidate the increasing importance of conducting outreach in all disciplines, characterize science outreach activities regarding their aims, audiences, and degree of public participation, and mention existing practical recommendations for conducting such activities.

4.1.1 Science outreach

Scientists of all types of disciplines are being called upon to improve their efforts in science outreach, which is broadly defined as "any scientific communication that engages an audience outside of academia" (Poliakoff & Webb, 2007, p. 244; see also Agre & Leshner, 2010; Baram-Tsabari & Osborne, 2015; Davies, 2008; Nisbet & Scheufele, 2009). This development is reflected, for example, in the National Science Foundation's (NSF) Broader Impact Review Criterion, which expects proposers to describe "the potential to benefit society and contribute to the achievement of specific, desired societal outcomes" of their research (National Science Foundation, 2018). According to the NSF, this includes the improvement of science education and teachers' development in all educational levels and the improvement of public scientific literacy and public engagement with science, among others (National Science Foundation, 2018). As such, the goals of science outreach and those of the field of subject-specific didactics are aligned with each other. It has thus become essential for researchers to take these aspects into consideration and search for creative and effective ways of sharing the central ideas of their field with nonscientific audiences (Dudo, 2013; Ponzio et al., 2018; Varner, 2014).

Characterization of science outreach activities

Science communication efforts can vary greatly regarding the aims they follow, the audience to which they are oriented, and the degree to which the nonscientific actors are involved, all of which are inherently related to each other and ultimately define the form the activities take.

Several authors have described different but oftentimes overlapping aims of science outreach. These include improving public's awareness and understanding of scientific topics and processes, sharing the latest findings of specific research projects, increasing public appreciation of and support for scientific endeavors, contributing to public enjoyment and interest in science, influencing science-related opinions and behaviors, encouraging science-related career choices, building epistemic and moral trust in scientists, and making science more inclusive by, for example, collecting public's input about worthwhile research aims and making use of the public's cognitive resources and knowledge (Burns, O'Connor, & Stocklmayer, 2003; Cooke et al., 2017; Dudo & Besley, 2016; Husher, 2010; Kappel & Holmen, 2019; National Academies of Sciences, Medicine, et al., 2017).

The "public" that is referred to is not a homogenous group of people but rather highly diverse; it can consist of interested (and non-interested) laypeople, scientists from others fields, policymakers, and students and teachers from all educational levels (Cooke et al., 2017; Burns et al., 2003; Poliakoff & Webb, 2007; Stieben, Halpin, & Matyas, 2017). The intended audience and the aims of an activity are closely related to each other. In the special case of outreach oriented towards young children, the main goals are to give them opportunities to come in contact with scientists and with interesting scientific topics and experience enjoyment and fascination while doing so, whereas an usual aim of outreach oriented towards teachers is to improve their knowledge of domain-specific concepts and appropriate teaching strategies, i.e. their CK and PCK, and to influence their instructional practices accordingly. This type of outreach can take the form of educational resources, publications on teaching recommendations, one-time events at schools, at science museums, or at universities (e.g. open days), or long-term series of workshops held with small or big groups of students or educators (Rennie, 2012; Sadler, Eilam, Bigger, & Barry, 2018; Stieben et al., 2017; Willsher & Penman, 2011).

Science outreach initiatives also differ in the degree to which the nonscientific actors are involved. The original and possibly still most prevalent type of outreach activity can be described as an unidirectional flow of communication from experts to non-experts, e.g. the dissemination of scientific content through popular science books, documentaries, and science blogs. An example of this can be found in the work of Konrad Lorenz, a world-wide known behavioral biologist who has written several books oriented towards a nonscientific public, such as "On aggression" (1963) and "Man meets dog" (1949b). His work exemplifies how this type of science outreach can have great impact on its audience, as can be seen in the prologue of the Spanish edition of Lorenz's "King Solomon's ring" (1949a), in which Miguel Delibes de Castro, a Professor at the Dioñana Biological Station in Spain, reveals that this book influenced his and many of his colleague's decision to pursue biology as a career. Another well-known example is the book "The limits to growth" by Meadows, Meadows, Randers, and Behrens (1972), a report on the results of research projects that investigated the problematics of exponential population growth, resource use and pollution. This report was written in colloquial language and aimed at encouraging policy makers to reflect on these global issues, and continues to be an important source of debate up to this day (Meadows et al., 1972).

This type of science communication can thus be very effective in achieving some of the main aims of outreach mentioned above. Nevertheless, some of the underlying assumptions are not free of criticism. As many surveys have shown, scientists often see laypeople as ignorant about and uninterested in science, and hold the belief that the only thing preventing public's support for certain scientific issues, such as climate change or the theory of evolution, is their lack of knowledge (Bauer, Allum, & Miller, 2007; Besley & Nisbet, 2013; Bronson, 2014; Davies, 2008; Dudo, 2015). They thus perceive a moral responsibility to educate the public through communication efforts that can be described as a top-down flow of information from experts, i.e. knowledge authorities, to the public, i.e. knowledge deficient (Besley & Nisbet, 2013; Davies, 2008; Jensen, Rouquier, Kreimer, & Croissant, 2008; Royal Society, 2006; Suldovsky, 2017). This so-called "deficit model" of science communication has been widely criticized for ignoring the complex relation that exists between knowledge, beliefs, behavioral intentions, and actual behaviors (Varner, 2014). Further, it has been criticized for its paternalistic view of the public, for perceiving it as merely passive receivers of information, thus disregarding how their opinions, local knowledge, and skills could be of value for the process of communication and for the scientific research itself (Kappel & Holmen, 2019). The idea behind this criticism is not to condemn any type of one-way communication (Trench, 2008). It is rather to highlight the importance of acknowledging that individuals are not "empty containers of information, but rather process information according to social and psychological schemas that have been shaped by their previous experiences, cultural context, and personal circumstances" (Lewenstein, 2003, p. 3) and to encourage scientist to take the public's diverse needs, views, knowledge and cognitive resources into consideration. As a response to this, the last decades have seen an increase in outreach activities that facilitate the dialogue and collaboration between experts and the public, e.g. public forums, citizen science projects, and interactions through social media (Kappel & Holmen, 2019; Parks & Takahashi, 2016; Varner, 2014). As Trench (2008) states, however, both one-way and two-way communication efforts can coexist, as each approach has a specific set of benefits and disadvantages and will continue to be useful in different circumstances.

Recommendations for science outreach activities

Even though most scientists regard science communication as a valuable endeavor, they often do not feel properly trained to engage with the public (Besley & Nisbet, 2013; Jensen et al., 2008; Royal Society, 2006). Further, they hold certain beliefs that discourage them to engage in it; they consider it difficult to communicate in a clear and understandable way and to spark interest in the public for research topics that may not be relevant for them, and see it as a dangerous task that can lead audiences to misunderstand or misuse scientific information (Davies, 2008).

As a response to this, several authors have stated diverse recommendations for conducting science outreach and interacting with the public in a respectful and inclusive manner. Cooke et al. (2017), for example, lists 16 considerations for doing so. These include getting to know and listening to the target audience, collaborating with experienced people, understanding the science of science communication, and integrating science communication into the research projects. Further, Varner (2014) proposes a model for science outreach that serves as a framework for scientists to approach outreach in a systematic way. The model comprises three main phases: Development, implementation, and evaluation. In the development phase, the idea is to first define the goals of the outreach activity, which may include learning goals for the scientists themselves, search for collaborations with experts in science communication and interface organizations when necessary, and ultimately tailor the activity to a specific audience, taking their existing knowledge, experiences, values, and beliefs into consideration. The implementation phase consists, as the name reveals it, of the implementation of the outreach activity. In activities in which the scientists interact directly with the public, they should hold participants' situational interest and encourage their active engagement in the learning process, e.g. by giving them opportunities to formulate their own ideas and conduct their own observations. While the activity is taking place, a formative assessment serves to track the progress and interest level of the participants and recognize any misconception that may have formed, allowing for immediate improvements. The last phase, evaluation, can be conducted formally through the use of control groups or informally via surveys, tests, or discussions with the participants to assess whether the goals set at the beginning were reached and to collect feedback about the activity itself, all of which can inform the development of new outreach initiatives (Varner, 2014).

4.2 Conducted outreach activities

The outreach aspect of this doctoral project consists of the development and implementation of diverse outreach initiatives that follow the general aim of contributing to the improvement of early science education. As such, the audience towards they were oriented are preschool children and preschool teachers. The level of public involvement varies, as some activities were conducted directly with preschool children, whereas others were published so that preschool teachers can make use of them for the development of their own science learning opportunities with preschool children.

The outreach activities can thus be distinguished as:

1. Activities in which basic principles of the field of science didactics and the findings of study 2 were directly put to use with 5-7 year old children who were not part of the research studies. This includes:

   a) Development and implementation of a concept-based and inquiry-based learning activity on the topic of ants and snails (implemented in two different occasions)

   b) Development of an observation exercise of different bird species. The implementation was design following two different formats: Through face-to-face interactions with groups of 5-6 preschool children (implemented in two different occasions) and through a series of short-videos that are published online.

2. Activities in which basic principles of the field of science didactics and the findings of study 2 were communicated to preschool teachers so that they themselves can make use of this knowledge when implementing learning activities about life science topics with 5-7 year old children. This includes:

   a) Publication of a practical recommendations article, in which the principles of concept-based and inquiry-based learning activities are described and three core teaching recommendations are provided for early education professionals that are looking to engage young children with biology topics

   b) Publication of a video abstract, in which the theoretical background, methodology and main findings of study 2 are presented in plain language

In the following, I will give a detailed description of each of these outreach activities.

4.2.1 Outreach activities oriented towards preschool children

1a) Concept-based and inquiry-based outreach activity

Content

The content of this activity refers to two small animals that are familiar to young children: ants and snails. This activity is characterized as *concept-based*, as it focuses on the relation between structure and function in these animals regarding two important behaviors, namely their feeding and their moving behaviors. Specifically, it touches on:

- the relation between an ant's mouth structure and its ability to cut off pieces of food
- the relation between an ant's flexible body and its ability to move in narrow spaces
- the relation between a snail's rasp tongue and its ability to scrape off pieces of food
- the relation between a snail's muscle contractions and its ability to move forward

Further, it is characterized as *inquiry-based*, given that the procedure follows four phases of the inquiry cycle: question, hypothesis generation, investigation, and conclusion.

In the following, I will first give a description of the materials that were used to represent the corresponding structures and functions and afterwards a description of the procedure that was followed in the implementations of this learning activity in a way that can be reproduced in future implementations.

Concept-based materials

The materials consist of four stations, each presenting one of the relations between structure and function mentioned above. Figure 4.2 shows the materials of each of these stations.

The stations about the moving and eating behaviours of ants, as well as the station about the eating behaviour of snails, consists of two models each: One that represents the real structure and is therefore able to fulfil the given function, and one that possesses another structure that does not fulfil the function and thus serves as comparison. The models in the station about the feeding behaviour of ants consist of two pliers, namely one cutting plier that represents the ant's mouth, and one round nose plier that serves as comparison, and some food, e.g. an apple or a sugar cube. The task here is to discover which plier, i.e. which mouth structure, is better able to cut off a piece of the food that is presented. In the station about the moving behaviour of ants, the materials consist of two ant models made out of wood, one is flexible and can thus be bent to the sides and represents the flexible junctions of an ant's body, whereas the other one is not flexible and thus serves as a comparison model. Further, there is a wood labyrinth consisting of narrow passages. Here, children are asked to discover which of the two ants (flexible or not flexible) is better able to move in such narrow spaces. The station about the feeding behaviour of snails consists of two tools, namely a rasp tool that represents the snail's rasping tongue and a long and smooth metal spatula for comparison, and some food, e.g. a carrot. Here, the task is to discover which tool is better for scrapping off pieces of food.

In comparison to this, the station about the snail's moving behaviour consists of a terrarium with a small amount of live snails and a sleeping bag that was designed to look like a snail.

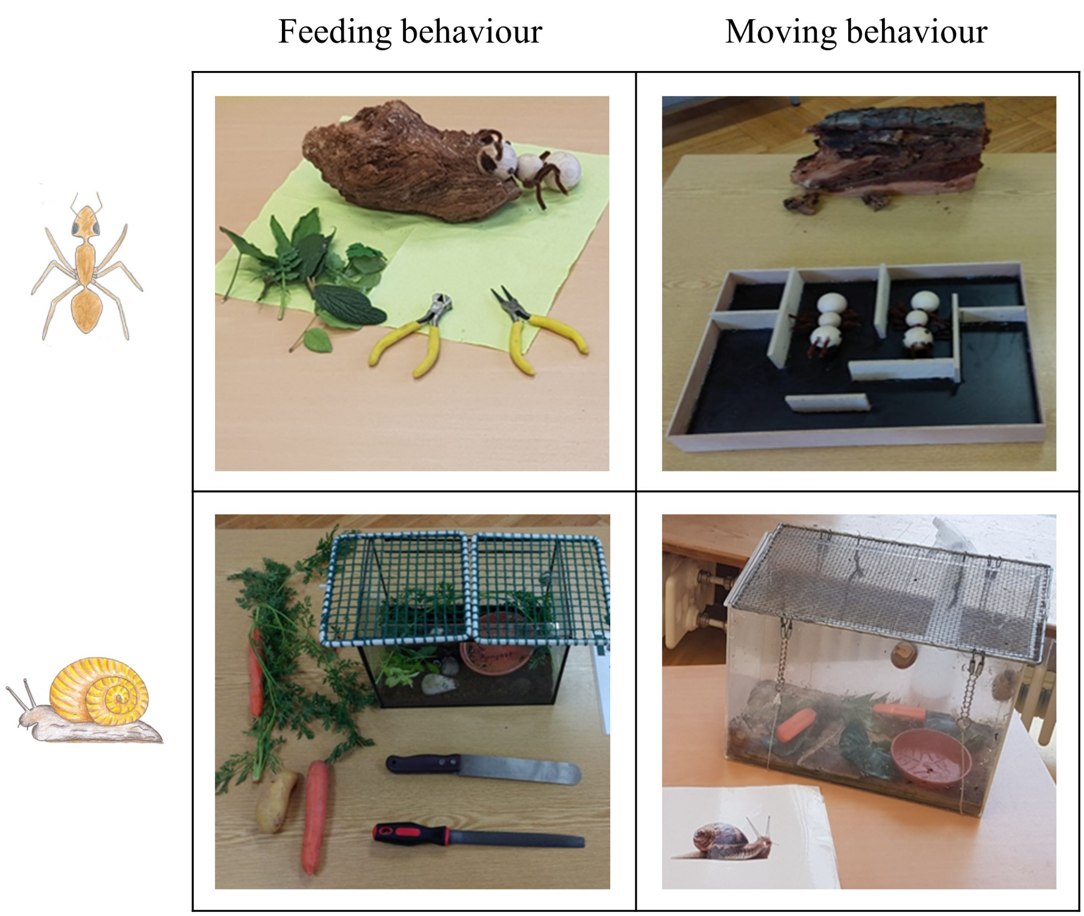


Figure 4.2: Materials of the concept-based and inquiry-based outreach activity displaying the feeding and moving behaviour of ants and snails

Inquiry-based procedure
In the first three stations, children are guided through four phases of the inquiry cycle:

1. Question: The instructor asks a question about the presented animal and the corresponding behaviour. For example, in the station about the feeding behaviour of snails, children are asked how these animals eat, considering that they don't have teeth.
2. Hypothesis Generation: Children are then encourage to generated a hypothesis by predicting which one of the two models is the best to fulfil the given function. In the example mentioned above, children had to choose whether the rasp or the smooth spatula is better able to scrap off a piece of food.
3. Investigation: Children are then encouraged to try both models out and observe what happens with each one of them, e.g. what happens when you try to scrap a piece of food with a rasp and with a smooth spatula. They are then guided by the instructor to summarize what they observed with each of the models and compare them regarding their capacity to fulfil the given function. In the station used as example, children tried to scrap off a piece of carrot with both tools and could observe that it only worked with the rasp.
4. Conclusion: At the end of each station, children are guided to discuss their observations in relation to the question posed at the beginning and to their own hypotheses. Here, the instructor asks them to remember which model they first thought was better and to compare their first ideas with their observations, and encourages them to explain why one model is better than the other. In the example of the snail's feeding behaviour, children stated that the rasp was better at scrapping off pieces of food due to its rough and scratchy surface. This way, children can learn that snails are able to scrap off food because their tongue has a scratchy surface.

In comparison to this, the station about the moving behavior of snails is conducted differently, as it is based solely on the observation of live snails. Children are encouraged to observe the underside of a snail while it moved on top of a transparent glass. This way, they can observe the waves of muscular contraction and relaxation that allow the animal to move forward. Afterwards, children are encouraged to imitate this type of movement by slipping into the sleeping bag that looks like a snail, and trying to move forward without using their hands.

Implementation

This outreach activity has been implemented with preschool children outside the research studies in two occasions. First, during the open day at the Faculty of Biology of the LMU München in July 2019, it was conducted with four different groups of approximately 10 children each: two groups of preschoolers and two groups of 1st graders. Second, it was implemented in September 2019 at the Institute for Biology Education with one neighboring preschool group of approx. 15 children. In the second case, only the stations about the ants were used, as children participated in another activity that will be presented below.

In both cases, the activity started with an introductory phase, in which the instructors introduced themselves by saying their name, explaining that they are scientists who enjoy observing and learning about animals and plants, and revealing their favorite animals. Children were then asked to also say their name, age, and favorite animal, and after each presentation the whole group was encouraged to make the noises or movements that are usually associated to the given animal, e.g. if a child's favorite animal was a lion, the whole group would roar. This served as a fun and relaxing ice-breaker for children to get familiar with the instructors and for instructors to learn the names of the participating children. Instructors and children then talked about what it is a person can do when they find an animal interesting and want to learn more about it. They mentioned, for example, that one can observe it, describe it, and ask questions about anything they want to know, e.g. where the animal lives, what it eats, how it protects itself from enemies, etc. Finally, the instructors told children that during this activity, they could engage with some animals as a scientist would do in order to learn more about them. Children were then divided in small groups of 3-5 children, each of which visited the stations in a different order. Additionally, the activities finished with a closure in which the whole group met for a final round of conversation. The instructors asked children if they enjoyed the activity, what they learned about ants and snails, and if they were excited to learn more about other animals in the future. The general response was very positive, as both preschoolers and first graders showed great enjoyment in the tasks and showed an understanding of the relation between the biological structures and functions presented to them.

1b) Observation of bird species

Content

This activity centers around different bird species, namely the black bird, woodpecker, great tit, blue tit, song thrush, and chaffinch. The goal is for children to practice their observation skills by describing and comparing the birds' body parts, colors and songs.

Materials

The materials of this activity consist of actual stuffed animals and plush toys from the LBV-Naturshop. These plush toys are constructed in a way that they illustrate the same colors of the feathers, the beak and even the eyes of the corresponding bird (see Figure 4.3). Further, each of the toys contains a pushbutton that makes the same sound of the species they represent.

Figure 4.3: Materials of the outreach activity consisting of the observation of bird species. Top: stuffed animals; bottom: plush toys from the LBV-Naturshop

Implementations

Two formats of implementations were developed. In the first one, the outreach activity was designed as a face-to-face interaction with young children, so they are able to interact with the materials and the instructor. In the second one, the activity was developed as a series of four short videos, in which children can practice their observation skills but without directly interacting with the instructor or materials. This second format was chosen to provide young children with a learning activity they could engage in during lockdown in the year 2020. As such, the videos can be used whenever children cannot go to the preschool facilities, but also independently from this, for example whenever parents or caretakers wish to explore biology topics with their children at home.

Face-to-face implementation. As stated above, the first format consists of a face-to-face learning activity (see Figure 4.4). It follows four steps:

1. Children are encouraged to think about birds and name their body parts, namely the head, belly, back, wings, tail, and legs. This way, their previous knowledge is activated before continuing with the observation exercise.
2. Children are presented with the plush toys one after the other, and are encouraged to observe each toy and state what colors the different body parts have. The toys are presented in the following order: black bird, woodpecker, great tit, blue tit, song thrush, and chaffinch. This way, the level of difficulty increases, as it starts with a bird that only shows one colour (back), follows with a bird that shows three colours (black, white, and red), and so on. After the observation of each plush toy, the instructor pushes the button that make the sounds of the respective species.
3. Children are presented with all six stuffed animals. They are then encouraged to assign the stuffed birds to the respective toys based on the colours of their feathers. Further, they asked to compare the stuffed animals and the plush toys regarding the similitudes and differences, e.g. the plush toys do not have legs and are all of the same size, whereas the real birds have legs and they are of different sizes.
4. Finally, children are asked whether they know the name of the different birds and, in the cases in which they do not know, they are encouraged to come up with a name that would make them remember how the bird looks like. For example, in one implementation, children did not know the name of the song thrush, and one group came up with a German name that translates to “dotted birdy”.

This activity has been implemented twice. Once with a preschool group of 6 children, and once with a group of approx. 15 children from a preschool near the Institute for Biology Education (the same that participated in the implementation of activity 1a). In both cases, the activity started with a presentation round similar to the one presented in the implementation of the concept-based and inquiry-based learning activity. The bigger preschool group were divided into small groups of 5 children.

Figure 4.4: Face-to-face implementation of the outreach activity consisting of the observation of bird species

Implementation as a video series. This consists of a series of four videos titled “Exploring animals like a biologist” in which children get the opportunity to develop their observations skills while learning about the male and female black bird, the woodpecker, the great tit and the blue tit in an active manner, as they are encouraged and given time to observe, describe, compare, and listen to the different bird species. These videos can be used whenever children cannot go to the preschool facilities, such as during lockdown phases, and whenever parents or caretakers wish to explore biology topics with their children from home. The videos were scripted and directed by the author of this dissertation in cooperation with Prof. Birgit J. Neuhaus and were produced by Inga Oberbeil and Marius Eckert. They are conducted in German, and can be found under this link.

The titles of the videos are as follows:

1) “What do biologists do?”
2) “How to recognize a bird”
3) “My favorite bird”
4) “A little secret for you”

The first video “What do biologists do?” serves as an introductory episode. Here, the instructor introduces herself and welcomes the viewers to the video series. She then states that she is a biologists and explains what biologists do, namely to study animals and plants, starting by posing all kinds of questions about them, for example regarding where they live, what they eat, whether they live alone or in a group, and so on. To find answers to these questions, she explains that biologists first observe the animals very carefully and then describe them as precise as possible. She then tells the viewers that in this video series, they will have the opportunity to get to know some exciting animals and behave like biologists, and recommends to watch the videos accompanied by a partner, e.g. a parent or a friend.

In the second video “How to recognize a bird”, the instructor starts by presenting all stuffed birds that are part of the video series and asks viewers to think about the features by which one can recognize a bird and to discuss it with their partners, for which she gives the viewers a couple of seconds. She then presents the stuffed male black bird as an example by which viewers can recognize the typical features of a bird. She encourages viewers to observe it carefully, for which a close-up of a 360° display of the stuffed animal is presented, so that viewers can have time to observe it at ease (see Figure 4.5). Afterwards, she lists following features: feathers, a beak, two feet with claws, two wings, and a tail. She further describes the male black bird with its black feathers and yellow beak, as well as the female bird, who is completely brown. After this, she comments that many birds can sing, presents the corresponding plush toy and pushes the button to make the sound of the male black bird’s song. She then mentions that viewers have probably already heard this sound, as this bird species is very common near human populations. Finally, she praises the viewers for having observed and described the animal with her and gives them the task of asking friends and family what their favorite bird is, and promises to reveal her own favorite bird in the next video.

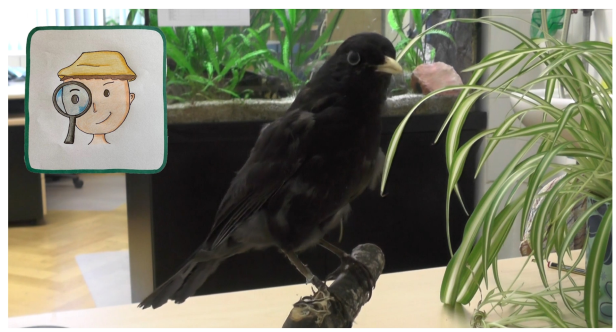


Figure 4.5: Part of the video ”How to recognize a bird”

Figure 4.6: Part of the video "My favorite bird"

In the following video "My favorite bird", the instructor reveals that her favorite bird is the spotted woodpecker. She then reminds the viewers that the first step to learn about an animal is to observe it quietly and describe it as precisely as possible. She then encourages them to observe and describe the woodpecker with their partners, for which a 360° close-up of the bird is presented with enough time for children to conduct the tasks calmly (see Figure 4.6). Afterwards, she goes on to describe the woodpecker herself. First, she highlights that compared to the black bird, the woodpecker's feathers have three different colors: black, white, and red. She then describes it in more detail, including the black head with a red patch on top, the red eyes, the black and white feathers on the back, the black wings with white spots, the white breast, the red underbelly, and the strong claws with which woodpeckers can hold on to the trees. She further mentions that if viewers ever find a black feather with white spots in the forest or in the park, they now know that it belonged to a spotted woodpecker. Further, she uses the corresponding plush toy to show the sound that these birds make, and highlights that it cannot be described as a song but rather as a cackle. To further illustrate this, she presents again the plush toy of the black bird so that viewers can compare the different sounds. At last, she gives the viewers a new task: To pay attention to their surroundings next time they're outside and look for what birds they get to see or hear, and try to observe and describe it in detail as they have already done in these videos so far.

The last video "A little secret for you" starts with the instructor recapitulating the task of the previous video and saying that lately she saw two birds in her surroundings, namely the great tit and the blue tit, while presenting the corresponding stuffed animals. As in the last videos, she encourages viewers to first observe and describe the great tit using a 360° close-up, and then describes it herself, mentioning following characteristics: the black head, the small beak, the white cheeks, the greenish back, the grey-black wings with thin white stripes, and the yellow belly with a black central stripe. Afterwards, the same procedure is conducted with the blue tit. She mentions that, similar to the great tit, the blue tit has a small beak, white cheeks and greenish back, but it has a blue head, blue wings, and a yellow breast with a grey patch. To further illustrate these similitudes and differences, she presents both stuffed birds side by side. Further, she demonstrates the difference in size between these animals and the black bird. She then uses the plush toys of the great tit and the blue tit and makes the sound one after the other. Finally, she summarizes that throughout this video series, viewers have learned about different bird species by observing and describing them just as a biologist would do. She then reveals viewers "a little secret": They can always explore the world like a biologist, given that wherever they are, be it in the forest, by the river, or in their own backyard, they can always find interesting animals; the trick is just to be aware of their surroundings and pay attention in order to perceive them. She further reminds viewer that whenever they find an animal interesting, they ought to be very quiet and just observe it attentively and, if they find all of this fascinating, they may think about becoming real biologists later in life.

4.2.2 Outreach activities oriented towards preschool teachers

2a) Practical recommendations article

The aim of the article is to provide three core teaching recommendations for early education professionals that are looking to engage young children with biology topics. In summary, the three recommendations state that the biological concept of structure and function is suitable for the preschool level as it can be well understood by young children through the comparison of different biological structures, and that the inquiry-based approach can be used to structure science learning opportunities in preschool. In the article, these recommendations are sustained by theory and illustrated through exemplary everyday situations as well as through the use of the learning materials developed for this doctoral project. Further, a brief summary of the findings of study 2 about children's involvement was included to demonstrate the effect of embedding the scientific inquiry method on children's learning experiences with science.

The article was published in the journal Kita Aktuell, Germany's largest advice and knowledge platform for day care centre directors, and is cited as follows:

> Flores, P., Kohlhauf, L., & Neuhaus, B. J. (2020). Der Wald kommt in den Kindergarten [The forest comes into the kindergarten]. *Kita Aktuell Spezial, 1*, 22–25.

2b) Video abstract

A video titled " 'Do fish have eyelashes?' - Using the Scientific Inquiry Method to address Children's Questions" was produced to display the theoretical background, the methods, the main findings and the conclusions of study 2. The intended audience are preschool teachers that are looking to become familiar with ways of engaging young children with scientific topics. The video can be found under this link.

The video is divided in three parts. In the first part, the theoretical background of the study is presented, starting with a situation in which a preschool teacher is confronted with several children's questions that she does not know how to answer. Further, the scientific inquiry method and the inquiry-based learning approach are presented, leading to the research questions of study 2. In this part of the video, the voice-over is accompanied by self-made illustrations. The second part consists of a video clip in which the author of this dissertation presents some of the learning materials and the difference between the inquiry-group and the control group. The third and final part of the video is again accompanied by self-made illustrations. Here, the main results of study 2 are presented, i.e. the effect of the inquiry-based approach on children's involvement and ability to describe and explain the relationship between biological structures and functions of different organisms, as well as the positive correlation that could be found between these two aspects. Finally, the video summarizes that the inquiry-based approach has positive effects on children's learning experiences and outcomes, and goes back to the situation presented at the beginning, concluding that preschool teachers can use children's questions as the starting point of investigations, even when they may not be familiar with the content that is being investigated.

In the following, the script of the video will be presented (see also Figures 4.7-4.9).

First part:

" 'Do fish have eyelashes?' 'What do snails eat for breakfast?' 'Where do butterflies come from?' 'Do plants like orange juice?' We all know that children love to ask questions. But what should we do when we have no idea how to answer them?

Humans have been asking questions and looking for answers for thousands of years. It's our way of learning about the world and understanding how things work. Over time, we have developed a way of investigating things in a systematic and objective way. We call it "the scientific inquiry method", and it's something we can all do, no matter how old we are or how much we know about a topic.

So, what is this scientific inquiry method? Well, it actually consists of several steps… We start by asking a question – what do we want to find out? Then, we think about what the answer might be, based on what we already know about the subject. This possible answer is called a "hypothesis". Afterwards, we conduct an observation or an experiment in order to collect some evidence that we can then analyze and interpret it, finally asking ourselves: Was our hypothesis correct or not? If it's correct, then we answered our question! And if it's not, well, then that's sometimes even better, because that leads us to new questions, thus starting a new cycle of investigation.

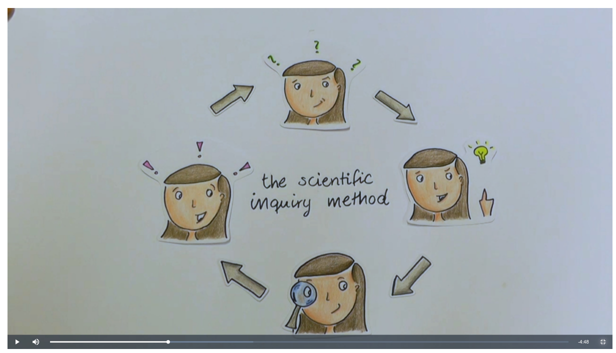


Figure 4.7: 1st part of the video abstract

For years, teachers have used the scientific inquiry method in their science lessons. This educational approach is called inquiry-based learning. With this approach, teachers guide children through the whole investigative process. This way, students benefit the most because they are active participants in their own learning. In the last years, inquiry-based learning has been gaining increasing attention in preschool education, but until now, only few studies have investigated how this approach benefits young children.

Therefore, we decided to conduct a study to find out: what effect does the inquiry-based educational approach have on preschool children's learning experiences and learning outcomes? And how do these two relate to each other? Learning experience refers to the level of involvement that children display during a learning activity. This can be identified through several indicators of behavior, such as their facial expression and body language. Involvement is believed to be an important factor driving children's learning and is therefore an interesting subject of investigation. Learning outcome refers to how much children learn about the scientific concepts handled during a learning activity. In preschool education, the idea is that children develop a basic understanding of scientific concepts that they encounter in their everyday life, so they can use this understanding to make sense of the world around them.

Now, let's take a look at the study we conducted..."

Second part:

"We developed learning materials that represent different body parts of several forest animals, such as the feet of a woodpecker, the mouth of an ant, and the shell of a snail. With these models, children could learn an important concept in biology: how the structure of a body part is closely related to the function it serves.

Figure 4.8: 2nd part of the video abstract

To address our research question, we invited preschool children to participate in a learning activity. We divided them in two halves. One half was called the "inquiry group". With them, we discovered the relation between the biological structures and their functions by following all the steps of the scientific inquiry method. For example, we told children "Imagine you're a bird and you're very hungry. Suddenly you see a snail and a snug on the ground and start wondering which one would be easier to catch. . . " We then asked them: "Which one do you think is more protected?". To this, children could then pose an hypothesis by choosing one of the models: either the snail or the snug. Afterwards, they could make observations by interacting with the models. In this case, the instructor told them to try to catch them as if they were the hungry bird, and then pulled the snail into its shell so that children could not reach it – just like this. This way, children learned that the shell of a snail is a hard structure and because of this, snails can protect themselves against predators and other dangers in their environment.

The other half of the children was called the "control group". They were encouraged to observe and interact with the model of the snail, and they learned that the hard structure is important for protection, but they did not pose nor test an hypothesis by observing different models. This way, they learned about the concept of structure and function but without following the steps of the scientific inquiry method."

Third part:

"By dividing our participants in two groups, we could observe which group had better learning experiences and learning outcomes and, based on this, interpret the effects of the inquiry-based approach. As it turns out, children of the inquiry group showed a higher level of involvement compared to the control group. Also, they showed a higher ability to describe and explain the relationship between biological structures and functions of different organisms. Interestingly, we found that children that displayed a high level of involvement also had a high ability to describe and explain structure and function relationships. These results indicate that the inquiry-based approach is an appropriate strategy for engaging preschool children with science, as it has a positive effect on both their learning experiences and outcomes.

Figure 4.9: 3rd part of the video abstract

So what does this mean for preschool teachers? It means that, when a child asks a question, it doesn't really matter if we know the answer right away! What matters is to know how to use their questions as the starting point of an investigation. This way, we can guide children to pursue their own questions by matters of their own investigation, allowing them to fulfil their exploratory drive, and even we can learn something in the process! So the next time a child asks you something you don't know how to answer, remember: You can always make use of the scientific inquiry method and answer with: 'Let's find out!' "

4.3 Discussion

Domain-specific science didactics, the research field to which this doctoral project pertains, follows two main goals: To gain fundamental understanding about the processes of teaching and learning, and to make use of this understanding in order to improve science instruction in all educational levels. As such, this field can be described as use-inspired research and thus falls within the so-called "Pasteur's quadrant" of Stokes's (1997) Quadrant Model of Scientific Research. The framework of this doctoral project was thus guided by the motivation to reach both goals of the use-inspired research field of science didactics. This was achieved by complementing the three research studies with a set of diverse science outreach activities oriented towards preschool teachers and children, in which the findings of the studies and basic principles of life science didactics were put to use to contribute to the improvement of early science education.

The outreach activities that were developed and implemented within the framework of this doctoral project can be divided in two types, based on how the fundamental understanding about best practices in early science education was put to use. In the first type, this understanding about best practices was directly applied in science learning activities with preschool children. These were (1a) a concept-based and inquiry-based activity about ants and snails and (1b) an observation exercise about bird species. In the second type, this understanding was shared with early childhood educators with the hope that they themselves implement these best practices in their own science learning opportunities with preschool children. They include the publication of (2a) a practical recommendations article and (2b) a short video about study 2.

Outreach activities are characterized by their audiences, degree of public participation, and aims. As described above, the audience of activities 1a and 1b consisted of preschool children, whereas 2a and 2b sought the audience of preschool teachers. Activity 1a and the first format of 1b consisted of face-to-face interactions with the children, and thus contained a high level of public participation. The second format of 1b, as well as the activities 2a and 2b, consisted of the publications of an article and short videos, so they can be characterized as one-way communications without direct public participation. The general aim of all four activities was to contribute to the improvement of early science education. Regarding the goals of science outreach described by several entities (e.g., Burns et al., 2003; Cooke et al., 2017; Dudo & Besley, 2016; Husher, 2010; Kappel & Holmen, 2019; National Academies of

Sciences et al., 2017), the two types of activities followed different, more specific goals. The activities oriented towards preschool children (1a and 1b) aimed at improving children's understanding of scientific topics, i.e. ants, snails and birds, and contributing to children's enjoyment and interest in science. The activities oriented towards preschool teachers (2a and 2b) aimed at sharing the findings of the research studies with preschool teachers and influencing behaviors related to science teaching.

For the planning of these outreach activities, several recommendations that can be found in the literature were taken into consideration (Cooke et al., 2017; Varner, 2014). First of all, the conducted research studies were used to get to know and listen to the target audiences and learn about their existing knowledge, interests, beliefs, and motivations. In the development phase of each outreach activity, the learning goals were defined for the audience as described above.

During the implementation of the activities with direct participation of children (1a and first format of 1b), their situational interest was hold successfully, given that they experienced autonomy, competency and a sense of belonging during the whole learning process (Krapp, 2002). They were, for example, encouraged to formulate their own hypotheses, describe their observations, and collaborate with each other, e.g. when they were asked to assign all the plush toys to their corresponding stuffed animals (Varner, 2014). These activities were evaluated while they were taking place, i.e. through formative assessments regarding children's learning progress and interest levels (Varner, 2014), and also afterwards in the closing conversations, where they were asked if they liked the activity, what they have learned, and whether they would like to learn more. In all cases, children showed and expressed enjoyment and interest in the tasks and wished to discover more about these topics. Further, some of the preschool teachers that accompanied the children during the activities expressed great appreciation not only about the materials and the instructional strategies that were implemented, but also about the fact that their children were simultaneously joyful and fully immersed in the tasks.

In the case of the one-way communication activities, the evaluations were conceived differently. The video series (second format of 2b) was evaluated by asking a small amount of parents and teachers to watch it with their children and let the author know about children's reactions and engagement with the tasks. Here, the response was very positive, although a higher amount of participants would have been desirable to reach a reliable conclusion. The practical recommendations article (2a) was reviewed by an expert in the field of early science education that approved the article's content, structure and language considering the targeted audience. The concept behind the video abstract (2b) was reviewed by a science communication expert. A pilot version was watched by colleagues and a small group of laypeople that gave feedback on the content, structure and language, which was implemented in the development of the video's final version. Even though the quality of these activities were successfully confirmed in these ways, it was not possible to conduct any further evaluation to assess how many preschool teachers read the article and implemented its recommendations, or how many watched and made use of the videos. Therefore, in these cases it was not possible to fully assess the extent to which the corresponding goals were reached.

Part V

Overall discussion

Overall discussion

In the introduction of this dissertation, I elucidated that current assumptions about best practices in early science education are mostly based on the theoretical frameworks and empirical findings of research conducted with school teachers and students, given that there are still very few studies focusing specifically on preschool teachers and children. Against this background, I presented three important research gaps that can be found in the literature on early science education. These concern (1) the assessment of children's conceptual knowledge, specifically of the concept of structure and function, (2) the effect of the inquiry-based approach on young children's learning experiences and outcomes as well as the relation between them, and (3) the role of preschool teachers' science-related professional knowledge in their instructional practice. Further, I mentioned that this doctoral project pertains to the use-inspired research field of science didactics, and as such, it aimed at not only gaining fundamental understanding about early science teaching and learning, but also at putting this understanding to use for the improvement of early science education through the implementation of a diverse set of outreach activities oriented towards preschool teachers and children. In the following, I will summarize how the results of the studies presented here contribute to closing these research gaps and to defining the extent to which the theoretical frameworks stemming from research at school can be transferred to the context of preschool. Considering the pilot nature of the conducted research studies, the findings must be understood as preliminary results that provide an important first insight into the respective foci of investigation and that can be built upon by future research endeavors. Following this, I will shed light on the implications that this doctoral project entails for both future research and outreach.

The findings of the first study, which aimed at the development and evaluation of an instrument to measure young children's knowledge of the biological concept of structure and function, entail four key revelations. First, children's conceptual knowledge of structure and function can be characterized through two different cognitive processes, i.e. their ability to match structures and functions (*recognize*), and their ability to explain these relationships in a logical or cause-effect manner (*explain*). Second, although these cognitive processes represent discrete abilities, they also are inherently related to each other, as can be seen in the existing correlation between the two cognitive processes *recognize* and *explain*. Third, the wide range of person measures in both tiers demonstrates that there is a wide distribution in preschool-aged children regarding these two different cognitive processes. And fourth, children's conceptual knowledge is closely related to their linguistic abilities, as revealed by the correlation that could be found between subjects' language skills and their person measures in both tiers.

These findings join those of previous studies in demonstrating that preschool children already possess and can develop a basic understanding of the scientific concepts that are used to structure science lessons in school (Ahi, 2017; J. L. Anderson et al., 2014; Samarapungavan et al., 2008, 2011). Therefore, the development of conceptual knowledge is not only an appropriate goal of science education in school but also in the context of preschool. The conceptualization used in this study to characterize conceptual knowledge, namely through the two cognitive processes *recognize* and *explain*, is based on theoretical frameworks that aimed at defining the ways by which school students' conceptual knowledge is reflected (De Jong & Ferguson-Hessler, 1996; Förtsch et al., 2018; Krathwohl, 2002; Mayer, 2002; Van Boxtel et al., 2000). The results of the evaluation presented here show that this characterization can successfully be transferred to the measurement of preschool children's conceptual knowledge. The two-tier item structure, which has so far only been used in instruments that assess older students' knowledge (Haslam & Treagust, 1987; Treagust & Mann, 1998; Treagust, 1988; Liu et al., 2011), could also be applied for the measurement of young children's knowledge. Along with these parallels between preschoolers and older students, this study also illustrates two important differences in the measurement of conceptual knowledge of these two groups of people. The first refers to the format of the assessment. While older children can participate in paper-and-pencil tests and thus a great amount of students can be tested simultaneously, preschool children usually cannot read and write, so research studies focusing on this group require a different format. In this study, one-on-one interviews with two-tier items and drawings that support children's reasoning proved to be an excellent method to assess preschool children's knowledge. The second difference refers to the content that should be addressed in the specific items of such an instrument. Before starting school, young children form their first basic ideas about scientific concepts based on their everyday experiences with natural phenomena, whereas older students acquire further understanding through science lessons in school (e.g., Inagaki & Hatano, 1996, 2004). This may be one of the reasons why previous studies on preschool children's understanding of the relation between structure and function seem to indicate that they are able at recognizing relations between structures and functions in examples that they can directly observe and have probably already observed in their everyday life but have difficulties in doing so in examples that they cannot observe (Ahi, 2017; J. L. Anderson et al., 2014; Samarapungavan et al., 2008, 2011). Therefore, when assessing young children's conceptual knowledge, it is important to choose topics that are already embedded in their own experiences.

The second study focused on the effect of the inquiry-based learning approach on preschool children's learning experience, i.e. their involvement during the learning situation, and on their learning outcomes, i.e. their conceptual knowledge of structure and function, as well as the mediating effect of involvement. The three key findings of this study are as follows. First, the inquiry-based approach has an effect on preschool children's learning outcomes. Specifically, the inquiry-based learning activity conducted in the study did not have an influence on children's ability to recognize relations between structure and function, but it did have an effect on their ability to give conceptually based explanations of the relations that they did recognize. This goes in line previous studies that demonstrated the positive influence of inquiry learning on preschool children's knowledge of basic scientific concepts (Samarapungavan et al., 2008, 2011; Steffensky et al., 2012). Second, the inquiry-based approach has a positive effect on preschool children's learning experience. This is reflected in the fact that the involvement of the inquiry-group was significantly higher than that of the control group. With this, study 2 corroborates in a quantitative manner what other studies have previously described only qualitatively about the positive effect of inquiry learning on young children's learning experiences (Andersson & Gullberg, 2014; Howitt et al., 2011). Third, children's learning experience and learning outcome are correlated with each other, but no evidence could be found regarding the mediating effect of the former on the latter after including the corresponding covariates in the analysis, which may be due to the fact that the small sample size entailed a statistical power too low to detect existing effects in complex analyses such as a mediation analysis. This study is the first to investigate the relation between children's involvement and learning outcome as well as the way in which the former influences the latter. With this approach, it makes a unique contribution to the still growing literature in the field of early science education.

The inquiry-based science education approach has played an important role in school and university education for many decades (Bittinger, 1968; Hermann, 1969; Huber, 2014; Council et al., 1996, 2012). As several reviews on research with school children have shown, guided inquiry learning is more effective than unguided inquiry and other expository forms of instruction in eliciting knowledge gains (Alfieri et al., 2011; Carolan, Hutchins, Wickens, & Cumming, 2014; D'Angelo et al., 2014; Furtak, Seidel, et al., 2012; Lazonder & Harmsen, 2016). In study 2, an inquiry-based learning activity had a positive effect on children's learning outcomes. These findings thus contributes to the existing literature by demonstrating that the guided inquiry approach can be implemented in both school and preschool to achieve one of the main goals of science education, i.e. the development of conceptual knowledge, taking into consideration that in the case of preschool, the idea is not for children to fully transform naïve conceptions into scientifically accurate knowledge but to develop a basic knowledge that helps them understand the natural phenomena they encounter in their everyday life (Gelman & Brenneman, 2004; Möller & Steffensky, 2010; Samarapungavan et al., 2011; Steffensky, 2017).

Study 2 further investigated the effect of an inquiry-based learning activity on preschoolers' involvement. The assessment of involvement as an indicator of a person's learning experience stems from research with preschool children (Laevers, 2000, 2003), although it has been used by Waldenmaier et al. (2015) to investigate the effect of an inquiry-based science course on primary school children's learning experience. There was therefore in this case no direct transfer from research with school students to research with preschool children; in fact, most studies investigating inquiry-based learning in school infer its effect exclusively from students' learning outcomes (Lazonder & Harmsen, 2016). Rather, the transfer that took place for the conceptualization of study 2 can be described as a feedback loop from a concept that originated in the context of preschool, was implemented in the context of primary school to investigate the benefits of inquiry-based learning (Waldenmaier et al., 2015), and then used again in this study with preschool children to address a similar research question, partly based on the findings of Waldenmaier et al. (2015).

The third study focused on the relation between preschool teachers' professional knowledge and their instructional practice, and the main findings are as follows. First, the PCK-group and the CK+PCK-group differed in the content dimension of their instructional practice (*single facts*) but did not differ in their implementation of any scientific inquiry activity, which suggests that teachers that possess science-related PCK can engage in the scientific inquiry process with children even when they lack the relevant CK. On one hand, this supports the co-constructive view that for preschool teachers, the knowledge of how to structure a science learning opportunity is more important than the knowledge about the specific content (see Anders, 2012; Anders et al., 2018). On the other hand, given that preschool teachers often hold misconceptions about scientific topics (Kallery & Psillos, 2001), the question rises as to how beneficial is it for children to engage in scientific inquiry activities if their understanding of the content may not be properly fostered by the instructor. Second, the CK+PCK-group was significantly better than the CK-group in both content dimensions of instructional practice (*single facts* and *relations*) and in implementing the more complex steps of the scientific inquiry method, namely formulating hypotheses and interpreting the findings of an investigation. This suggests that for preschool teachers, PCK is necessary in order to conduct inquiry in a deeper and more meaningful manner, as the CK+PCK-group was better than the CK-group in providing children with opportunities to formulate their own ideas and predictions and in creating not only hands-on but also minds-on learning opportunities. The significant differences in the content dimension, together with the significant correlations found between the content subdimensions and the inquiry subdimensions, further suggests that the implementation of scientific inquiry activities provides a crucial framework in which the content of the learning activity can be explored.

These preliminary findings go in line with previous studies in the fields of early physics and mathematics education that have provided evidence on the effect of preschool teachers' professional knowledge on their instructional practices (Dunekacke et al., 2016; Gropen et al., 2017; J. Lee et al., 2003; J. Lee, 2005; McCray & Chen, 2012). As such, study 3 joins those previous studies in illustrating how two important aspects of research with school teachers can be transferred to investigations with preschool teachers. The first refers to the theoretical framework that is used to characterize teachers' professional competence as a multidimensional set of dispositions that include their professional knowledge, which in turn consists of teachers' CK and PCK (Baumert et al., 2010; Baumert & Kunter, 2013; Blömeke et al., 2015; Borko, 2004; Brunner et al., 2013; Darling-Hammond, 2010; Kunter et al., 2011; Park & Oliver, 2008; L. S. Shulman, 1986; L. Shulman, 1987). The second aspect refers to the empirical findings that demonstrate that the different knowledge facets of school teachers' professional knowledge have an influence on the quality of their mathematics and science lessons (e.g., Abell et al., 2013; Ball, 1988; Ball et al., 2005; Baumert et al., 2010; Förtsch et al., 2016; Kulgemeyer & Riese, 2018; Kunter et al., 2013). This study thus contributes to the still growing literature about the importance of different knowledge facets for the quality of science instruction in every educational level.

Finally, as this doctoral project is located within the field of subjects-specific didactics, an important goal was to complement the research studies with outreach initiatives that aimed at contributing to the improvement of early science education. For this, a diverse set of science outreach activities were developed for both preschool teachers and children. They took different formats, such as face-to-face interactions and one-way communications. Their specific aims were to improve children's knowledge of different animals, contribute to their enjoyment and interest in science, share the fundamental understanding about best practices in early science education with preschool teachers, and influence their behaviors related to science teaching. Reaching these aims could have an effect on other, more distal goals of science outreach further down the road, such as encouraging children's science-related career choices later in life and increasing preschool teachers' appreciation of and support for research in the field of early education (Burns et al., 2003; Cooke et al., 2017; Dudo & Besley, 2016; Husher, 2010; Kappel & Holmen, 2019; National Academies of Sciences et al., 2017).

In general, the conducted science outreach activities were a crucial element of this doctoral project, not only as an effort to reach both goals of the use-inspired research field of science didactics, but also as an important experience for the author of this dissertation. They represented an invaluable source of information about the audience's existing knowledge, interests, and reception of the provided learning opportunities, and opened up new possibilities for the development of further science activities both for future research and outreach.

Implications for future research and outreach

Although early science education has established itself as a crucial element of preschool, research in this field is still scarce. This thesis sheds a first light on several important foci of investigation, and the results presented here are preliminary and must thus be reinforced by future investigations. Moreover, they open up new possibilities for further research, as will be described in the following.

Study 1 entails several implications for future research endeavors. First of all, the limitations of the instrument must be tackled before it can be used to address new research questions. One limitation that must be addressed is the low person reliability, which was a result of the length of the test. As described above, the pre- and post-test contained 9 and 10 questions each. This amount of items is presumably too low to provide high person reliabilities. Future implementations of this instrument could use more items in order to broaden the length of the test and herewith improve the person reliability. The second limitation is the issue of the low anchor quality. As described by Boone and Staver (2020), the anchoring can be improved by analysing the number, distribution, certainty, and drift of the anchor items and subsequently excluding malfunctioning items. This, however, requires a higher amount of items in general and of anchor items in particular, compared to the pre- and post-test used in this study. In summary, these two limitations could be resolved by increasing the amount of items. The presented pool of 16 items can be used as a basis for the development of new items, provided that the integration of such items is conducted using the Rasch technique. Further, the representation of the item pool in a two-axis coordinate system can inform which set of items should be chosen for measuring young children's conceptual knowledge and, in cases in which different test forms are required, which items should act as anchors. For example, each group of items (easy, middle, and hard) can provide a set of anchor items. Also, items that are very close to each other and thus assess a similar level of difficulty, such as *Dog's ears* and *Rose's thorns*, should not be used in the same test form. Rather, they could be implemented at different time points, e.g. one item could be part of a pre-test whereas the other could be present in the post-test.

Provided that these limitations are resolved, this instrument can be used to investigate a variety of new research questions. These include, for example, the identification of different types of preconceptions that young children hold about structure and function, as well as the identification of potential predictors of conceptual knowledge, e.g. domain-general or cross-domain scientific reasoning skills and diverse environmental factors belonging to the preschool setting and the family environment (Klemm & Neuhaus, 2017; Koerber & Osterhaus, 2019; Kuger & Kluczniok, 2009; Niklas, 2015; Niklas & Schneider, 2013; Sodian, Zaitchik, & Carey, 1991). Another worthwhile focus of investigation is the role of children's previous knowledge of the organisms that are mentioned in the items. The test items consisted of structural and functional relationships that were expected to be familiar to young children and, if not, could be deduced from their knowledge about the general principle of structure and function. The results indicate that children's previous knowledge could be an important factor influencing the order of difficulty found in the item pool. For example, it could be expected that children have more previous knowledge about woodpeckers' beaks or moles' forefeet than about fishes' mouths or conifer needles, given that children have more opportunities to observe and learn about woodpeckers and moles in their everyday lives, in children's books and learning materials, compared to fishes and conifers. This hypothesis could be studied in future research on young children's conceptual knowledge.

An improved version of the instrument could be applied not only in future research endeavours but also in the praxis. For example, this instrument could be used to evaluate children's level of conceptual knowledge at the moment of transition from preschool to 1st grade. With this information, primary school teachers could shape their lessons by taking their students' level of understanding about structure and function into consideration.

Regarding the second study, there were some constraints due to the limitations of the instrument and the sample size, so these findings are preliminary. Consequently, further research studies should be conducted with a greater sampling and an improved version of the instrument to reinforce the results presented here. Further, future research studies could solve the difference in instruction time found between the inquiry and the control group.

One of the hypotheses that could not be confirmed is the mediating effect of involvement. As stated before, this may be due to the influence of other factors, i.e. the covariates. Another possible explanation is that the effects found in the mediation analysis may be underestimated. As presented above, there was a significant difference between the inquiry and the control group regarding their language ability. This led to a reduction of the effect of the inquiry-based learning context on the dependent variables and may have also influenced the mediation analysis, which means that the results of the mediation analysis may also be underestimated and a significant effect could have been found if the groups had equal language abilities. Further research would thus be necessary to address this uncertainty and reveal the true indirect effect of an inquiry-based learning context on children's conceptual understanding through their involvement.

Study 2 focused on domain-specific factors, e.g. children's previous knowledge of the biological concept of structure and function and their interest in animals and plants. However, studies have shown that young children possess domain-general scientific reasoning skills that may have an influence on their learning processes (Klemm & Neuhaus, 2017; Koerber & Osterhaus, 2019; Sodian et al., 1991). Future research studies could thus investigate the role of children's scientific reasoning skills, e.g. their control of variables strategy and their experimentation and data interpretation skills (Koerber & Osterhaus, 2019; Sodian et al., 1991), on their learning experience and outcome.

Further, this study addressed the relation between an inquiry-based learning activity and children's conceptual learning through one aspect of children's learning experience, namely their involvement during the learning situation. According to the Laevers' experiential education model, however, children's emotional well-being also plays a role as a mediator between learning context and outcome (Laevers, 2000). Taking into consideration that Klemm and Neuhaus (2017) found a mediating role of involvement between well-being and the performance of a biological observation task in a study with preschool children, a follow-up study could include children's emotional well-being and investigate its relation with their involvement and learning outcomes.

Given the pilot nature of study 3, future research studies would be necessary to reinforce the findings presented here. To achieve this, the first step would be to solve the limitations that have been described above. One of the most important improvements for future studies is the sample size. This would allow for a Rasch analysis of the data, increase the statistical power, and allow for more complex statistical analyses, as described above. Further, the research design would need improvement in order to achieve a higher participation in the post-test. This could be accomplished, for example, by assigning the post-tests to a subsequent day or by conducting the training and the post-test during the weekend. With this type of change, participants may be more likely to fill out the post-tests properly and, as a consequence, the direct effect of the PD training on participants' knowledge could be measured more precisely. Moreover, a longer duration of the PD training would also be desirable. A possibility for this would be, for example, to design the intervention as a PD course that takes place during the time span of several weeks, although the experience in the development of study 3 demonstrated that preschool teachers often do not have the time or flexibility to take part in long-term PD opportunities. Another possibility would be to embed the PD training within preschool teachers' pre-service training. This, however, would entail important difficulties regarding the implementation of instructional practices with young children, given that pre-service teachers do not yet work in a preschool and thus do not have a group of young children that are familiar with them, so that their interactions would not be particularly natural. Finally, another potential improvement would be a video documentation of the instructional practice. With this, the observations of participants' interactions with the children would be more precise, as raters would have no time constraints and could focus on measuring one aspect of the instructional practice at a time. Having tackled these limitations, follow-up studies could provide more conclusive evidence regarding the effect of different knowledge facets on preschool teachers' instructional practice.

Follow-up research projects could also include other important factors that were not part of this study. As described in section 3.1, teachers' professional competence not only consists of their professional knowledge, but also of other dispositions, such as their motivational orientations, beliefs, and self-regulation (Kunter et al., 2011), as well as situation-specific skills, i.e. the perception and interpretation of a particular situation and the consequent decision-making (Blömeke et al., 2015). All of these elements of teachers' competence can interact with their professional knowledge and have an impact on their instructional practice. Therefore, it would be worthwhile to include them in future research studies.

In study 3, the focus lied on the relation between preschool teachers' professional knowledge and their instructional practice. In the previous study (study 2), it lied on the relation between an instructional practice based on the inquiry approach and preschool children's learning experience and outcomes. There is therefore still a need to investigate the complete chain of effects, from preschool teachers' professional knowledge through their instructional practice to children's learning experiences and outcomes. Future research studies could thus extend the research design of study 3 in order to include the assessment of children's involvement and conceptual knowledge. Here again, a video documentation of the interactions would be beneficial, as different aspects of both preschool teachers and children could be investigated separately without the difficulties of live observations.

The science outreach activities implemented within the framework of this doctoral project also entails implications for future research endeavors. As this experience has made clear, conducting outreach is not only beneficial for the audience, but also for the scientists themselves, as it can be used to gain an important insight into the group of interest and can even open up new possibilities for further research. Moreover, outreach activities can be a valuable exercise that allows researchers to further develop their science communication skills, which in turn is beneficial for their professional lives in different contexts. The science outreach activities presented here represent a first creative attempt at sharing the central ideas of the field and the findings of the research with nonscientific audiences (Dudo, 2013; Ponzio et al., 2018; Varner, 2014). These efforts, although not yet perfect, will hopefully inspire other researchers in the field to take into consideration the different goals of use-inspired research projects and develop their own science outreach initiatives as a means to achieve these goals. This way, this dissertation not only contributes to the still growing research in the field of early science education, but also to the outreach movement that is increasingly becoming a crucial aspect of modern scientific endeavours.

Conclusion

Giving young children opportunities to come in contact with animals and plants is highly beneficial for several reasons, but this contact alone does not seem to be sufficient for experiencing high involvement in the task or the development of conceptual knowledge. It is rather the way in which the learning opportunities take place that is decisive: A guided inquiry approach, in which children are encouraged to engage in the process of scientific investigation in order to answer an interesting question, especially through the scientific procedure of comparison, allows them to fulfil their exploratory drive and has positive effects on their learning experiences and outcomes. In order to be able to provide such learning opportunities, preschool teachers require knowledge of science concepts and phenomena (CK) as well as knowledge of how to structure inquiry-based learning opportunities by implementing different scientific inquiry activities (PCK). This, in turn, allows them to support young children's understanding of the content that is being addressed. As such, both preschool teachers and children can discover, together, that knowledge can be gained through investigation, which is arguably one of the most important goals of early science education.

Appendix A

Appendix

A.1 Interventions

Intervention of Study 2:

- A.1.1 Materials of the learning activity
- A.1.2 Script of the inquiry-based learning activity
- A.1.3 Script of the control learning activity

Intervention of Study 3:

- A.1.4 Instructional plan of the CK-Training
- A.1.5 Instructional plan of the PCK-Training
- A.1.6 Instructional plan of the CK+PCK-Training

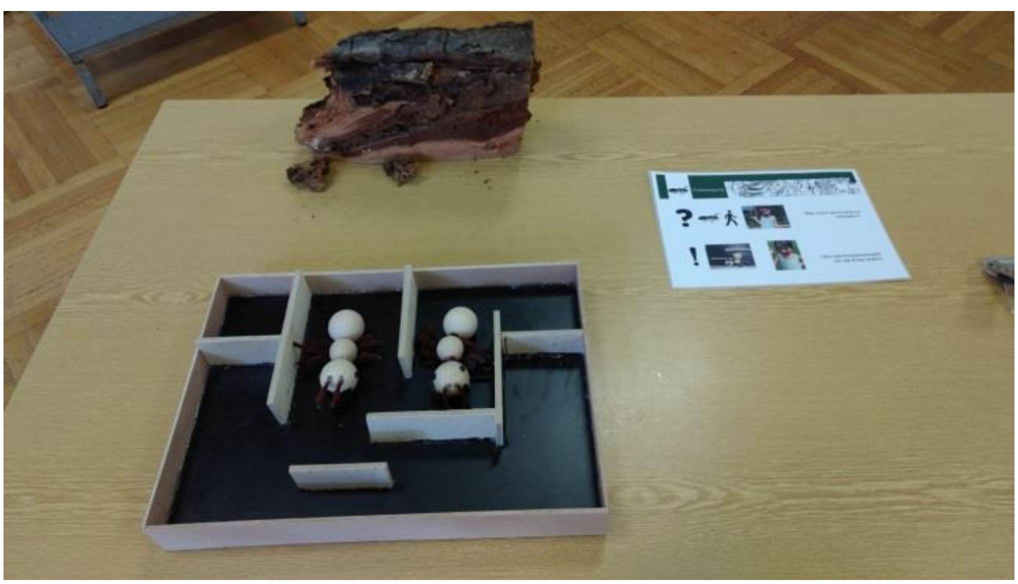
Appendix A.1.1: Materials of the learning activity

Station „Fortbewegung Specht“

Materialien/Modelle: Baumstamm, Stopfpräparat Specht, Fuß mit Krallen (‚Original‘), Fuß mit Schwimmhäuten (‚Vergleichsmodell‘, nur in Führung Erkenntnisgewinnung)

Station „Fortbewegung Ameise“

Materialien/Modelle: Ameisenbau in Holzstamm, Labyrinth, Ameise beweglich (‚Original‘), Ameise unbeweglich (‚Vergleichsmodell‘, nur in Führung Erkenntnisgewinnung)



Station „Sinne Eichhörnchen“

Materialien/Modelle: 2 mal 3er-Gruppen von Filmdosen auf Holzscheibe (einmal mit Aroma ‚Original‘, einmal ohne ‚Vergleichsstück‘, nur in Führung Erkenntnisgewinnung), Tuch, Blätter und Fichtenzapfen, Stopfpräparat Eichhörnchen

Station „Sinne Eule“

Materialien/Modelle: Trichter aus Plastik (ursprünglich ein Hundeschutzkragen) → ‚Original‘ mit Trichter auf dem Kopf; ‚Vergleichsstück‘ ohne Trichter (nur in Führung Erkenntnisgewinnung), Stopfpräparat Eule

Station „Schutz Schnecke“

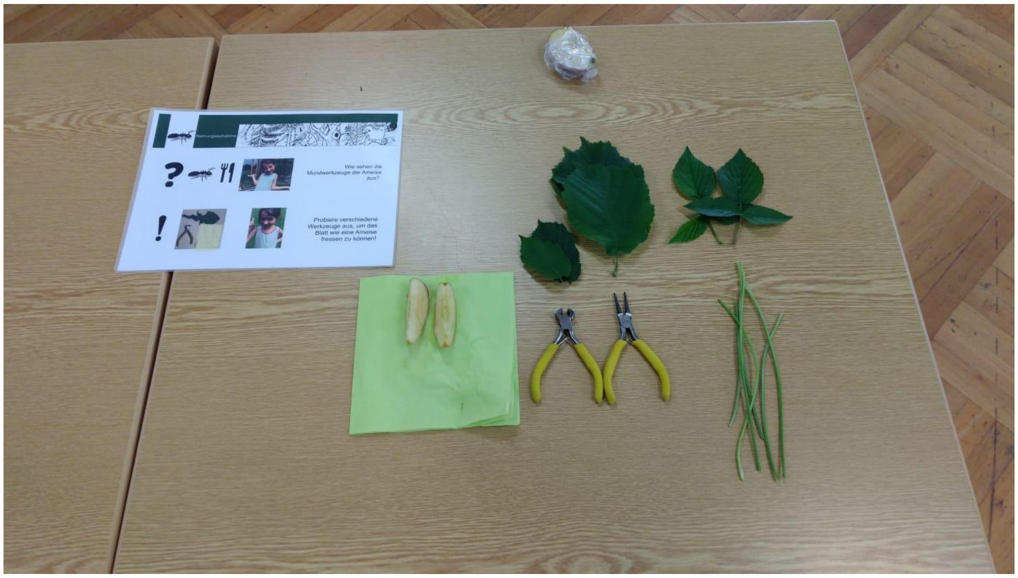
Materialien/Modelle: Tuch, Blätter, Schnecke (mit Schneckenhaus ‚Original‘), Nacktschnecke (ohne Schneckenhaus ‚Vergleichsstück‘, nur in Führung Erkenntnisgewinnung)

Station „Schutz Fichte“

Materialien/Modelle: Baumstamm (halb mit Rinde ‚Original‘; halb ohne Rinde ‚Vergleichsstück‘), Pinzetten

Station „Nahrungsaufnahme Ameise"

Materialien/Modelle: Apfelschnitze, Grashalme, Blätter, links: Beißzange (‚Original'), rechts: Greifzange (‚Vergleichsstück', nur in Führung Erkenntnisgewinnung)



Station „Nahrungsaufnahme Schnecke"

Materialien/Modelle: Karotten, Kartoffeln, Terrarium mit lebenden Schnecken, Modell Zunge Feile (rau: ‚Original'), Modell Zunge Kelle (glatt: ‚Vergleichsstück', nur in Führung Erkenntnisgewinnung)

Appendix A.1.2: Script of the inquiry-based learning activity

Führungsskript Erkenntnisgewinnung

Hallo ihr Lieben. Bevor wir gleich zusammen durch unseren kleinen Wald spazieren gehen, möchte ich dir noch ein paar wichtige Regeln erklären. (…)

Du weißt ja, dass ich Biologe bin, also ein Forscher, der Tiere und Pflanzen untersucht. Und wenn ich etwas erforsche, dann gibt es dabei immer eine ganz bestimmte Reihenfolge, was man als erstes macht, was als zweites usw. Und genauso, wie ich als Biologe, darfst du jetzt auch forschen. Hast du darauf Lust?

Super! Damit es für dich leichter ist, gebe ich dir immer ein Zeichen. Zum Beispiel bedeutet das (…) Beobachten. Dabei darf nicht gesprochen werden (…), also musst du ganz leise sein und dabei ganz genau hinschauen. Und das hier (…) bedeutet beschreiben, also erklären, wie etwas aussieht. Genauso wie du es schon mit dem Eichhörnchen gemacht hast. Aber bevor du loslegst musst du dich immer zuerst melden (…) und darfst erst sprechen, wenn du aufgerufen wirst. OK? Dann kann ich nämlich auch mal einfach jemanden aufrufen und es redet dann immer ein anderes Kind und jeder kommt dran.

> Wiederholen:
>
> a) Beobachten → evtl. melden vergessen (melden)
>
> b) leise sein
>
> c) Beschreiben

Spitze! Jetzt können wir eigentlich direkt loslegen. Wenn wir an eine Station kommen, möchte ich, dass du deine Hände bei dir behältst und nur (beobachtest).

Station Fortbewegung:

a) Specht - Füße:

Als erstes guckst du leise (…) hin und schaust, was du siehst. Dann (…) beschreibst du das, was du siehst. Wer möchte das machen? Denke daran dich immer zuerst zu melden (…) … Super gemacht X!

→ Vorinformation: Du hast den Specht ja bereits beschrieben. Der Specht ist ein Vogel, der sich gerne auf Bäume setzt und deshalb kann er sehr gut die Bäume hoch und runter klettern.

→ Frage: Und jetzt passt alle gut auf! Ich stelle dann immer eine wichtige Frage. Glaubst du es ist besser, wenn der Specht solche (…) oder solche Füße (…) hat? Warum glaubst du das? (Vermuten)

Dann gucken wir mal ob das stimmt. Du testest es jetzt selber aus (testen)

Ok. Also wir haben jetzt ein bisschen ausprobiert. Was ist dir denn aufgefallen? Erkläre uns, was du gemacht hast und warum du jetzt glaubst, dass der Specht genau solche Füße hat. (Auswerten/Interpretieren)

b) Ameise - Segmente

leise Beobachten

Beschreiben

→ Vorinformation: Wie ihr schon erkannt habt ist das ein Labyrinth. Und die Ameisen leben auch in solchen Labyrinthen, die heißen dann in Echt Ameisenbau. In diesem Ameisen Bau gibt es ganz viele solcher kleinen engen Gänge, wie hier (…).

→ Frage: Glaubst du für Ameisen ist es besser, wenn sie so (…) einen Körper haben, oder wenn sie so (…) einen Körper haben? Und warum glaubst du, ist das denn so?

Vermuten

Testen

Auswerten/Interpretieren

Station - Nahrung:

a) Ameise - Zange

→ Vorinformation: Auch Ameisen haben keine Zähne wie wir Menschen. Aber auch die Ameisen können leckere Sachen wie z.B. einen Apfel essen, zumindest kleine Stückchen davon. Und zwar machen sie das mit ihren Mundwerkzeugen.

→ Frage: Glaubst du, die Mundwerkzeuge einer Ameise schauen eher so oder eher so aus? Erkläre mir auch, aus welchem Grund du dich für eine Zange entscheidest.

b) Schnecke - Raspel

→ Vorinformation: Schnecken haben keine Zähne wie wir Menschen. Trotzdem können Schnecken aber sehr gut Blätter oder ähnliches fressen. Das besondere an Schnecken ist, dass sie mit ihren Zungen fressen.

→ Frage: Warum könnte die Zunge einer Schnecke eher so ausschauen oder vielleicht sogar so? Erkläre mir weshalb du dich für eine Zunge entscheidest.

Station - Schutz:

a) Schnecke - Haus

→ Vorinformation: Stell dir vor beide Schnecken sitzen im Garten und nagen gerade an einem Blatt. Auf dem Baum der im Garten steht sitzt ein Vogel, der den beiden zusieht, weil er sie am liebsten fressen würde.

→ Frage: Was glaubst, welcher der beiden Schnecken sich weniger Sorgen machen muss vor dem Vogel? Und erkläre mir auch warum du das denkst!

b) Fichte - Rinde

→ Vorinformation: Im Wald gibt es ja ganz viele Bäume. Das hier ist zum Beispiel ein Stamm einer Fichte. Und Bäume sind ja im Boden festgewachsen, die können also nicht weglaufen. Manchmal kommt es vor, dass ein Hirsch mit seinem großen Geweih vorbeikommt und damit an dem Baum kratzt.

→ Frage: Glaubst du für den Baum ist es besser, wenn er außen herum so etwas hat oder wenn er so aussieht? Du kannst mir dann mit Sicherheit auch sagen, warum du das vermutest!

Station - Sinne:

a) Eule - Gehör und Augen

→ Vorinformation: Wie dir sicherlich schon aufgefallen ist, hat die Eule gar keine Ohren. Wir haben Ohren damit wir gut hören können. Die Eule kann auch ohne Ohren hören. Sie hat um ihr Gesicht herum die Federn so angeordnet, dass sich so eine Art Trichter wie hier (…) bildet. Zuerst darf mal der/die X sich etwa 3m von dir (X) entfernt aufstellen und wir flüstern dann etwas und du musst versuchen zu hören was wir gesagt haben. Dann darfst du diesen Trichter hier aufsetzen und so tun, als ob du eine Eule wärst und dann nochmal genau hinhören, wenn wir beiden flüstern.

→ Frage: Glaubst du, dass du uns besser flüstern hörst, wenn du wie ein Mensch hörst, oder wie eine Eule? Und versuche mir auch zu erklären, warum du das glaubst.

b) Eichhörnchen - Geruch

→ Vorinformation: Hier unter dem Tuch befinden sich immer 3 kleine Dosen (hier drei und hier drei), und in einer dieser drei Dosen sind Nüsse versteckt. Wir versuchen jetzt dann die Nüsse durch schnuppern zu finden. Einmal darfst du hier schnuppern wie ein Mensch. Und hier darfst du dann schnuppern wie ein Eichhörnchen.

→ Frage: Glaubst du, du findest die Nüsse besser, wenn du so schnupperst wie ein Mensch oder wenn du so schnupperst wie ein Eichhörnchen.

Appendix A.1.3: Script of the control learning activity

Station Fortbewegung:

a) Specht - Füße:

Ich habe hier einen Vogel, könnt ihr ihn mir beschreiben? Ihr kennt auch sicher seinen Namen?

Genau, das ist ein Specht. Hat schon einmal einer von euch gesehen wie der Specht auf Bäumen klettern kann? Er hat besondere Füße mit Krallen, die dafür sorgen, dass der Specht auf Baumstämmen hochlaufen kann.

(Model zeigen) So sehen die Füße vom Specht aus. Durch die Form der Füße und der Krallen ist er in der Lage sich auf Baumstämmen festzuhalten. Probiert doch mal wie gut er sich damit an der Rinde festkrallen kann.

b) Ameise - Segmente

Ihr wisst doch sicher wo Ameisen leben, oder? Könnte ihr es mir beschreiben? Genau, im Ameisenbau. Da drin sind ganz viele kleine und enge Gänge. Wisst ihr auch wie der Körper einer Ameise aufgebaut ist? Der Körper von Ameisen ist in drei Teile aufgeteilt - Kopf, Rumpf und Hinterteil. An dem Modell hier seht ihr, dass die drei Teile nicht fest aneinander sitzen, sondern beweglich sind. Versucht mal mit der Ameise durch dieses Labyrinth/Ameisenbau hier zu laufen und beobachtet dabei, dass die Ameise bewegliche Körperteile haben muss um durch die engen Gänge durchzukommen.

Station - Nahrung:

a) Ameise - Zange

Könnt ihr mir beschreiben wie Ameisen etwas essen? Haben Ameisen Zähne? Nein, sie haben Mundwerkzeuge mit denen sie beißen und kauen können. Hier habe ich eine Zange die so ähnlich funktioniert wie die Mundwerkzeuge bei den Ameisen. Probiert es mal aus ein Blatt oder die anderen Dinge damit zu “beißen”.

b) Schnecke - Raspel

Und wie isst die Schnecke? Hat die Schnecke Zähne? Die Schnecke hat auch keine Zähne. Sie hat aber eine besondere Zunge. Mit dieser Zunge kann sie z.B. Blätter abraspeln. Hier ist eine Feile die so ähnlich ist wie die Raspelzunge einer Schnecke. Probiert es mal aus damit einer Karotte zu raspeln.

Station - Schutz:

a) Schnecke - Haus

Was tragen Schnecken immer mit sich herum? Genau, ihr Haus. Beschreibt es Mal. Wieso machen sie das eigentlich? Zum Schutz. Ich habe hier eine große Schnecke dabei (Modell). Schaut mal was passiert wenn die Schnecke Angst bekommt und sich versteckt. Sie ist jetzt geschützt in ihrem Haus und ein z.B. Vogel kann sie nicht mehr so leicht fressen.

b) Fichte - Rinde

Im Wald leben nicht nur Tiere, sondern auch Bäume. Könnt ihr mir den Baumstamm beschreiben? Das ist der Baumstamm einer Fichte. Auch Bäume können sich schützen. Dazu haben sie eine Rinde. Nehmt einen Nagel und versucht Kratzer in die Rinde des Baumes zu machen. Was könnt ihr beobachten?

4. Station - Sinne:

a) Eule - Gehör und Augen

Ihr könnt mir sicher sagen, was das für ein Tier ist. Beschreibt es mir bitte. Es ist eine Eule. Eulen haben ein besonders gutes Gehör. Das Gesicht einer Eule hat einen Schleier und er wirkt wie ein Trichter der Geräusche einfängt und an die Ohren weitergibt. Wer von euch mag diesen Trichter ausprobieren und schauen ob sich sein Gehör verbessert?

b) Eichhörnchen - Geruch

Habt ihr eine Idee was Eichhörnchen am liebsten fressen? Wisst ihr auch wie Eichhörnchen die Nüsse finden? Sie benutzen dazu ihre Nase. Ich habe hier unter dem Tuch ein paar kleine Dosen Nüsse versteckt. In manchen sind Nüsse, in anderen nicht. Versucht herauszufinden wo die Nüsse drin sind. Ihr dürft mal daran schnuppern.

Appendix A.1.4: Instructional plan of the CK-Training

Unterrichtsphase	**Unterrichtshandlung**	**Medien**	**Aktions-form**
Begrüßung	Begrüßen der Teilnehmer/innen		
Einstieg **20 Minuten**	- Vorstellen der Sammlung im Institut der Didaktik der Biologie - Definition der Fachwissenschaft Biologie - Bezug zum bayerischen Bildungs- und Erziehungsplan für Kinder in Tageseinrichtungen bis zur Einschulung - Vorwissensaktivierung: Tiere des Waldes benennen - Schichten des Waldes benennen - Nahrungsnetz erstellen (andere Tiere) - Übertragung auf das Wald-Plakat	PowerPoint Magnettafel, Magnete Tiere; Stockwerke des Waldes, Wolle, Nahrungsnetz Spiel	UG Plenum
Erarbeitung **55 Minuten**	- Definition von Struktur: „Fast jede Struktur hat einen evolutionsbedingten Sinn und erfüllt somit eine Funktion." - Definition von Funktion: „Funktion hat immer eine Struktur, die diese ermöglicht." - Verdeutlichen des Zusammenhangs anhand der Beispiele Spaltfüße, Kletterfüße, Schwimmfüße - Gruppeneinteilung - **Arbeitsauftrag:** Gestalten Sie mit Hilfe der Arbeitsmaterialien ein Plakat zu Ihrer Verhaltensweise (Fortbewegung, Sinne, Schutz und Nahrungsaufnahme). Suchen Sie hierfür die für Sie wesentlichen Inhalten aus den Informationstexten. - Erarbeitung der Lebewesen: Schutz, Nahrungsaufnahme, Sinne, Fortbewegung - Erstellung von Plakaten mit den Lebewesen Baum, Specht, Eichhörnchen, Eule, Schnecke, Ameise	PowerPoint Bildkarten 4 Tiere in je 4 Farben PowerPoint Plakate Bilder/ Sachtexte Tierpräparate	UG GA
Sicherung **15 Minuten**	- Gruppenpuzzle: Zusammensetzen in Expertengruppen anhand der Tierfarben. Gruppentische sind farblich markiert= Treffpunkt/Ausgangspunkt des Rundganges - Arbeitsauftrag: „Finden Sie sich in Ihren neuen Gruppen zusammen und treffen Sie sich an den farblich passenden Tischen. Präsentieren Sie Ihrer neuen Gruppe Ihr Modell und Ihren Weg der Erkenntnisgewinnung mit Hilfe Ihres Plakates und Ihres Fahrplans."	Plakate, Tierpräparate	Gruppen-puzzle, GA
Verabschiedung	Bedanken für die Teilnahme und Aufmerksamkeit, Ausfüllen der Postteste		

Appendix A.1.5: Instructional plan of the PCK-Training

Unterrichtsphase	**Unterrichtshandlung**	**Medien**	**Aktions-form**
Begrüßung	Vorstellen der Teilnehmer		
Einstieg Problemorientierte Hinführung 20 Minuten	- Vorstellen der Sammlung im Institut der Didaktik der Biologie - Definition der Fachwissenschaft Biologie - Bezug zum *Bildungs- und Erziehungsauftrags* Bayern - Vergleich Forscher vs. Vorschulkind **Fokusfrage: Wie unterstützt man Kinder beim Forschen?** - Präsentation Erkenntnisgewinnung Kreislauf → Ausblick auf den Ablauf der Fortbildung	Power-Point	UG
Erar-beitung 55 Minuten	**Begegnung mit dem Lebewesen** - Gruppeneinteilung durch ziehen der Arbeitsaufträge • Gruppe 1: 4 Erzieher • Gruppe 2.1: 2 Erzieher: Tasthaare • Gruppe 2.2: 2 Erzieher: Fortbewegung - Arbeitsauftrag 1: „Schauen Sie den Film an. Um welches Tier geht es in dem Film? Ist Ihnen etwas neu oder hat Sie etwas besonders überrascht?" oder - Arbeitsauftrag 2: „In dem Film werden die Schnurrhaare der Füchse gezeigt aber nicht benannt. Diese Haare haben sie im Gesicht. Achten Sie auf die entsprechende Stelle im Film. Beschreiben Sie die Schnurrhaare, indem Sie die Farbe der Haare benennen, die Stelle(n) im Gesicht beschreiben an denen diese zu finden sind. Vergleichen Sie die Länge des Fellhaares mit dem der Schnurrhaare." oder - Arbeitsauftrag 3: „Der Fuchs ist ein schnelles Tier. Er bewegt sich sehr flink. Seine Pfotenballen unterstützen ihn dabei. Beschreiben Sie die Pfotenballen, indem Sie drei im Film erkennbare Merkmale benennen." Gruppe 1: Wahrnehmung Gruppe 2: gezielte Beobachtung - Film Fuchs vom Fuchs: Quelle: https://www.youtube.com/watch?v=GT3HIeco0gA - Anschließender Arbeitsauftrag: „Halten Sie Ihre Gedanken auf dem Notizzettel fest." - Die Notizen werden von den Teilnehmern vorgelesen und an einer Flipchart gesammelt - Vergleich der Beschreibungen: Gemeinsames Erarbeiten der Definitionen und Kriterien von ***Wahrnehmen*** und ***Beobachten***, Beschreiben ohne/mit Details **Wahrnehmen**	Power-Point Arbeitsaufträge Füchse in 4 verschied. Farben gekennzeichnet Film –Power-Point Power-Point Post-It's Stifte Flipchart Power-Point	UG EA UG

	- Allgemeine Aussagen - Meist oberflächlich, nicht fokussiert - Nicht Kriterien geleitet **Beobachten** - Gezielte Beobachtungsaufträge - Fokus liegt auf bestimmten Eigenschaften - Kriteriengeleitet - Detailreiche Beschreibungen Abfrage der Erfahrungen allgemein- mögliche Kinderäußerungen		
	Gruppeneinteilung zur Erarbeitung des Erkenntnisgewinnungsweges anhand der Farben der Füchse	Power-Point Farbliche markierte Arbeits-aufträge	

	<u>**Weg der Erkenntnisgewinnung**</u>
	1. Naturwissenschaftliche Frage
	- Hinweise für die Umsetzung im Kindergarten:
	  - Beachten der Basiskonzepte: Struktur/Funktion, Entwicklung, System
	  - Aus dem Alltag der Kinder aufgreifen (vom Kind gestellt), selbst eine Frage mit den Kindern zusammen formulieren anhand von Beobachtungen
	  - Fragen wählen, welche mit verfügbaren Mitteln überprüfbar sind
		Power Point	

	- Arbeitsauftrag: „Stellen Sie eine naturwissenschaftliche Frage? Schreiben Sie diese auf eine Denkblase.“
	- Zielfragen:
	  - Welche Funktion haben die Tasthaare beim Fuchs?
	  - Welche Funktion haben die Pfotenballen beim Fuchs?
		Denkblase
		Stifte
			GA

	2. Vermutung
	- Hinweise:
	  - Definition: gedachte noch nicht gesicherte Antworten
	  - Mit Kindern gemeinsam vermuten
	  - Bei Schwierigkeiten Wahlmöglichkeiten dem Kind anbieten
	  - Falsche Vermutungen nicht korrigieren, mittels Erkenntnisgewinnungsweg überprüfen
		Power-Point	UG

	- Arbeitsauftrag: „Welche Vermutungen könnten Kinder zu der Frage der anderen Themengruppe äußern? Schreiben Sie Ihre Vermutung auf eine Gedankenblase.“	Power-Point Denkblasen Stifte	GA oder PA

	3. Planung
	- Hinweise zur Umsetzung im Alltag
	  - Gut überprüfbare Themenbereiche: Nahrungsaufnahme, Sinne, Fortbewegung, Schutz
	- Beobachten am Original:
	  - begeistert die Kinder, jedoch meist zu schnell **oder** nicht verfügbar **oder** häufig langwieriges Beobachten nötig, um die Vermutung zu
		Power-Point	UG

	prüfen **oder** manche Vermutung durch visuelles Beobachten nicht überprüfbar
	  - Beispiele aus dem Kindergarten-Garten
	- Möglichkeiten zur Überprüfung - Beobachten am Funktionsmodell
	  - Definition: „Funktionsmodelle lenken den Blick auf die wesentlichen Merkmale, um die Funktion/Mechanismus einer Struktur analysieren zu können →häufig mit realitätsfremden Materialien
	  - Darstellung des Zusammenhangs zwischen Struktur und Funktion
	  - Einen Vergleich möglich machen
	  - Wahrnehmung als Mensch und als Tier
	  - Unterschiedliche Strukturen nutzen z.B. verschiedene Zangen
	  - Kreatives Bauen und ausprbieren		

	Fördern der kindlichen Beobachtungskompetenz
	- Beispiele für den Alltag gegeben:
	  - Schmetterlingspuzzle, Quelle: *https://drive.google.com/file/d/0B2IveiIis3aQam45OEVvXzlPRUU/view*
	  - Käfermemory, Quelle: *https://drive.google.com/file/d/0B2IveiIis3aQTnI2SVE2cDZRSk0/view*
	  - Stoffvögel mit Zwitschern
	  - Vogel-Quartett *(Eigentum der des Institutes Didaktik der Biologie)*
		Material-Tisch	UG

	a) Minuten Pause
	- Arbeitsauftrag: „Konstruieren Sie mit Ihrem Partner ein Modell zu Ihrer Forscherfrage. Nutzt dazu die Modellboxen:
	  - Lest die Funktion eurer Struktur im Forschertext nach – haltet diese Information geheim
	  - Konstruiert mit Hilfe der vorgegebenen Materialien ein Modell – Stellt die Funktion dar, nicht die Struktur
	  - Probiert aus und seid kreativ
		Modellboxen
		Infotexte
			GA

	4. Beobachten und Testen - Nochmals den Bezug zum Wahrnehmen herstellen - Gezielte Beobachtungsaufträge - Fokussierung der Aufmerksamkeit aus ausgewählte Merkmale	Power-Point	UG

	5. Beschreiben
	- Hinweise zum Beschreiben
	  - Sachliche Wiedergabe der Beobachtungen
	  - Keine Deutungen oder Interpretation
	  - Erfordert Übung
	  - Auf klare Trennung zwischen Beobachtung und Interpretation achten
	  - Auf Fachsprache achten
		Power-Point	

	- Arbeitsauftrag zu 4.+5.: „Testen Sie nun mit Ihrem Partner ein Modell der anderen Forschergruppe. Achten Sie hierbei auf: Was können Sie	Modelle	GA

	beobachten? Beziehen Sie sich dabei auf die vorgegebene Forscherfrage - Beschreiben Sie Ihre Beobachtungen bitte auf eine Denkblase“ **6. Deuten** - Hinweise zum Deuten: - Rückbezug auf Vermutungen - Interpretation der Ergebnisse - Eingehen auf falsche Vermutungen - Fehler als Lernchance betrachten-positive Fehlerkultur - Neue Forschungsfragen generieren - Arbeitsauftrag: „Erinnern Sie sich an Ihre Vermutung. Interpretieren Sie Ihre Ergebnisse und schreiben Sie diese auf eine Denkblase.“ **Modellbewertung** - Hinweise zur Modellkritik: - Vergleich zum Original - Unterschiede in der Größe - Unterschiede im Material - Wurde was hinzugefügt? (Beiwerk) - Im Sinne der Entsprechung **Abschluss einer gemeinsamen Aktivität, Möglichkeiten:** - Mit den Kindern gemeinsam reflektieren, Entdecktes zusammenfassen, Neue Forschungsaktivitäten zu diesem Themenbereich überlegen	Hilfestellung: vorkonstruierte Modelle *(siehe fachdidaktische Fortbildung)* Denkblasen Power-Point Denkblase	 UG GA
Sicherung mit Erkennt-nisgewinn 15 Minten	Arbeitsauftrag 1: „Versuchen Sie die Wortkarten in eine sinnvolle Reihenfolge zu ordnen und stellen dies als Kreislauf dar.“ Arbeitsauftrag 2: „Erstellen Sie nun ein Plakat über das „Forschendes Entdecken in der Biologie mit Vorschulkinder“. Sortieren Sie die Wortkarten und Ihre Gedankenblasen den Schritten zu.“	Wortkarten *(Siehe Anhang Wortkarten für Plakat fachdidaktische Fortbildung*) Plakat	GA
Verabschiedung	**Bedanken für die Teilnahme und Aufmerksamkeit, Ausfüllen der Postteste**		

Appendix A.1.6: Instructional plan of the CK+PCK-Training

Unterrichtsphase	Unterrichtshandlung	Medien	Aktions-form
Begrüßung	Begrüßen der Teilnehmer/innen		
Einstieg **20 Minuten**	- Vorstellen der Sammlung im Institut der Didaktik der Biologie - Definition der Fachwissenschaft Biologie - Bezug zum bayerischen Bildungs- und Erziehungsplan für Kinder in Tageseinrichtungen bis zur Einschulung - Vergleich Forscher vs. Vorschulkind **Fokusfrage: Wie unterstützt man Kinder beim Forschen?** - Präsentation Erkenntnisgewinnung Kreislauf → Ausblick auf den Ablauf der Fortbildung	PowerPoint	UG
Erarbeitung **55 Minuten**	- Bezug zum Alltag, aufzeigen geeigneter Themenbereiche der Biologie, Lebewesen im Kindergarten-Garten	PowerPoint	UG

	- Gruppeneinteilung zur Erarbeitung des Erkenntnisgewinnungsweges
	  - Gruppe 1: Fortbewegung Specht
	  - Gruppe 2: Sinne Eule
	  - Gruppe 3: Nahrungsaufnahme Ameise
	  - Gruppe 4: Schutz Schnecke
	<u>Weg der Erkenntnisgewinnung</u>
	Während der Erarbeitung werden die Teilaufgaben in einem Fahrplan individuell festgehalten.
	1. Naturwissenschaftliche Frage
		Bildkarten
		4 Tiere in je 4 Farben	

	- Hinweise für die Umsetzung im Kindergarten:
	  - Beachten der Basiskonzepte: Struktur/Funktion, Entwicklung, System
	  - Aus dem Alltag der Kinder aufgreifen (vom Kind gestellt), selbst eine Frage mit den Kindern zusammen formulieren anhand von Beobachtungen
	  - Fragen wählen, welche mit verfügbaren Mitteln überprüfbar sind
		PowerPoint	UG

	- Arbeitsauftrag: „Stellen Sie eine zu Ihrem Modell passende naturwissenschaftliche Frage? Machen Sie sich zunächst mit Ihrem Modell vertraut. Welche Materialien haben Sie? Worum geht es bei Ihrem Modell?“	Fahrplan 4 Stationen	GA

	- Zielfragen:
	  - Welche Struktur ermöglicht dem Specht sich an den Baum festzuhalten?
	  - Welche Struktur ermöglicht es der Eule so gut zu hören?
	  - Welche Struktur ermöglicht eine gute Nahrungsaufnahme bei der Ameise?
	  - Welche Funktion hat das Schneckenhaus für die Schnecke?
		Wortkarten/Flip chart
		PowerPoint	

	2. Vermutung
	- Hinweise:
	  - Definition: gedachte noch nicht gesicherte Antworten
	  - Mit Kindern gemeinsam vermuten
	  - Bei Schwierigkeiten Wahlmöglichkeiten dem Kind anbieten
	  - Falsche Vermutungen nicht korrigieren, mittels Erkenntnisgewinnungsweg überprüfen
		PowerPoint
		FlipChart
			UG

	- Arbeitsauftrag: „Formulieren Sie eine mögliche Antwort auf Ihre naturwissenschaftliche Frage?	Stationen Fahrplan	GA
	3. Planung - Definition von Struktur: „Fast jede Struktur hat einen evolutionsbedingten Sinn und erfüllt somit eine Funktion.“ - Definition von Funktion: „Funktion hat immer eine Struktur, die diese ermöglicht.“ - Verdeutlichen des Zusammenhangs anhand der Beispiele Spaltfüße, Kletterfüße, Schwimmfüße	PowerPoint FlipChart	UG

	Erarbeiten von Struktur und Funktion an den Modellen
	- Arbeitsauftrag: „Gestalten Sie mit Hilfe der Arbeitsmaterialien ein kleines Plakat zu Ihrer Verhaltensweise (Fortbewegung, Sinne, Schutz und Nahrungsaufnahme) am Beispiel Ihres Waldbewohners.
	Stellen Sie die wesentlichen Inhalte aus den Informationstexten übersichtlich und anschaulich dar.“
	- Zusätzliche Anmerkungen:
	  - Überschrift: zum Modell gehörende Verhaltensweise
	  - Nutzen Sie die Bilder auf den Texten für Ihre Plakate
	  - Informationen: Kurz und knapp – Stichpunkte
	
	<u>5-minütige Pause</u>
		Stationen
		Plakate
		Bilder/
		Sachtexte
			GA

	Möglichkeiten zur Überprüfung - Beobachten am Funktionsmodell - Definition: „Funktionsmodelle lenken den Blick auf die wesentlichen Merkmale, um die Funktion/Mechanismus einer Struktur analysieren zu können →häufig mit realitätsfremden Materialien - Darstellung des Zusammenhangs zwischen Struktur und Funktion - Einen Vergleich möglich machen - Wahrnehmung als Mensch und als Tier - Unterschiedliche Strukturen nutzen z.B. verschiedene Zangen	PowerPoint	UG

	4. Beobachten und Testen
	- Hinweise zum Beobachten
	  - Gezielte Beobachtungsaufträge
	  - Fokus liegt auf bestimmten Eigenschaften
	  - Kriteriengeleitet
	  - Detailreiche Beschreibungen
	5. Beschreiben
		PowerPoint
		FlipChart
			UG

	- Hinweise zum Beschreiben
	  - Sachliche Wiedergabe der Beobachtungen
	  - Keine Deutungen oder Interpretation
	  - Erfordert Übung
	  - Auf klare Trennung zwischen Beobachtung und Interpretation achten
	  - Auf Fachsprache achten
	- Arbeitsauftrag zu 4.+5.: „Testen Sie nun Ihre Modelle. Was können Sie beobachten? Versuchen Sie genau zu beschreiben. Welche Schwierigkeiten können auftreten?“
	6. Deuten
	- Hinweise zum Deuten:
	  - Rückbezug auf Vermutungen
	  - Interpretation der Ergebnisse
	  - Eingehen auf falsche Vermutungen
	  - Fehler als Lernchance betrachten-positive Fehlerkultur
	  - Neue Forschungsfragen generieren
	- Arbeitsauftrag: „Erinnern Sie sich an Ihre Vermutung. Interpretieren Sie Ihre Ergebnisse.“
	Modellbewertung
	- Hinweise zur Modellkritik:
	  - Vergleich zum Original
	  - Unterschiede in der Größe
	  - Unterschiede im Material
	  - Wurde was hinzugefügt? (Beiwerk)
	  - Im Sinne der Entsprechung
	- Arbeitsauftrag: „Führen Sie an Ihrem Modell die Modellkritik durch.“
	
	Abschluss einer gemeinsamen Aktivität, Möglichkeiten:
	Mit den Kindern gemeinsam reflektieren, Entdecktes zusammenfassen, Neue Forschungsaktivitäten zu diesem Themenbereich überlegen
	Zeit zum Beenden des Fahrplans
		PowerPoint
		Flipchart
		
		Stationen
		Fahrplan
		
		PowerPoint
		FlipChart
		
		Staitonen
		Fahrplan
		
		Power-Point
		FlipChart
		
		Stationen
		Fahrplan
		
		Power-Point
			UG
			
			GA
			
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			GA
			
			UG

Sicherung **15 Minuten**	Gruppenpuzzle: Zusammensetzen in Expertengruppen anhand der Tierfarben. Gruppentische sind farblich markiert= Treffpunkt/Ausgangspunkt des Rundganges - Arbeitsauftrag: „Finden Sie sich in Ihren neuen Gruppen zusammen und treffen Sie sich an den farblich passenden Tischen. Präsentieren Sie Ihrer neuen Gruppe Ihr Modell und Ihren Weg der Erkenntnisgewinnung mit Hilfe Ihres Plakates und Ihres Fahrplans.“	Ausgefüllte Fahrpläne, Plakate, Stationen	Gruppen-puzzle, GA
Verabschiedung	**Bedanken für die Teilnahme und Aufmerksamkeit, Ausfüllen der Postteste**		

A.2 Instruments

Instrument of Study 1 & 2:

- A.2.1 Preschool children's conceptual knowledge of structure and function

Instruments of Study 2:

- A.2.2 Preschool children's involvement
- A.2.3 Preschool children's description competency
- A.2.4 Preschool children's language ability & interest in animals and plants

Instruments of Study 3:

- A.2.5 Preschool teachers' previous knowledge
- A.2.6 Preschool teachers' instructional practice

Appendix A.2.1: Preschool children´s conceptual knowledge of structure and function

Pre-test

Audio-Nr: __________________

Kindergarten: ___________________ **Datum: _____________________**

Kind/ ID-Code: __________________ **Interviewer:_________________**

Prätest – Struktur & Funktion

Einstieg - Interviewer: „(Beschreiben: Du hast es super gemacht, Glückwunsch!) Ich habe noch ein paar Fragen, du kannst mir dabei bestimmt helfen…“

Nahrung - Fisch Maul

Ich war gestern am See und habe dort einen Fisch beobachtet. Der Fisch ist die ganze Zeit am Boden vom See entlanggeschwommen und hat am Boden nach Essen gesucht. Jetzt zeig ich dir hier Bilder von verschiedenen Fischen; und schau mal, die haben alle ein unterschiedliches Maul.

Was glaubst du, was für ein Maul hatte der Fisch, den ich da gesehen habe?
Warum glaubst du, es ist für einen Fisch hilfreich, das Maul so zu haben?

Endständiges Maul	Oberständiges Maul	Unterständiges Maul	Keine Antwort

Fortbewegung – Wasservogel Fuß

Gestern am See habe ich auch einen Vogel beobachtet. Ich erzähle dir gleich was über den, aber erstmal hab ich hier drei Bilder von Füßen, die Vögel haben können. Wenn ich dir jetzt was von dem Vogel erzähle, kannst du mir bestimmt sagen, was für Füße der hatte! - Also der Vogel, den ich beobachtet habe, war im Wasser und ist gemütlich am Rande vom See entlanggeschwommen.

Was meinst du, welche Füße hat dieser Vogel?
Warum glaubst du, ist es für den Vogel gut, solche Füße zu haben?

Entenfuß	Taubenfuß	Spechtfuß	Keine Antwort

Nahrung - Insekte Mundwerkzeug

Weißt du was Insekten sind? … Ameisen, Käfer, Bienen, Fliegen… Sie haben alle auch einen Mund, aber der kann ganz unterschiedlich aussehen. Manche haben so einen Mund, wie so ein Rüssel, andere haben so einen Mund, wie eine Zange, und andere haben so einen Mund, wie eine Spritze.

Eine Mücke ernährt sich von Tierblut. Dafür muss sie erstmal mit ihrem Mund durch die Haut der Tiere durch. Was glaubst du, was hat sie für einen Mund?
Warum glaubst du ist es für die Mücke hilfreich, so einen Mund zu haben?

Beißender MWZ	Leckend-saugender MWZ	Stechend-saugender MWZ	Keine Antwort

Sinne - Insekten Fühlern

Hast du schon mal gemerkt, dass viele Insekten zwei Antennen auf dem Kopf haben? Ich habe mich schon immer gefragt, wozu sie gut sind… Was glaubst du, warum es für Insekten hilfreich ist, Antennen zu haben?
Glaubst du, sie können damit besonders gut…?
Warum glaubst du, die Antennen sind besonders gut dafür geeignet?

Ihre Umgebung antasten	Duftstoffe riechen	Geräusche hören	Keine Antwort

Sinne - Pflanzen Insekten anlocken

Andere Insekte sind z.B. Bienen und Schmetterlinge. Diese Insekten ernähren sich vom Nektar, das ist eine süße Flüssigkeit, die von bestimmten Pflanzen produziert wird. Dafür müssen aber Bienen und Schmetterlinge von diesen Pflanzen angelockt werden! Hier siehst du drei Bilder von verschiedenen Pflanzen. Welche dieser Pflanzen glaubst du, kann die Insekten am besten anlocken?
Warum glaubst du, kann diese Pflanze es besser als die anderen Pflanzen?

Pflanze mit Blüte	Süßgräser (Mais)	Brennnessel	Keine Antwort

Pflanzen Samen

Pflanzen haben Samen, und aus den Samen können neue Pflanzen wachsen, wie die hier z.B. (Zeichnung). Am besten ist es für die neue Pflanze, wenn sie ganz weit weg von der alten wächst, damit sie genügend Platz hat. Deswegen sind manche Samen von Pflanzen so gemacht, dass sie besonders gut durch die Luft fliegen können, dann trägt der Wind sie davon. Andere Samen bewegen sich im Wasser oder mit der Hilfe von Tieren. Hier siehst du Bilder von drei verschiedenen Samen.

Welcher glaubst du, kann sich besonders gut mit dem Wind bewegen?
Warum glaubst du, dieser Samen ist besonders gut dafür geeignet?

Ahorn	Klette	Haselnuss	Keine Antwort

Schutz - Nadelbaum – Wachsschicht

Jetzt stell dir vor, aus einem Samen hat sich so ein Baum entwickelt (Zeichnung)! Jetzt zeige ich dir drei Bilder von Blättern, die Bäume haben können. Einige Arten haben solche Blätter, die ganz breit sind. Andere Bäume haben dünne Blätter, wie diese hier. Es gibt aber auch Bäume mit dünnen Blättern, die mit einer Schicht aus Wachs umgeben sind.

Jetzt stellt dir vor, an einem Tag wird´s richtig, richtig kalt.
Welche dieser Blätter glaubst du kann sich am besten vor dem Einfrieren schützen?
Warum glaubst du, können sich solche Blätter besser als die anderen vor dem Einfrieren schützen?

Laubblatt	Nadelblatt mit Wachsschicht	Nadelblatt ohne Wachsschicht	Keine Antwort

Schutz - Eichhörnchen Kobel

Schau mal, was ist das? Genau, ein Eichhörnchen. Eichhörnchen leben in solchen kleinen Kobeln, die sie an den Astgabeln bauen. Wenn du dir diesen Kobel genau anschaust, kannst du erkennen, dass dieser Kobel zwei Eingänge hat.
Du kannst mir bestimmt sagen: Warum glaubst du ist es für die Eichhörnchen hilfreich, so einen Kobel mit zwei Eingängen zu bauen? Glaubst du, sie können damit besonders gut…?
Warum glaubst du, ist dieser Kobel besonders gut dafür geeignet?

Vor Feinden fliehen	Nahrung sammeln	Sich warm halten	Keine Antwort

Fortbewegung - Maus Schwanz

Schau mal, was ist das? Richtig, eine Maus. Das ist eine ganz normale Maus mit einem ganz normalen Schwanz. Das hier ist auch eine Maus, die hat aber nur so einen kurzen dünnen Stummelschwanz. Und diese Maus hat auch nur einen kurzen Schwanz, der ist aber dicker.

Was glaubst du, kann diese Maus (mit normalem Schwanz) besser als die anderen?
Glaubst du, sie kann besser…?
Warum glaubst du, diese Maus (mit normalem Schwanz) kann es besser als die anderen?

Schneller laufen	Tunnel graben	Über einen dünnen Ast laufen	Keine Antwort

Schutz - Fliegenpilz

Du kannst mir bestimmt sagen, was diese sind. Genau, Pilze! Das hier ist ein Fliegenpilz und das hier ist ein Pfifferling. Anders als Pfifferlinge sind Fliegenpilze dafür bekannt, dass sie sehr giftig sind.
Was glaubst du, kann ein giftiger Pilz wie der Fliegenpilz besser als ein Pfifferling, der nicht giftig ist?
Glaubst du, der kann (sich) besser…?
Warum glaubst du, kann es der Fliegenpilz besser als der Pfifferling?

(Sich) vor Fressfeinden schützen	(Sich) vor Krankheiten schützen	Andere Pilze zerstören	Keine Antwort

Nahrung - Mensch Zähne

Was haben wir im Mund? Richtig, Zähne! Und die können ganz unterschiedlich aussehen. So, das sind die hier ganz vorne (Schneidezähne); oder so, das sind die hier an den Seiten (Eckzähnen); oder so, das sind die da hinten (Backenzähne). Wir müssen ja mit unseren Zähnen verschiedene Sachen machen, z.B. abbeißen oder kauen.

Was glaubst du, welcher Zahn ist gut geeignet zum Kauen?
Warum glaubst du, ist dieser Zahn besonders gut dafür geeignet?

Schneidezahn	Eckzahn	Backenzahn	Keine Antwort

Sprungbeine

Hier siehst du Bilder von drei verschiedenen Tieren. Weißt du, welche es sind? Ja, das ist ein Frosch, das eine Hase, und das hier ist ein Floh (Flöhe sind sooo klein! Hunde oder Katzen haben manchmal Flöhe, die müssen sich dann kratzen!). Die drei sind ja ganz unterschiedliche Tiere, aber es gibt eine Sache, die alle diese drei Tiere sehr gut können.

Glaubst du, diese drei Tiere können besonders gut…?
Wenn du dir die Tiere genau anschaust… Kannst du mir vielleicht sagen: Warum glaubst du, dass alle drei sehr gut hüpfen (klettern/schwimmen) können?

Klettern	Hüpfen	Schwimmen	Keine Antwort

Sinne - Maulwurf Augen

Du kennst bestimmt auch Maulwürfe. Die wohnen unter der Erde und kommen nur ganz selten ans Tageslicht. Hier sind Bilder von drei verschiedenen Augen: ein großes, ein kleines und ein Glubschauge.

Welche Augen glaubst du, hat ein Maulwurf?
Warum glaubst du, es ist für den Maulwurf gut, solche Augen zu haben?

Großes Auge	Kleines Auge	Glubschauge	Keine Antwort

Ende – Danach: Fragebogen Interesse!!!

Ganz am Ende - Interviewer: „Super, vielen Dank, du hast es super gemacht! Ich habe aber noch eine kleine Bitte an dich: Erzähl bitte den anderen Kindern nicht, was wir hier gemacht haben, oder über welche Tiere wir hier gequatscht haben, ok? Damit es für alle Kinder eine Überraschung ist, und spannend und interessant wird, ok!? Versprochen? Super, danke!!! Wir sehen uns in ein paar Tagen wieder und du kannst unser kleines Museum besuchen. Wir freuen uns schon drauf!

Post-test

Audio-Nr: ___________________

Kindergarten: ____________________ **Datum: ______________________**

Kind/ ID-Code: ___________________ **Interviewer:__________________**

<u>Posttest – Struktur & Funktion</u>

Einstieg - Interviewer: „Hallo, X! Wie hat dir das Museum gefallen? Was hast du am besten gefunden? (Bisschen reden lassen)… Jetzt habe ich noch ein paar Fragen, mit denen du mir bestimmt helfen kannst! Vielleicht kommen dir ein paar dieser Fragen schon mal bekannt vor. Das macht aber nichts, ok?“

Nahrung – Specht Schnabel – *Parallel zu Ameisen-Mundwerkzeug: Die Struktur des Mundes (Schnabels) ist gut dafür geeignet, um an die Nahrung zu kommen.*

Wir haben uns heute schon einen Specht angeschaut. Der Specht hält sich am Baumstamm fest und wenn er Hunger hat, holt er sich mit dem Schnabel Käfer, die sich unter der Rinde verstecken - genau wie auf diesem Bild (Zeichnung).
Was meinst du, welchen Schnabel hat der Specht?
Warum glaubst du, ist es für den Specht hilfreich, so einen Schnabel zu haben?

Dünn und kurz	Dünn und lang	Greifvogel-Schnabel	Keine Antwort

Sinne - Hund Ohren – *Parallel zu Eulen-Trichtergesicht: Die Form um das Gehörorgan ist dafür geeignet, um Geräusche gut aufzunehmen.*

Wir haben heute gelernt, Eule können besonders gut hören. Andere Tiere, wie z.B. Hunde, können das aber auch. Hier siehst du drei Bilder von verschiedenen Ohren, die Hunde haben können.
Mit welchen Ohren glaubst du, können Hunde besser hören?
Warum glaubst du, können Hunde mit diesen Ohren besser als mit den anderen Ohren hören?

Bulldog (kurz)	Schäferhund (nach oben)	Labrador (nach unten)	Keine Antwort

Fortbewegung - Sprungbeine

Hier siehst du Bilder von drei verschiedenen Tieren. Weißt du, welche es sind? Ja, das ist ein Frosch, das eine Hase, und das hier ist ein Floh (Flöhe sind sooo klein! Hunde oder Katzen haben manchmal Flöhe, die müssen sich dann kratzen!). Die drei sind ja ganz unterschiedliche Tiere, aber es gibt eine Sache, die alle diese drei Tiere sehr gut können.

Glaubst du, diese drei Tiere können besonders gut…?
Wenn du dir die Tiere genau anschaust… Kannst du mir vielleicht sagen: Warum glaubst du, dass alle drei sehr gut hüpfen (klettern/schwimmen) können?

Klettern	Hüpfen	Schwimmen	Keine Antwort

Nahrung – Frosch Zunge – *Parallel zu Schnecke-Raspelzunge: Die Struktur der Zunge ist dafür geeignet, um an die Nahrung zu kommen.*

Und weißt du was Frösche fressen? Genau, Fliegen und anderen Insekten, die sehr schnell davon entfliehen können! Hier siehst du drei Bilder von Zungen. Diese Zunge ist glatt, diese hat Haken, und diese ist lang und klebrig.
Was glaubst du, wie die Zunge des Frosches aussieht?
Warum glaubst du ist es für den Frosch hilfreich, so eine Zunge zu haben?

Glatte Zunge	Zunge mit Haken	Lange klebrige Zunge	Keine Antwort

Fortbewegung – Kaulquappe - *Parallel zu Ameisen-Segmente: Struktur im Körper ist für die besondere Umgebung geeignet, in der sich das Tier bewegt.*

Frösche sind eigentlich Amphibien. Weiß du was Amphibien sind? Das sind Tiere, die teilweise im Wasser und teilweise auf Land leben, wie z.B. der Frosch. So sieht ein kleines Amphibien-Baby aus.

Wo glaubst du, kann sich dieses kleine Amphibien-Baby am besten bewegen?
Glaubst du, es kann sich am besten … bewegen?
Warum glaubst du, sie kann sich dort am besten bewegen?

Auf dem Waldboden	Im Wasser	Auf Sand	Keine Antwort

Sinne - Hai Blut – *Parallel zu Eichhörnchen-Geruchssinn: Ein Körperteil (die Nase) ist speziell für den Geruch geeignet.*

Schau mal, was ist das? Genau, ein Hai! Anders als Amphibien leben Haie sein ganzes Leben lang im Wasser. Haie können es sehr gut merken, wenn ein anderes Tier im Wasser sich verletzt hat und blutet, sogar wenn dieses Tier sehr weit weg vom Hai schwimmt.

Was glaubst du, womit kann ein Hai das besonders gut erkennen? Mit…
Warum glaubst du, seine Nase ist (Augen, Haut sind) besonders gut dafür geeignet?

Seiner Nase	Seinen Augen	Seiner Haut	Keine Antwort

Schutz - Nadelbaum – Wachsschicht

Was ist das hier? Genau, ein Baum! Jetzt zeige ich dir drei Bilder von Blättern, die Bäume haben können. Einige Arten haben solche Blätter, die ganz breit sind. Andere Bäume haben dünne Blätter, wie diese hier. Es gibt aber auch Bäume mit dünnen Blättern, die mit einer Schicht aus Wachs umgeben sind.

Jetzt stellt dir vor, an einem Tag wird´s richtig, richtig kalt.
Welche dieser Blätter glaubst du, kann sich am besten vor dem Einfrieren schützen?
Warum glaubst du, können sich solche Blätter besser als die anderen vor dem Einfrieren schützen?

Laubblatt	Nadelblatt mit Wachsschicht	Nadelblatt ohne Wachsschicht	Keine Antwort

Schutz Rosen Dornen – *Parallel zu Stammrinde: Im Pflanzenreich, eine Struktur im Körper ist für den Schutz gut geeignet.*

Schau mal, was ist das? Richtig, eine Rose. So wie viele andere Blumen, haben Rosen, einen Stängel mit Dornen, grüne Blätter und eine bunte Blüte. Hast du dir schon mal überlegt; anders als Tiere können Pflanzen, wie diese Rose, nicht weglaufen, wenn sie vor Gefahren stehen. Trotzdem können sie sich sehr gut schützen. Womit glaubst du, kann sich eine Rose besonders gut schützen?

Glaubst du, sie kann sich gut schützen, weil sie… haben?
Warum glaubst du, sind die Dornen (die grüne Blätter, ist die schöne Blüte) besonders gut dafür geeignet?

Grüne Blätter	Bunte Blüte	Dornen am Stangel	Keine Antwort

Sinne - Maulwurf Augen

Du kennst bestimmt auch Maulwürfe. Die wohnen unter der Erde und kommen nur ganz selten ans Tageslicht. Hier sind Bilder von drei verschiedenen Augen: ein großes, ein kleines und ein Glubschauge.

Welche Augen glaubst du, hat ein Maulwurf?
Warum glaubst du, es ist für den Maulwurf gut, solche Augen zu haben?

Großes Auge	Kleines Auge	Glubschauge	Keine Antwort

Fortbewegung – Maulwurf Fuß - *Parallel zu Specht-Fuß: Die Struktur der Extremitäten sind gut für eine besondere Bewegung geeignet*

Jetzt, wo wir noch beim Maulwurf sind; schau dir seine Füße ganz genau an. Was glaubst du, kann ein Maulwurf mit solchen Füßen besonders gut?

Glaubst du, der kann damit besonders gut…?
Warum glaubst du, sind seine Füße besonders gut dafür geeignet?

Schnell laufen	Nahrung festhalten	Tunnel graben	Keine Antwort

Nahrung - Insekte Mundwerkzeug

Weißt du was Insekten sind? … Ameisen, Käfer, Bienen, Fliegen… Sie haben alle auch einen Mund, aber der kann ganz unterschiedlich aussehen. Manche haben so einen Mund, wie so ein Rüssel, andere haben so einen Mund, wie eine Zange, und andere haben so einen Mund, wie eine Spritze.

Eine Mücke ernährt sich von Tierblut. Dafür muss sie erstmal mit ihrem Mund durch die Haut der Tiere durch. Was glaubst du, was hat sie für einen Mund?
Warum glaubst du ist es für die Mücke hilfreich, so einen Mund zu haben?

Beißender MWZ	Leckend-saugender MWZ	Stechend-saugender MWZ	Keine Antwort

Schutz – Schildkröte Panzer – *Parallel zu Schneckenhaus: Im Tierreich, eine Struktur im Körper ist für den Schutz gut geeignet.*

Und was ist das? Richtig, eine Schildkröte. Und weiß du, was das ist? Genau, ihr Panzer. Was glaubst du, was kann die Schildkröte mit ihrem Panzer besonders gut?

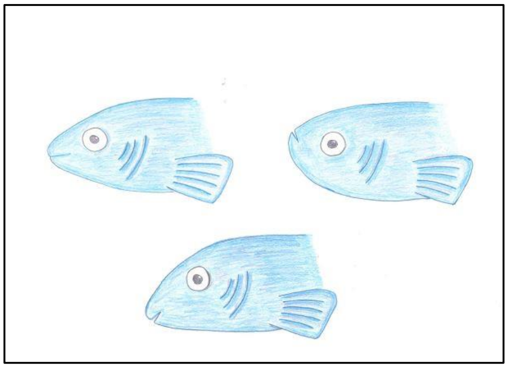
Glaubst du, mit ihrem Panzer kann sie besonders gut…?
Warum glaubst du, ist der Panzer besonders gut dafür geeignet?

Nahrung finden	Sich vor Feinden schützen	Geräusche hören	Keine Antwort

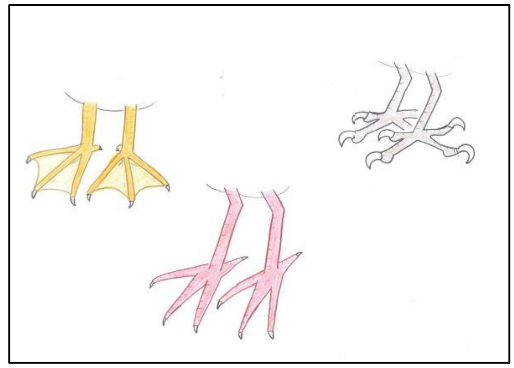
Ende - Interviewer: „Super, vielen Dank, du hast es super gemacht! Ich habe aber noch eine kleine Bitte an dich: Erzähl bitte den anderen Kindern nicht, was wir hier gemacht haben, oder über welche Tiere wir hier gequatscht haben, ok? Damit es für alle Kinder eine Überraschung ist, und spannend und interessant wird, ok!? Versprochen? Super, danke!!!“ → Kleines Geschenk!

Figures

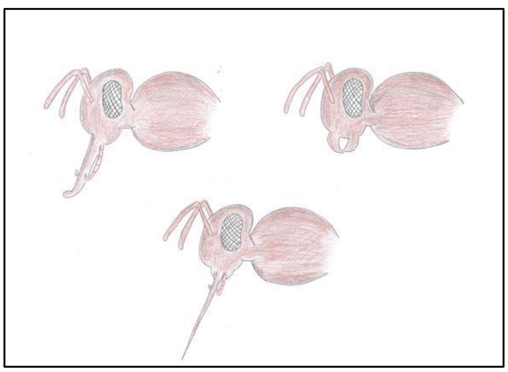
Fisch Maul



Wasservogel Fuß

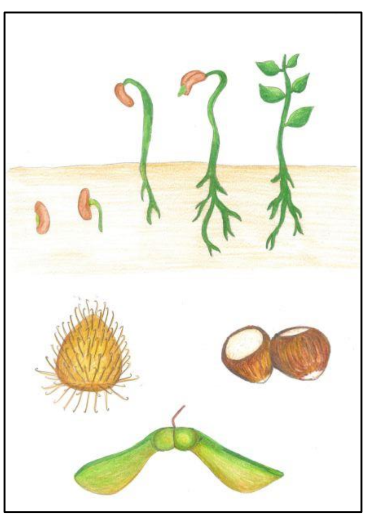


Insekte Mundwerkzeug & Insekte Fühlern

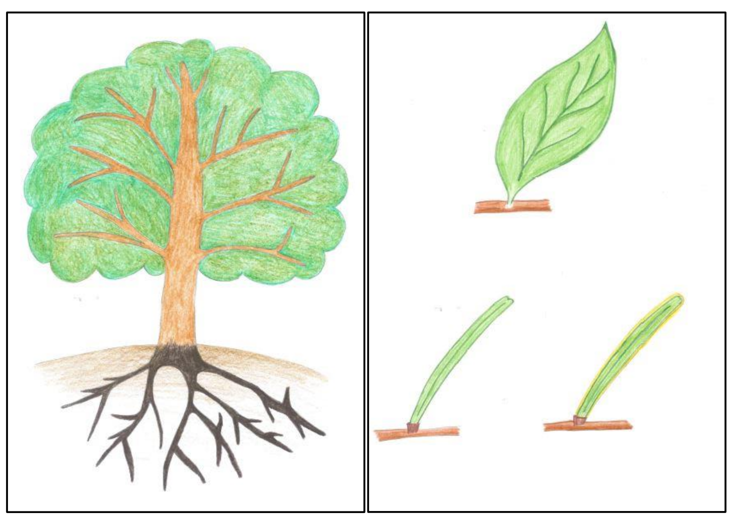


Pflanzen-Insekten anlocken

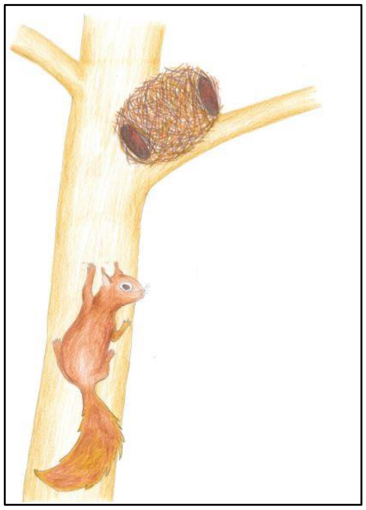
Pflanzen Samen



Nadelbaum Wachsschicht

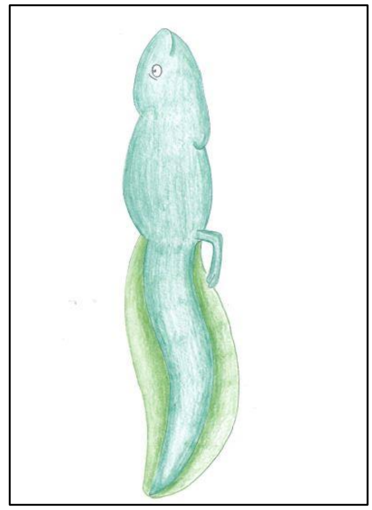


Eichhörnchen Kobel



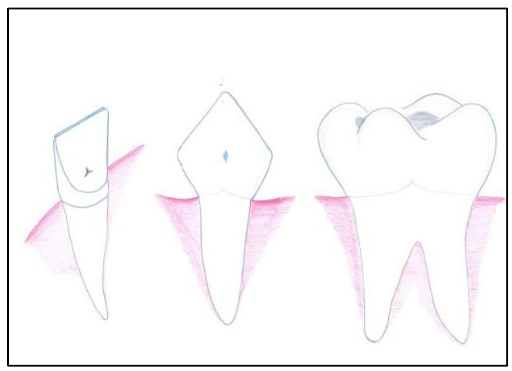
Rosen Dornen

Kaulquappe



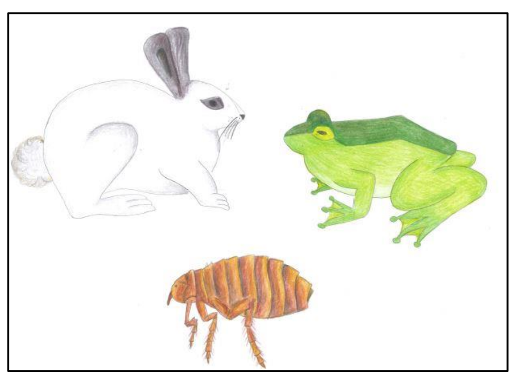
Maus Schwanz

Mensch Zähne

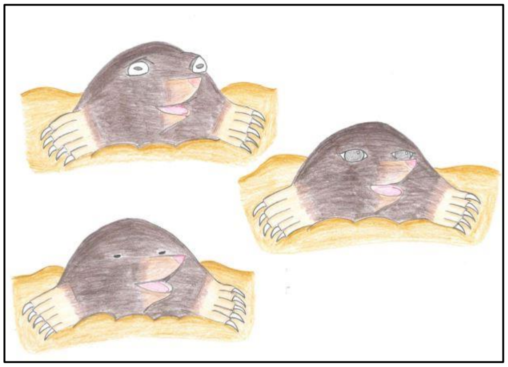


Fliegenpilz

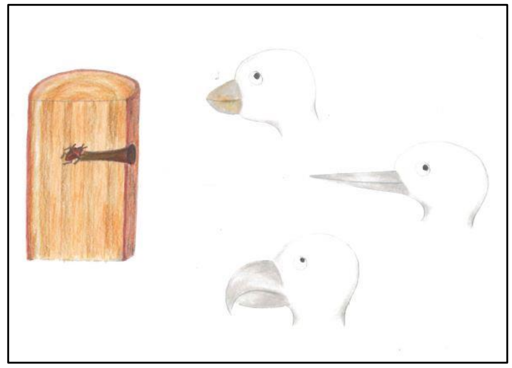
Sprungbeine



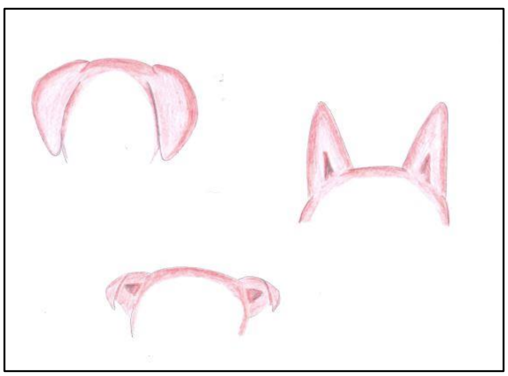
Maulwurf Augen & Maulwurf Fuß



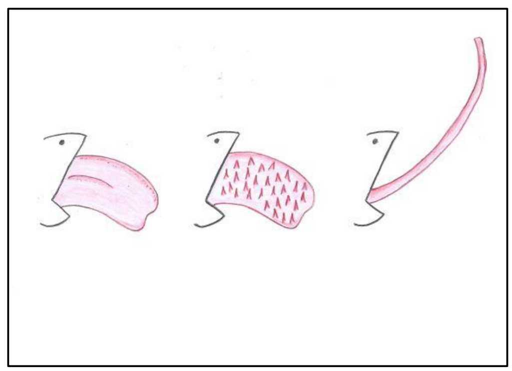
Spechtschnabel



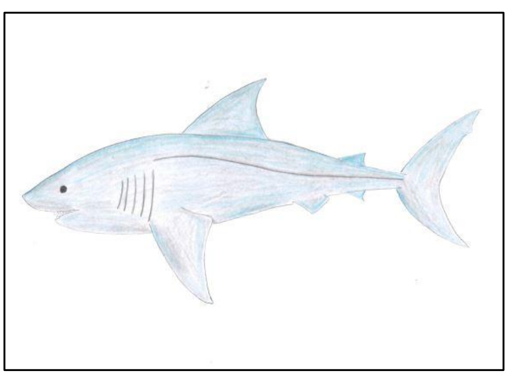
Hundohren



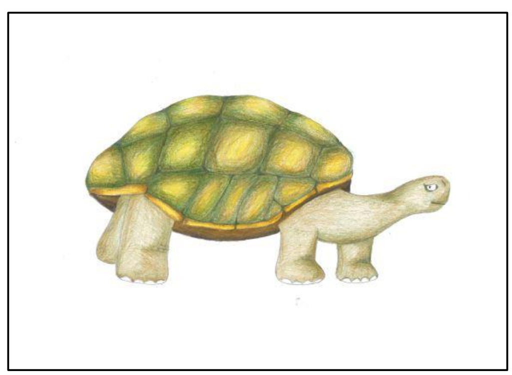
Froschzunge



Hai Blut



Schildkröten Panzer



Coding scheme

	1. Frage	2. Frage	
	Richtige Auswahl	**Struktur**	**Funktion**
Fisch Maul (Prä1)	Unterständiges Maul	Mund/Maul nach unten	Essen, fressen, suchen
Wasservogel Fuß (Prä2)	Entenfuß	Schwimmhaut, Flossen	Schwimmen, rudern, paddeln
Insekt Mundwerkzeug (Prä3 & Post11)	Stechend-saugender MWZ	Spitzig	Reinpiecksen, durch die Haut reinkommen
Pflanzen Insekten anlocken (Prä5)	Pflanze mit Blüte	Blüte, visuell auffällig, offen, groß; Staubfaden, gelb; Nektar drinnen	Insekten anlocken, Bienen brauchen Nektar
Pflanzen Samen (Prä6)	Ahorn	Flügel, Segel, leicht, flach	Im Wind fliegen, durch die Luft hin und her
Nadelbaum Wachsschicht (Prä7 & Post7)	Nadelblatt mit Wachsschicht	Ein Wachsschutz, gelbe Schicht, Wachs	Sich vor Kälte schützen, warm bleiben
Eichhörnchen Kobel (Prä8)	Vor Feinden fliehen	zwei Eingänge	Ein anderes Tier kommt, rauskommen…
Maus Schwanz (Prä9)	Über einen dünnen Ast laufen	Schwanz, lang	Balancieren, Gleichgewicht, über den Ast laufen
Sprungbeine (Prä12 & Post3)	Hüpfen	Beine, Füße, Pfoten, groß, lang, flach	Springen, abfedern, Sprung nehmen
Specht Schnabel (Post1)	Dünn und lang	Schnabel lang, dünn, schmal	Reinkommen, Essen holen,
Hund Ohren (Post2)	Schäferhund (nach oben)	Ohren offen, auf, hochstehen, spitze	Gut hören
Frosch Zunge (Post4)	Lange klebrige Zunge	Zunge lang, klebrig	Fliege (in der Luft/weit weg) schnappen, Fliege bleibt kleben/hängen
Kaulquappe (Post5)	Im Wasser	Flosse, Schwanz	Schwimmen, paddeln, sich im Wasser bewegen
Rosen Dornen (Post8)	Dornen am Stangel	Dornen, spitze, stachelig	Piecksen, wehtun
Maulwurf Fuß (Post10)	Tunnel graben	Krallen, spitze, scharf	Erde/Löcher graben/schaufeln, buddeln
Schildkröte Panzer (Post12)	Sich vor Feinden schützen	Haus, Panzer, hart, dick	Verstecken, Reinkriechen, Sich Einziehen, Schützen

Appendix A.2.2: Preschool children´s involvement

Observation sheet

Beobachtungsbogen zur Engagiertheit

Station/ Exponat: ______________________________

Gruppe: ______________________________

□ Kontrollgruppe □ Gruppe Erkenntnisgewinnung

ID-Nummer des Kindes: ______________________________

Signal der Engagiertheit	**1**	**2**	**3**	**Anmerkungen**
Gezielte Aufmerksamkeit				
Gesichtsausdruck und Körperhaltung				
Reaktionsbereitschaft				
Verbale Äußerungen				
Zufriedenheit				

Pro Kind werden 8 Tabellen (jeweils eine pro Station) ausgefüllt.

Appendix A.2.3: Preschool children´s description competency

Interview

Leitfaden Interview Beschreibungskompetenz

Vor Beginn der Befragung:

Babyvogel in Nest/Vogelhaus o.ä.

Eichhörnchen Original irgendwo versteckt bereithalten

Tonaufnahmegerät einschalten

(Je nach Situation) L: Hallo … . Du kennst mich ja bereits, ich bin die/der … . Wundere dich nicht, wenn ich manchmal auf mein Blatt schaue oder wenn ich mir manchmal auch etwas notiere. Ich lese dir gleich eine Geschichte vor. Bevor ich loslege, darfst du aber mal vorsichtig...

Kind hebt Tuch hoch und entdeckt in der Kiste einen kleinen Kuscheltier-Vogel. Lehrer beginnt dann direkt mit dem Vorlesen…

V: Hallo! Mein Name ist Emma und ich bin ein Babyvogel, ein sogenanntes Küken. Wie heißt du denn?

K: Ich heiße …

V: Schön, dass du da bist …! Ich muss dir nämlich etwas Wichtiges erzählen. Und zwar ist meine Mama gerade nicht zu Hause und ich bin jetzt ganz allein in unserem Nest. Leider kann ich noch nicht fliegen und kann nicht mit. Deshalb weiß ich gar nicht wirklich wie es dort im Wald so aussieht! Meine Mama erzählt mir immer von den anderen Waldbewohnern, wie z.B. vom Daniel Dachs und von Fridolin Fuchs. Aber ich kann mir gar nicht vorstellen wie diese ganzen Tiere überhaupt aussehen, da ich diese ja noch nieee gesehen habe. Siehst du zufällig da draußen ein Tier in deiner Nähe?

Lehrer stellt ein Original eines Eichhörnchens auf den Tisch vor das Kind.

K: Ja ich sehe hier ein Tier. Das ist ein Eichhörnchen!

V: Oh das klingt ja total spannend. Meine Mutter hat mir schon öfter einmal von dem Eichhörnchen erzählt. Aber leider kann ich mir auch nicht vorstellen, wie das so ausschaut. Kann ich dich was fragen? Könntest du mir bitte so genau wie möglich das Eichhörnchen/das Tier beschreiben. Denke daran, dass ich außer meiner Mama noch nie ein anderes Tier gesehen habe. Beschreibe es mir am besten von oben nach unten.

K: *beschreibt*

V: Super hast du das gemacht...! Jetzt kann ich mir schon viel besser vorstellen wie so ein Eichhörnchen ausschaut. Du hast es so gut beschrieben, dass ich es fast schon direkt vor mir sehen kann.

Danke dir … Das Küken braucht jetzt leider wieder seine Ruhe und deshalb machen wir mit etwas anderem weiter

Coding scheme

	Wertung	Nennung	Äußerungen des Kindes zum jeweiligen Körperteil
Benennung des Eichhörnchens beim Präsentieren			
Körperteile (Gesamtwertung)	24		
Kopf	1		
Details*	1		
Augen	1		
Details*	1		
Nase	1		
Schnurrhaare	1		
Details* (zu Nase oder Schnurrhaare)	1		
Maul	1		
Zähne	1		
Details* (zu Maul oder Zähne)	1		
Ohren	1		
Tasthaare	1		
Details* (zu Ohren oder Tasthaare)	1		
Körper	1		
Bauch/Rücken	1		
Fell	1		
Details* (zu Körper oder Fell)	1		
Extremitäten	-		
Nennung Beine/Arme	1		
Unterscheidung Vorder- und Hinterbeine	1		
Pfoten	1		
Krallen	1		
Details*	1		
Schwanz	1		
Details*	1		
Nicht auswertbare Äußerungen			

Appendix A.2.4: Preschool children´s language ability & interest in animals and plants

Questionnaire for preschool teachers

Interesse & Sprachfähigkeit

Begleitfragebogen zum Minimuseum München

- Auszufüllen von einer pädagogischen Fachkraft -

Zur Ergänzung unserer Untersuchungen zum Museumsbesuch der Vorschulkinder ihres Kindergartens benötigen wir noch Einschätzungen der Sprachfähigkeit und des Interesses der einzelnen Kinder ihrer Gruppe seitens einer pädagogischen Fachkraft. Wie alles andere auch werden die Daten anonymisiert und nur für Forschungszwecke verwendet. Bitte kreuzen Sie im Folgenden immer diejenige Kategorie an, die am ehesten allgemein auf das Kind zutrifft. Vielen Dank!

Kindergarten: ______________________________

Vorname des Kindes: ______________________________

Geburtsdatum (MM.JJ): ______________________________

ID-Code des Kindes: ______________________________

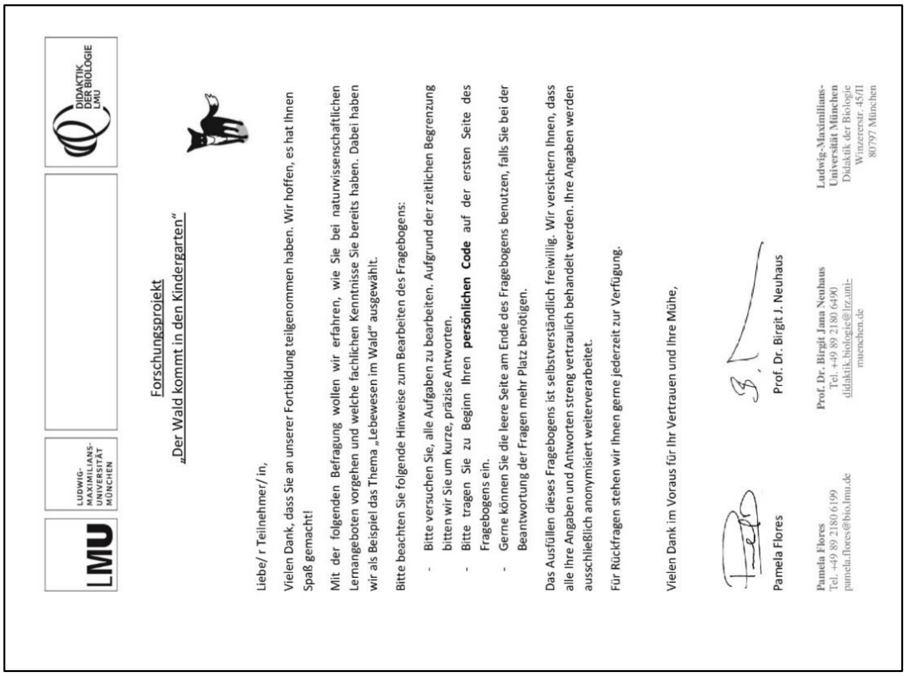
Das Kind …	trifft nicht zu	trifft wenig zu	trifft teilweise zu	trifft überwiegend zu	trifft völlig zu
…führt einfache Aufträge korrekt aus, die es nur sprachlich verstehen kann (nicht aus dem Zusammenhang/aus der Situation heraus), z.B. hol bitte deine Jacke.					
…führt mehrschrittige Aufträge korrekt aus, die es nur sprachlich verstehen kann (nicht aus dem Zusammenhang/aus der Situation heraus), z.B. hol bitte die Milch aus dem Kühlschrank und ein Glas aus dem Regal.					
…antwortet auf Fragen inhaltlich angemessen.					
…beteiligt sich aktiv an Gruppengesprächen und Diskussionen.					
…erzählt gern Geschichten und Erlebnisse.					
…kann Beobachtungen in der Natur (z.B. Wetterphänomene, Veränderungen in den Jahreszeiten) genau beschreiben.					

Das Kind …	trifft nicht zu	trifft wenig zu	trifft teilweise zu	trifft überwiegend zu	trifft völlig zu
…hat großes Interesse an Tieren und stellt häufig Fragen dazu					
...erzählt häufig von (bestimmten) Tieren.					
...hat großes Interesse an Pflanzen und stellt häufig Fragen dazu.					
...erzählt häufig von (bestimmten) Pflanzen (Blumen, Bäumen).					

Appendix A.2.5: Preschool teachers´ previous knowledge

Test

Seite 1:



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Forschungsprojekt
„Der Wald kommt in den Kindergarten"

Liebe/ r Teilnehmer/ in,

Vielen Dank, dass Sie an unserer Fortbildung teilgenommen haben. Wir hoffen, es hat Ihnen Spaß gemacht!

Mit der folgenden Befragung wollen wir erfahren, wie Sie bei naturwissenschaftlichen Lernangeboten vorgehen und welche fachlichen Kenntnisse Sie bereits haben. Dabei haben wir als Beispiel das Thema „Lebewesen im Wald" ausgewählt.

Bitte beachten Sie folgende Hinweise zum Bearbeiten des Fragebogens:

- Bitte versuchen Sie, alle Aufgaben zu bearbeiten. Aufgrund der zeitlichen Begrenzung bitten wir Sie um kurze, präzise Antworten.
- Bitte tragen Sie zu Beginn Ihren **persönlichen Code** auf der ersten Seite des Fragebogens ein.
- Gerne können Sie die leere Seite am Ende des Fragebogens benutzen, falls Sie bei der Beantwortung der Fragen mehr Platz benötigen.

Das Ausfüllen dieses Fragebogens ist selbstverständlich freiwillig. Wir versichern Ihnen, dass alle Ihre Angaben und Antworten streng vertraulich behandelt werden. Ihre Angaben werden ausschließlich anonymisiert weiterverarbeitet.

Für Rückfragen stehen wir Ihnen gerne jederzeit zur Verfügung.

Vielen Dank im Voraus für Ihr Vertrauen und Ihre Mühe,

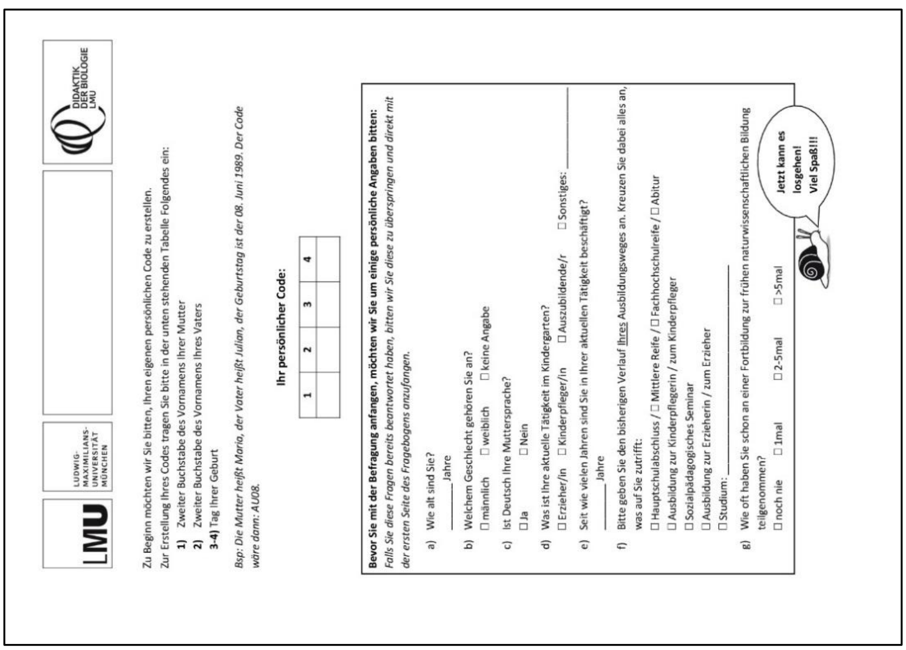
Pamela Flores   Prof. Dr. Birgit J. Neuhaus

Pamela Flores
Tel. +49 89 2180 6199
pamela.flores@bio.lmu.de

Prof. Dr. Birgit Jana Neuhaus
Tel. +49 89 2180 6490
didaktik.biologie@lrz.uni-muenchen.de

Ludwig-Maximilians-Universität München
Didaktik der Biologie
Winzererstr. 45/II
80797 München

Seite 2:



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Zu Beginn möchten wir Sie bitten, Ihren eigenen persönlichen Code zu erstellen.
Zur Erstellung Ihres Codes tragen Sie bitte in der unten stehenden Tabelle Folgendes ein:

1) Zweiter Buchstabe des Vornamens Ihrer Mutter
2) Zweiter Buchstabe des Vornamens Ihres Vaters
3-4) Tag Ihrer Geburt

Bsp: Die Mutter heißt Maria, der Vater heißt Julian, der Geburtstag ist der 08. Juni 1989. Der Code wäre dann: AU08.

Ihr persönlicher Code:

1	2	3	4

Bevor Sie mit der Befragung anfangen, möchten wir Sie um einige persönliche Angaben bitten:
Falls Sie diese Fragen bereits beantwortet haben, bitten wir Sie diese zu überspringen und direkt mit der ersten Seite des Fragebogens anzufangen.

a) Wie alt sind Sie?
_____ Jahre

b) Welchem Geschlecht gehören Sie an?
☐ männlich ☐ weiblich ☐ keine Angabe

c) Ist Deutsch Ihre Muttersprache?
☐ Ja ☐ Nein

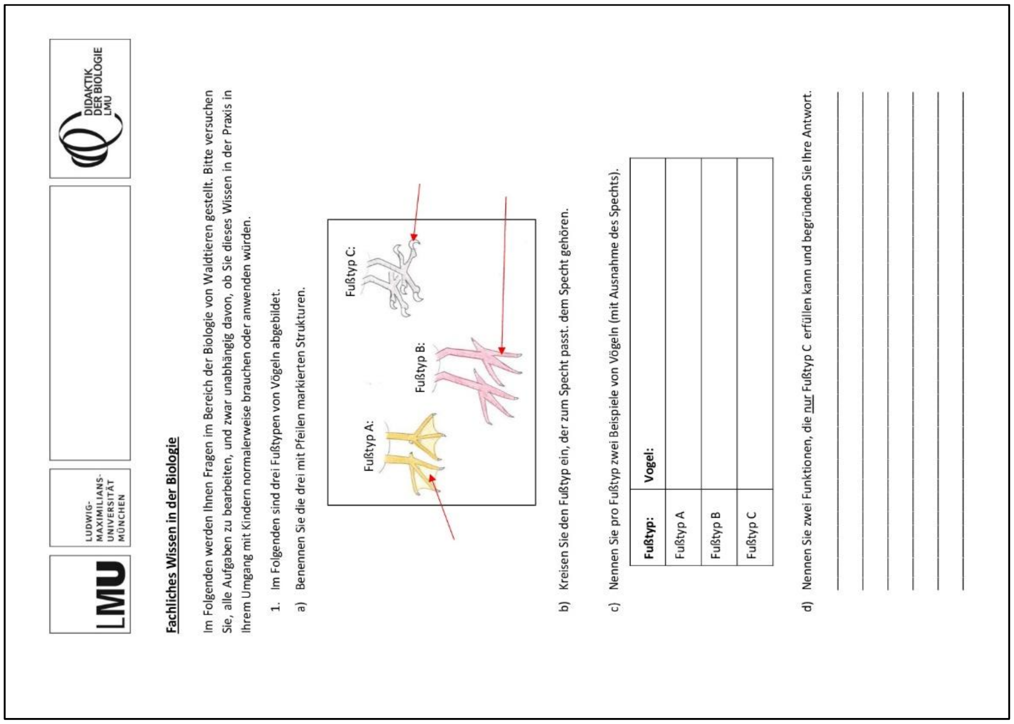
d) Was ist Ihre aktuelle Tätigkeit im Kindergarten?
☐ Erzieher/in ☐ Kinderpfleger/in ☐ Auszubildende/r ☐ Sonstiges: _____

e) Seit wie vielen Jahren sind Sie in Ihrer aktuellen Tätigkeit beschäftigt?
_____ Jahre

f) Bitte geben Sie den bisherigen Verlauf Ihres Ausbildungsweges an. Kreuzen Sie dabei alles an, was auf Sie zutrifft:
☐ Hauptschulabschluss / ☐ Mittlere Reife / ☐ Fachhochschulreife / ☐ Abitur
☐ Ausbildung zur Kinderpflegerin / zum Kinderpfleger
☐ Sozialpädagogisches Seminar
☐ Ausbildung zur Erzieherin / zum Erzieher
☐ Studium: _____

g) Wie oft haben Sie schon an einer Fortbildung zur frühen naturwissenschaftlichen Bildung teilgenommen?
☐ noch nie ☐ 1mal ☐ 2-5mal ☐ >5mal

Seite 3:



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Fachliches Wissen in der Biologie

Im Folgenden werden Ihnen Fragen im Bereich der Biologie von Waldtieren gestellt. Bitte versuchen Sie, alle Aufgaben zu bearbeiten, und zwar unabhängig davon, ob Sie dieses Wissen in der Praxis in Ihrem Umgang mit Kindern normalerweise brauchen oder anwenden würden.

1. Im Folgenden sind drei Fußtypen von Vögeln abgebildet.

a) Benennen Sie die drei mit Pfeilen markierten Strukturen.

b) Kreisen Sie den Fußtyp ein, der zum Specht passt. dem Specht gehören.

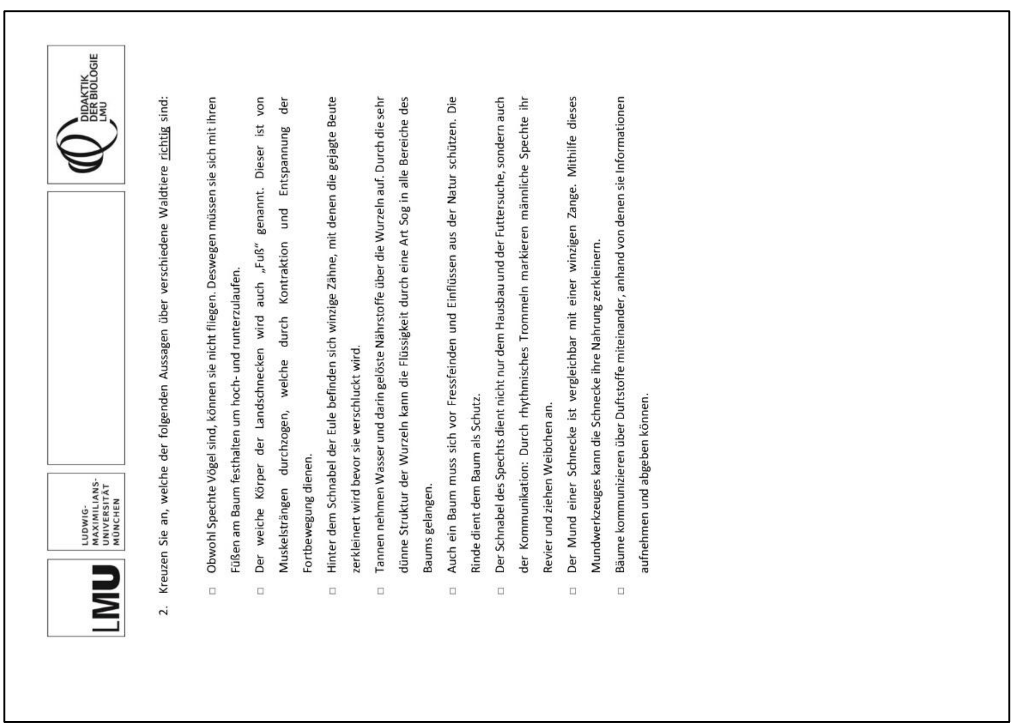
c) Nennen Sie pro Fußtyp zwei Beispiele von Vögeln (mit Ausnahme des Spechts).

Fußtyp:	**Vogel:**
Fußtyp A	
Fußtyp B	
Fußtyp C	

d) Nennen Sie zwei Funktionen, die <u>nur</u> Fußtyp C erfüllen kann und begründen Sie Ihre Antwort.

____

Seite 4:



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2. Kreuzen Sie an, welche der folgenden Aussagen über verschiedene Waldtiere <u>richtig</u> sind:

- □ Obwohl Spechte Vögel sind, können sie nicht fliegen. Deswegen müssen sie sich mit ihren Füßen am Baum festhalten um hoch- und runterzulaufen.
- □ Der weiche Körper der Landschnecken wird auch „Fuß" genannt. Dieser ist von Muskelsträngen durchzogen, welche durch Kontraktion und Entspannung der Fortbewegung dienen.
- □ Hinter dem Schnabel der Eule befinden sich winzige Zähne, mit denen die gejagte Beute zerkleinert wird bevor sie verschluckt wird.
- □ Tannen nehmen Wasser und darin gelöste Nährstoffe über die Wurzeln auf. Durch die sehr dünne Struktur der Wurzeln kann die Flüssigkeit durch eine Art Sog in alle Bereiche des Baums gelangen.
- □ Auch ein Baum muss sich vor Fressfeinden und Einflüssen aus der Natur schützen. Die Rinde dient dem Baum als Schutz.
- □ Der Schnabel des Spechts dient nicht nur dem Hausbau und der Futtersuche, sondern auch der Kommunikation: Durch rhythmisches Trommeln markieren männliche Spechte ihr Revier und ziehen Weibchen an.
- □ Der Mund einer Schnecke ist vergleichbar mit einer winzigen Zange. Mithilfe dieses Mundwerkzeuges kann die Schnecke ihre Nahrung zerkleinern.
- □ Bäume kommunizieren über Duftstoffe miteinander, anhand von denen sie Informationen aufnehmen und abgeben können.

Seite: 5:

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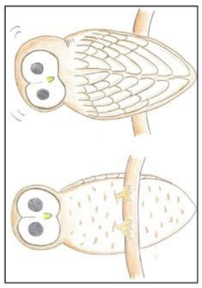
3. Stellen Sie sich folgende Situation vor: An einem Tag im Kindergarten kommt ein Kind zu Ihnen und sagt: *„Ich habe gestern einen Film über Eulen gesehen. Da wurde gesagt, dass Eulen richtig gut hören können. Aber das kann doch gar nicht sein, Eulen haben doch keine Ohren, oder?"*



Kreuzen Sie die fachlich korrekten Aussagen an, unabhängig davon, ob Sie dieses Wissen bei der Beantwortung der Kinderfrage anwenden würden:

- ☐ Eulen besitzen große runde Ohröffnungen. Diese sind aber durch einen dichten Federkranz so gut geschützt, dass sie nicht sichtbar sind.
- ☐ Der Gesichtsschleier der Schleiereule dient dem Gehör. Durch seine Form funktioniert er ähnlich wie ein Trichter: Es nimmt die kleinsten Geräusche auf, verstärkt sie, und leitet sie an die Ohröffnungen weiter.
- ☐ Zur Geräuschaufnahme bewegen Eulen auch ihren Kopf, der bis zu 270° in beide Richtungen drehbar ist.
- ☐ Die Ohröffnungen der Eulen sind nicht symmetrisch am Kopf angeordnet: eine Ohröffnung liegt etwas höher als die andere. Diese Asymmetrie dient der Geräuschortung.
- ☐ Einige Arten, wie z. B. die Waldohreulen, haben Ohrmuscheln entwickelt. Diese sind von Federn bedeckt und werden Federohren genannt.

Seite 6:

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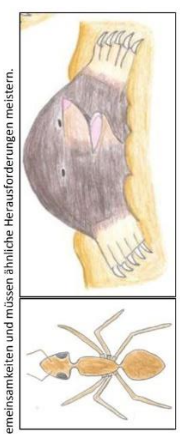
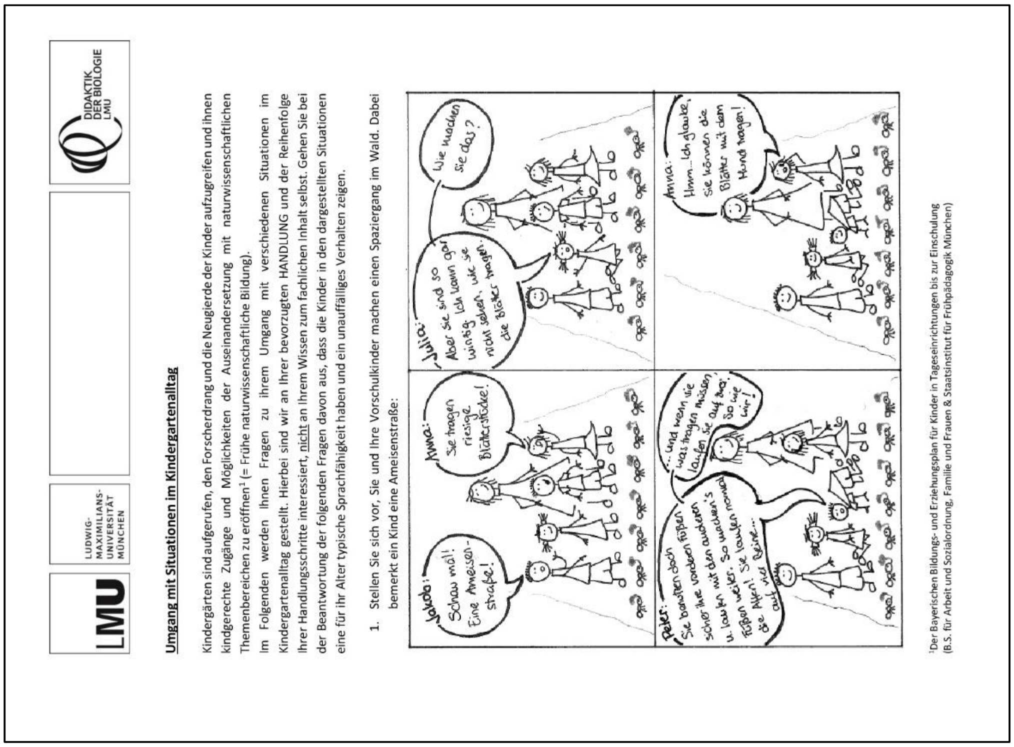
4. Die Ameise und der Maulwurf sind ganz unterschiedliche Tiere. Als Lebewesen teilen sie aber viele Gemeinsamkeiten und müssen ähnliche Herausforderungen meistern.



Nennen Sie möglichst viele Eigenschaften und Verhaltensweisen, die Ameisen und Maulwürfe als Lebewesen gemeinsam haben und erläutern Sie zu jeder genannten Eigenschaft und Verhaltensweise, wie diese beim jeweiligen Tier ausgeprägt ist.

Eigenschaft / Verhalten	Ameise	Maulwurf
z. B. Tiere pflanzen sich fort	Ameisen legen Eier	Maulwürfe sind lebendgebärend

Seite 7:



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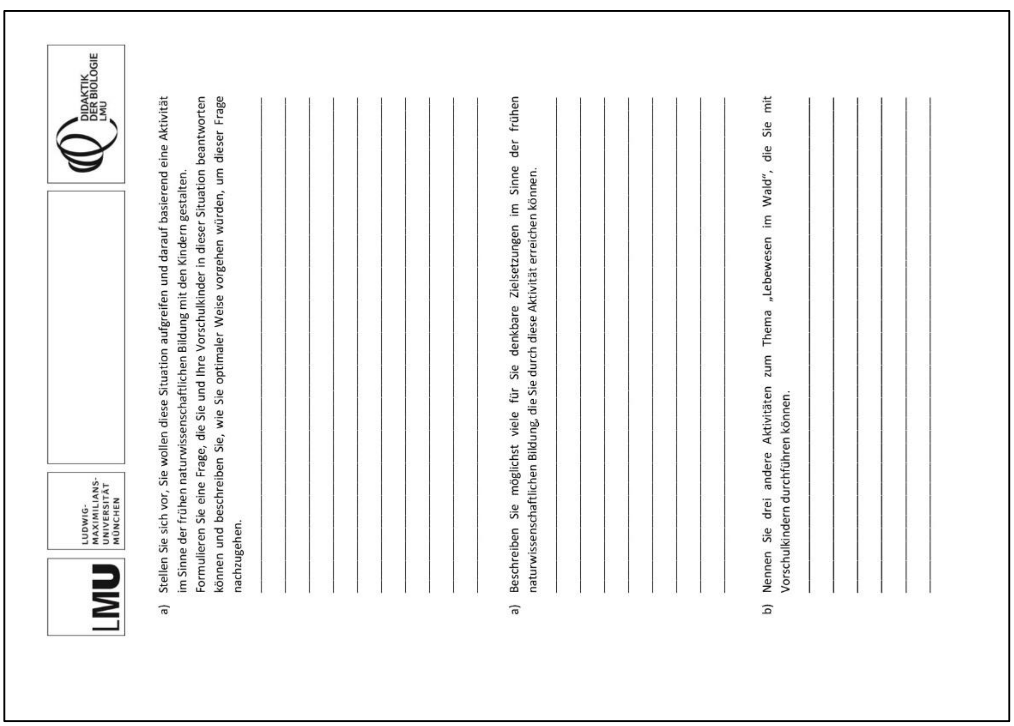
Umgang mit Situationen im Kindergartenalltag

Kindergärten sind aufgerufen, den Forscherdrang und die Neugierde der Kinder aufzugreifen und ihnen kindgerechte Zugänge und Möglichkeiten der Auseinandersetzung mit naturwissenschaftlichen Themenbereichen zu eröffnen[1] (= Frühe naturwissenschaftliche Bildung).
Im Folgenden werden Ihnen Fragen zu ihrem Umgang mit verschiedenen Situationen im Kindergartenalltag gestellt. Hierbei sind wir an Ihrer bevorzugten HANDLUNG und der Reihenfolge Ihrer Handlungsschritte interessiert, nicht an Ihrem Wissen zum fachlichen Inhalt selbst. Gehen Sie bei der Beantwortung der folgenden Fragen davon aus, dass die Kinder in den dargestellten Situationen eine für ihr Alter typische Sprachfähigkeit haben und ein unauffälliges Verhalten zeigen.

1. Stellen Sie sich vor, Sie und Ihre Vorschulkinder machen einen Spaziergang im Wald. Dabei bemerkt ein Kind eine Ameisenstraße:

[1]Der Bayerischen Bildungs- und Erziehungsplan für Kinder in Tageseinrichtungen bis zur Einschulung (B.S. für Arbeit und Sozialordnung, Familie und Frauen & Staatsinstitut für Frühpädagogik München)

Seite 8:



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a) Stellen Sie sich vor, Sie wollen diese Situation aufgreifen und darauf basierend eine Aktivität im Sinne der frühen naturwissenschaftlichen Bildung mit den Kindern gestalten.
Formulieren Sie eine Frage, die Sie und Ihre Vorschulkinder in dieser Situation beantworten können und beschreiben Sie, wie Sie optimaler Weise vorgehen würden, um dieser Frage nachzugehen.

a) Beschreiben Sie möglichst viele für Sie denkbare Zielsetzungen im Sinne der frühen naturwissenschaftlichen Bildung, die Sie durch diese Aktivität erreichen können.

b) Nennen Sie drei andere Aktivitäten zum Thema „Lebewesen im Wald", die Sie mit Vorschulkindern durchführen können.

Seite 9:

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2. Wilde Tiere, wie z. B. das Eichhörnchen, wecken das Interesse der Vorschulkinder, sind aber im Kindergartenalltag nicht immer direkt beobachtbar.
Lesen Sie bitte die Hintergrundinformation zum Eichhörnchen, bevor Sie folgende Fragen beantworten.

Das Eichhörnchen

Das Eichhörnchen ernährt sich von Nüssen, Fichtenzapfen und Obst. Aber auch Vogeleier, Würmer und Pilze mag es sehr gerne. Nüsse kann ein Eichhörnchen innerhalb weniger Sekunden öffnen. Eichhörnchen haben dazu vier große starke Schneidezähne. Die Zähne werden beim Nüsseknacken ganz schön beansprucht. Damit sie aber immer schön kräftig und groß bleiben, wachsen sie das ganze Leben lang.
Der Daumen des Eichhörnchens ist zurückgebildet und dient beim Fressen dem Festhalten der Nahrung. Nur der Daumen hat einen Fingernagel, die restlichen vier Finger und die fünf Zehen der Hinterfüße haben scharfe Krallen. Damit können sich Eichhörnchen hervorragend an der Baumrinde festhalten. Stammabwärts klettern Eichhörnchen kopfüber nach unten. Hierbei können sie die Hinterfüße um 180 Grad verdrehen, um einen optimalen Griff zu erreichen.
Die natürlichen Feinde des Eichhörnchens sind Greifvögel wie der Habicht oder Raubtiere wie der Baummarder. Zum Schutz vor diesen Tieren, aber auch vor Wind und Wetter baut sich das Eichhörnchen ein kleines Baumnest, den sogenannten Kobel, in hohlen Baumstämmen oder an den Astgabeln von Baumkronen. Der Kobel ist ein kleines rundliches Nest mit zwei Eingängen, von denen einer der Flucht dienen kann.
Für seinen Wintervorrat versteckt das Eichhörnchen viele Nüsse und Samen an den verschiedensten Stellen im Wald. Aber wie schafft es das Eichhörnchen, fast alle wiederzufinden? Das Eichhörnchen hat ein sehr gutes Raumgedächtnis und eine gute Nase: Es kann eine vergrabene Nuss noch unter 30 cm hohem Schnee erschnüffeln!

a) Nennen Sie zwei Eigenschaften oder Verhaltensweisen des Eichhörnchens und erklären Sie, wie Sie diese mit selbstgebastelten Modellen für Vorschulkinder erfahrbar machen können.

____
____
____
____
____
____

Seite 10:

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b) Formulieren Sie jeweils eine Frage, die Sie und Ihre Vorschulkinder anhand von diesen Materialien/Modellen beantworten können.

____
____
____
____
____
____

c) Nennen Sie eine Fehlvorstellung über Eichhörnchen (d. h. Vorstellungen, die der Realität nicht entsprechen), die Kinder durch diese Aktivität entwickeln könnten.

____
____
____
____
____
____

Coding scheme

Wissensdimension	Wissensart	Aufgabenstellung	ITEM	Antwortmöglichkeiten / Kategorien	Operationalisierung
Fachwissen	Deklarativ	Benennen Sie die drei mit Pfeilen markierten Strukturen.	Prä_FW_D1	A: Schwimmhaut (Flosse) B: Zeh C: Kralle	1 Punkt pro richtiger Begriff
	Deklarativ	Kreisen Sie den Fußtyp ein, der zum Specht passt.	Prä_FW_D2	Kreis: Fußtyp C	1 Punkt
	Deklarativ	Nennen Sie pro Fußtyp zwei Beispiele von Vögeln (mit Ausnahme des Spechts).	Prä_FW_D3	A: Ente, Gans, Schwan, Penguin, Möwe, Pelikan B: Amsel, Spatz, Taube, Schwalbe, Rotkelchen, Huhn, Pute, Kohlmeise, Krähe, Storch, Kranich, Fink, Rabe, Sperling C: Eule, Papagei, Uhu, Wellensittich	1 Punkt pro richtiges Beispiel (jeweils max. 2 Beispiele)
	Deklarativ	Nennen Sie zwei Funktionen, die <u>nur</u> Fußtyp C erfüllen kann und begründen Sie Ihre Antwort.	Prä_FW_D4	Funktionen: 1. Festhalten am Baum, 2. Greifen oder halten der Beute, 3. Reißen	1 Punkt pro richtige Funktion (max. 2 Punkte)
				Begründung: Zehenanordnung, Krallen (Struktur)	1 Punkt pro richtige Begründung (max. 2 Punkte)
	Deklarativ	Kreuzen Sie an, welche der folgenden Aussagen über Lebewesen des Waldes <u>richtig</u> sind.	Prä_FW_D5	**Multiple Choice:** FALSCH: Obwohl Spechte Vögel sind, können sie nicht fliegen… RICHTIG: Der weiche Körper der Landschnecken wird auch "Fuß" genannt… FALSCH: Hinter dem Schnabel der Eule befinden sich winzige Zähne… RICHTIG: Tannen nehmen Wasser und Mineralstoffe aus dem Boden über die Wurzeln auf… RICHTIG: Auch ein Baum muss sich vor Fressfeinden und Einflüssen aus der Natur schützen… RICHTIG: Der Schnabel des Spechts dient der Kommunikation… FALSCH: Der Mund einer Schnecke ist vergleichbar mit einer winzigen Zange… RICHTIG: Bäume kommunizieren über Duftstoffe miteinander…	1 Punkt pro richtig angekreuzte oder richtig nicht-angekreuzte Aussage
	Prozedural	Kreuzen Sie die fachlich <u>korrekten</u> Aussagen an, unabhängig davon, ob Sie dieses Wissen bei der Beantwortung der Kinderfrage anwenden würden.	Prä_FW_P1	**Multiple Choice:** FALSCH: Eulen besitzen große runde Ohröffnungen… RICHTIG: Der Gesichtsschleier der Schleiereule dient dem Gehör… RICHTIG: Zur Geräuschaufnahme bewegen Eulen auch ihren Kopf… RICHTIG: Die Ohröffnungen der Eulen sind nicht symmetrisch am Kopf angeordnet… FALSCH: Einige Eulenarten ahben Ohrmuscheln…	1 Punkt pro richtig angekreuzte oder richtig nicht-angekreuzte Aussage
	Konditional	Die Ameise und der Maulwurf sind ganz unterschiedliche Tiere. Als Lebewesen teilen sie aber viele Gemeinsamkeiten und müssen ähnliche Herausforderungen meistern. Nennen Sie möglichst viele Eigenschaften oder Verhaltensweisen, die Ameisen und Maulwürfe als Lebewesen gemeinsam haben.	Prä_FW_K1	**Kategorien:** 1 - Stoffwechsel: Nahrungsaufnahme (Ausscheiden) + dazugeh. Anatomie 2 - Stoffwechsel: Gasaustausch (Atmen) + dazugeh. Anatomie 3 - Selbstreproduktion: Vermehrung und Fortpflanzung + dazugeh. Anatomie 4 - Entwicklung: Individualentwicklung (Wachstum) + dazugeh. Anatomie 5 - Entwicklung: Evolutionäre Entwicklung (genetische Variabilität und Angepasstheit) + dazugeh. Anatomie 6 - Informationsaustausch: Sinneswahrnehmung + dazugeh. Anatomie 7 - Informationsaustausch: Kommunikation (mit eigener Spezies) + dazugeh. Anatomie 8 - System: Wechselwirkungen mit belebter Umwelt: Bezug zu anderen Tieren (z.B. Schutz), Organisation mit Tieren der eigenen Spezies (z.B. Ameisenstaat) + dazugeh. Anatomie 9 - System: Wechselwirkungen mit unbelebter Umwelt: Bezug zum Lebensraum (z.B. Fortbewegung) + dazugeh. Anatomie	1 Punkt pro genannte Kategorie und/oder dazugeh. Anatomie
Fachdidaktisches Wissen - Modelle	Prozedural	Modelle können gebastelt werden, um den Kindern bestimmte biologische Zusammenhänge näherzubringen, wie z.B. der Zusammenhang zwischen einer biologischen Struktur und ihrer Funktion. Nennen Sie eine Eigenschaft des Eichhörnchens, die sich Ihrer Meinung nach eignet, um den Zusammenhang von Struktur und Funktion anhand von einem Modell	Prä_FDWM_P1	MSt (Eigenschaft: Struktur): Wenn nur Struktur von etwas vorkommt. Nicht Mod_SF wenn z.B. Struktur von etwas, aber Funktion von was anderes	1 Punkt
				MFu (Eigenschaft: Funktion): Wenn nur Funktion von etwas vorkommt. Nicht Mod_SF wenn z.B. Struktur von	1 Punkt
				MStFu (Zusammenhang Struktur und Funktion): Wenn beide in Zusammenhang vorkommen	2 Punkte
				MMa (Materialien): Wenn die Materialien oder Ideen der Umsetzung genannt werden	1 Punkt
				MK (Keine Zuordnung)	
	Prozedural	Formulieren Sie möglichst viele Fragen, die Sie und Ihre Vorschulkinder anhand von diesem Modell nachgehen	Prä_FDWM_P2	Fragen mit dem Modell	1 Punkt pro genannte Frage
	Deklarativ	Nennen Sie möglichst viele Vor- und Nachteile, die sich aus dem Einsatz von selbstgebastelten Modellen mit Vorschulkindern ergeben können.	Prä_FDWM_D1	Vor- und Nachteile	1 Punkt pro genannter Vor-/Nachteil

Wissensdimension	Wissensart	Aufgabenstellung	ITEM	Antwortmöglichkeiten / Kategorien	Operationalisierung
Fachdidaktisches Wissen - Alltagssituationen & Experimente	Prozedural	Formulieren Sie eine Frage, der Sie mit Ihren Vorschulkindern nachgehen würden, um ihren Forscherdrang in dieser Situation aufzugreifen.	Prä_FDWE_P1	**Kategorien:**	
				FS_SN (Frage stellen & Situation nicht aufgreifen) - Frage mit Bezug auf die Ameisen, greift aber nicht die Fragen / Vermutungen der Kinder auf (z.B. wo leben die Ameisen?)	1 Punkt
				FS_SA (Frage stellen & Situation aufgreifen) - Frage mit Bezug auf die Ameisen, greift die Fragen / Vermutungen der Kinder auf (z.B. womit tragen sie die Blätter?)	2 Punkte
				*Falls andere EPAs vorkommen, hier auch codieren (z.B. HG ist bereits in der Frage integriert: "Wollen wir die Ameisen in Ruhe beobachten?")	
	Prozedural	Beschreiben Sie, wie Sie bei einer Aktivität optimaler Weise vorgehen würden, um dieser Frage mit den Kindern nachzugehen. Streben Sie dabei an, möglichst viele Phasen der Erkenntnisgewinnung einzuschließen.	Prä_FDWE_P2	**Kategorien:**	1 Punkt pro genannte EPA
				A) EPA: Epistemische Aktivitäten	
				FS_SN / FS_SA: *Siehe Kategorien bei Prä_FDWE_P1	
				HG (Hypothesen generieren): Vermutungen/Ideen von den Kindern in Bezug auf die gestellte Frage werden gesammelt	
				EG (Evidenzen generieren): Biologische Methoden (Beobachtungen, Vergleiche, Experimente, Arbeit mit Modellen, Arbeitstechniken. Artefakte z.B. Fotos für EE) werden geplannt / durchgeführt	
				EB (Evidenzen besprechen): Es wird explizit genannt, dass die Ergebnisse besprochen werden	
				EE (Evidenzen evaluieren): Ergebnisse aus der durchgeführten Methode werden mit Rückbezug zu den Hypothesen evaluiert/interpretiert	
				ES (Schlussfolgerungen aus Evidenzen ziehen): Generelle Schlussfolgerungen werden anhand von der durchgeführten Methode gezogen, z.B. zentrale Konzepte werden herangezogen, andere Tiere werden in Betracht gezogen.	
				EK (Ergebnisse kommunizieren): Ergebnisse werden dokumentiert und/oder für eine breitere Audienz kommuniziert, z.B. Fotos, Zeichnungen, Plakate	
				B) NEPA: Nicht-Epistemische Aktivitäten (keine Biologische Methoden)	
				IR (Information recherchieren): Informationen in Bezug auf die gestellte Frage werden aus verschiedenen Quellen (Bücher, Videos, Internet) recherchiert oder Institutionen werden besucht (Museum, Biotop, Tierpark). Biologische Methoden werden nicht durchgeführt	
				IB (Information besprechen): Es wird explizit genannt, dass die Informationen besprochen werden	
				IE (Information evaluieren): Informationen aus der Recherche werden mit Rückbezug zu den Hypothesen evaluiert/interpretiert	
				IS (Schlussfolgerungen aus Info ziehen): Generelle Schlussfolgerungen werden anhand von der recherchierten Information gezogen, z.B. zentrale Konzepte werden herangezogen, andere Tiere werden in Betracht gezogen.	
				IK (Informationen kommunizieren): Informationen werden dokumentiert und/oder für eine breitere Audienz kommuniziert, z.B. Zeichnungen und Plakate	
				BM (Bezug zum Mensch): Menschen werden als Vergleich in Betracht gezogen	
				RN (Reflexion über Natur): Es wird reflektiert, welche Bedeutung die Tiere für die Umwelt haben, wie man mit Tieren/Natur umgehen soll.	
				SA (Sonstige Aktivitäten): Andere Aktivitäten werden genannt, z.B. Lieder singen	
	Prozedural	Nennen Sie möglichst viele Ziele der frühen naturwissenschaftlichen Bildung, die Sie durch diese Aktivität erreichen könnten.	Prä_FDWE_P3	**Kategorien: Ziele der frühen naturwissenschaftlichen Bildung**	1 Punkt pro genanntes Ziel
				Z_EF (Erfahrungen)	
				Z_IB (Inhaltsbezogene Ziele): Phänomene, Zusammenhänge, Konzepte, Theorien und Gesetmäßigkeiten	
				Z_PB (Prozessbezogene Ziele): Denk- und Arbeitsweisen = Fragen stellen, Vermuten, Beobachten, Messen, Untersuchungen planen und durchführen, Vergleichen-Ordnen-Klassifizieren, Daten analysieren-interpretieren-Schlussfolgern-Generalisieren, Argumentieren, Modelle nutzen, Dokumentieren	
				Z_EP (Epistemologische Ziele)	
				Z_EN (Einstellungen gegenüber Naturwissenschaften)	
				Z_EU (Einstellungen gegenüber Umwelt): und andere Lebewesen, Verantwortung	
				Z_IN (Interesse): Kognitive Ebene, Neugier. Forscherdrang als Verfolgung der Interessen	
				Z_LF (Lernfreude): Lernemotionen, Affektive Ebene, Engagiertheit	
				Z_SV (Selbstvertrauen)	
				Z_BA (Bezug zu anderen Aspekten): Bezüge zu sozialen, gesellschaftlichen und technischen Aspekten herzustellen	
				Z_QB (Querverbindung zu anderen Bildungsziele): Emotionalität, Sozial, Sprache, Mathe, etc.	
				Z_KZ (Keine Zuordnung): Aussagen, die zu keinem Ziel zugeordnet werden können, z.B. "Bilderbücher"	
	Deklarativ	Nennen Sie fünf andere Situationen im Kindergartenalltag, die Sie aufgreifen würden, um Kindern eine Auseinandersetzung mit biologischen Themen zu ermöglichen.	Prä_FDWE_D1	5 andere Situationen / Aktivitäten	1 Punkt pro genannte Situation / Aktivität

Appendix A.2.6: Preschool teachers´ instructional practice

Observation sheet

LMU

LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

DIDAKTIK DER BIOLOGIE LMU

Beobachtungsbogen

Forschungsprojekt „Der Wald kommt in den Kindergarten“

Erzieher/in-Code:

1	2	3	4

Bitte tragen Sie folgendes ein:

1) Zweiter Buchstabe des Vornamens Ihrer Mutter
2) Zweiter Buchstabe des Vornamens Ihres Vaters
3-4) Tag Ihrer Geburt

Bsp: Die Mutter heißt Maria, der Vater heißt Julian, der Geburtstag ist der 08. Juni 1989. Der Code wäre dann: AU08.

Ludwig-Maximilians-Universität München
Department I für Biologie
Didaktik der Biologie
Winzererstr. 45/II
80797 München

Beobachtungsbogen – bei allen Stationen gleich

Beobachtungsbogen

Datum:__________ **Beginn:**__________ **Ende:**__________

Kindergarten:__________ **ID-Code Erzieher:**__________

Anzahl Kinder:__________ **Beobachter:**__________

Allgemeiner Einstieg (fachdidaktisches Wissen)

	Sichtbar	Bemerkung
Vorwissensaktivierung		
Kontextgebunden		
Regeln besprechen		

Allgemeiner Abschluss (fachdidaktisches Wissen)

	Sichtbar		Bemerkung
	Erz	Ki	
Reflexion			
Zusammenfassen			
Feedback			

Weitere Anmerkungen:

Einstieg Modell (fachdidaktisches Wissen)

	Sichtbar		Bemerkung
	Erz	**Ki**	
Vorwissensaktivierung			
Kontextgebunden Direkt am Anfang Während dessen			
Direkt Modellbeschreibung			

Abschluss des Modells (fachdidaktisches Wissen)

	Sichtbar		Bemerkung
	Erz	**Ki**	
Reflexion			
Zusammenfassen			
Feedback			

Weitere Bemerkungen:

Beobachtungsbogen – Station Fortbewegung Specht

Modell Specht Fachwissen:

	Sichtbar		Bemerkung
	Erz	**Ki**	
Bezeichnung des Tieres Vogel Specht Buntspecht			
Merkmalbenennung Körper			Anzahl:
Gezielte Benennung Struktur Fuß Krallen Muskel/Muskelkraft Zygodaktylie/Zehenstellung Schwimmhäute			
Benennung der Funktion Klettern festhalten Schwimmen			
Zusammenhang zwischen Struktur und Funktion Zygodaktylie/Zehenstellung Schwimmhäute			
Bezug zu anderen biologischen Phänomenen Frösche, Vögel			
Lehrt falsche Informationen			Anzahl:

Fachdidaktisches Wissen:

	Sichtbar		Bemerkung
Fordert Kinder auf allgemein zu **beschreiben (Wahrnehmen)** **Details zu beschreiben (Beobachten)** **Vergleiche zw. Fußmodellen**			
Gibt Frage vor Formuliert eine zum Modell **passende Frage** **Leitet die Kinder zu Fragen an**			
Lässt **Kinder Vermutungen** aufstellen **Impulse (z.B. Satzanfänge)** Gibt Wahlmöglichkeiten			
Prüft selbst Lässt **Kinder prüfen** **Lässt alle** Kinder prüfen Gibt Hilfestellung			
Beschreibt Vorgang **selbst** Lässt **Kinder** Vorgang **beschreiben** Lenkt Kinder zur **deutungsfreien Beschreibung** Achtet auf **Vergleich**			
Interpretiert selbst **gemeinsam** mit den Kindern Fehler**betonung** **Fehlvermutungen eingehen** Fehler sind **normal**			
Stellt den **Vergleich zum Original her** (Modellkritik) - Größe - Material - Struktur reduziert - Beiwerk	E	K	

Beobachtungsbogen – Station Sinne Eule

Modell Sinne Eule Fachwissen:

	Sichtbar Erz	Sichtbar Ki	Bemerkung
Bezeichnung des Tieres Vogel Eule Schleiereule/Waldkauz			
Merkmalbenennung Körper			Anzahl:
Gezielte Benennung Struktur Ohr/Gehör Kopfform Federn Schleier Trichter			
Benennung der Funktion Verstärken/Lauter Sammeln der Schallwellen			
Zusammenhang zwischen Struktur und Funktion Besser Hören			
Bezug zu anderen biologischen Phänomenen Fuchs, Mensch			
Lehrt falsche Informationen			Anzahl:

Fachdidaktisches Wissen:

	Sichtbar	Bemerkung
Fordert Kinder auf allgemein zu **beschreiben (Wahrnehmen)** **Details zu beschreiben (Beobachten)** **Vergleiche**		
Gibt Frage vor Formuliert eine zum Modell **passende Frage** **Leitet die Kinder zu Fragen an**		
Lässt **Kinder Vermutungen** aufstellen **Impulse (z.B. Satzanfänge)** Gibt Wahlmöglichkeiten		
Prüft selbst Lässt **Kinder prüfen** **Lässt alle** Kinder prüfen Gibt Hilfestellung		
Beschreibt Vorgang **selbst** Lässt **Kinder** Vorgang **beschreiben** Lenkt Kinder zur **deutungsfreien Beschreibung** Achtet auf **Vergleich**		
Interpretiert selbst **gemeinsam** mit den Kindern Fehler**betonung** **Fehlvermutungen eingehen** Fehler sind **normal**		
Stellt den **Vergleich zum Original her** (Modellkritik) - Größe - Material - Struktur reduziert - Beiwerk	E K	

Beobachtungsbogen – Nahrungsaufnahme Ameise

Modell Nahrungsaufnahme Ameise Fachwissen:

	Sichtbar		Bemerkung
	Erz	**Ki**	
Bezeichnung des Tieres Insekt Ameise Waldameise			
Merkmalbenennung Körper			Anzahl:
Gezielte Benennung Struktur Mund Zangenförmig Mundwerkzeuge Mandibeln/Oberkiefer			
Benennung der Funktion Abbeißen/Abreißen Festhalten			
Zusammenhang zwischen Struktur und Funktion Essen Transport (der Nahrung)			
Bezug zu anderen biologischen Phänomenen MWZ anderer Insekten, Mensch (Zähne)			
Lehrt falsche Informationen			Anzahl:

Fachdidaktisches Wissen:

	Sichtbar		Bemerkung
Fordert Kinder auf allgemein zu **beschreiben (Wahrnehmen)** **Details zu beschreiben (Beobachten)** **Vergleiche zw. Zangen**			
Gibt Frage vor Formuliert eine zum Modell **passende Frage** **Leitet die Kinder zu Fragen an**			
Lässt **Kinder Vermutungen** aufstellen **Impulse (z.B. Satzanfänge)** Gibt Wahlmöglichkeiten			
Prüft selbst Lässt **Kinder prüfen** **Lässt alle** Kinder prüfen Gibt Hilfestellung			
Beschreibt Vorgang **selbst** Lässt **Kinder** Vorgang **beschreiben** Lenkt Kinder zur **deutungsfreien Beschreibung** Achtet auf **Vergleich**			
Interpretiert selbst **gemeinsam** mit den Kindern Fehler**betonung** **Fehlvermutungen eingehen** Fehler sind **normal**			
Stellt den **Vergleich zum Original her** (Modellkritik) - Größe - Material - Struktur reduziert - Beiwerk	E	K	

Beobachtungsbogen – Station Schutz Schnecke

Modell Schutz Schnecke Fachwissen:

	Sichtbar Erz	Sichtbar Ki	Bemerkung
Bezeichnung des Tieres Weichtier Schnecke Waldschnecke/Weinbergsch. Nacktschnecke			
Merkmalbenennung Körper			Anzahl:
Gezielte Benennung Struktur Schneckenhaus Kalkhaltige Schale Deckel Nackt: Kein Haus Muskel			
Benennung der Funktion Schutz vor Feinden Schutz vor Frost Austrocknung Organhöhle			
Zusammenhang zwischen Struktur und Funktion Geschützte Fortbewegung			
Bezug zu anderen biologischen Phänomenen Igel, Nacktschnecke Sekret			
Lehrt falsche Informationen			Anzahl:

Fachdidaktisches Wissen:

	Sichtbar	Bemerkung
Fordert Kinder auf allgemein zu **beschreiben (Wahrnehmen)** **Details zu beschreiben (Beobachten)** **Vergleiche zw. Schnecken**		
Gibt Frage vor Formuliert eine zum Modell **passende Frage** **Leitet die Kinder zu Fragen an**		
Lässt **Kinder Vermutungen** aufstellen **Impulse (z.B. Satzanfänge)** Gibt Wahlmöglichkeiten		
Prüft selbst Lässt **Kinder prüfen** **Lässt alle** Kinder prüfen Gibt Hilfestellung		
Beschreibt Vorgang **selbst** Lässt **Kinder** Vorgang **beschreiben** Lenkt Kinder zur **deutungsfreien Beschreibung** Achtet auf **Vergleich**		
Interpretiert selbst **gemeinsam** mit den Kindern Fehler**betonung** **Fehlvermutungen eingehen** Fehler sind **normal**		
Stellt den **Vergleich zum Original her** (Modellkritik) - Größe - Material - Struktur reduziert - Beiwerk	E | K	

Coding scheme

Inhaltliche Aspekte des Fachwissens nach Modell-Typ

	Modell Specht	Modell Eule	Modell Ameise	Modell Schnecke
Bezeichnung des Tieres	Vogel Specht Buntspecht	Vogel Eule Schleiereule/ Waldkauz	Insekt Ameise Waldameise	Weichtier Schnecke Weinberg-schnecke/ Waldschnecke Nacktschnecke
Punktzahl	0-3	0-3	0-3	0-4
Gezielte Benennung der Strukturen	Fuß Krallen Muskel/ Muskelkraft Zehen-stellung / Zygo-daktylie Schwimm-häute	Ohr/Gehör Kopfform Federn Schleier Trichter	Mund Zangen(-förmig) Mundwerk-zeuge Oberkiefer (Mandibeln)	Schneckenhaus Kalkhaltige Schale Deckel Nackt: kein Haus Muskel
Punktzahl	0-5	0-5	0-4	0-5
Benennung der Funktion	Klettern Festhalten Schwimmen	Sammeln der Schallwellen Verstärkung der Schallwellen	Abbeißen/ Abreißen Festhalten	Schutz vor Feinden Schutz vor Austrocknung Organhöhle
Punktzahl	0-3	0-2	0-2	0-3
Zusammen-hang zwischen Struktur und Funktion	Zehen-stellung/ Zygo-daktylie-Festkrallen Schwimm-häute-Schwimmen	Besseres Hören	Essen Transport der Nahrung	Geschützte Fortbewegung
Punktzahl	0-2	0-1	0-2	0-1
Bezug zu anderen biologischen Phänomenen	Fortbewegung	Sinne	Nahrungs-aufnahme	Schutz
Punktzahl	0-1	0-1	0-1	0-1

Unterteilung des Fachdidaktischen Wissens mit jeweiliger Punktverteilung

	Deklaratives Wissen	**Prozedurales Wissen**	**Konditionales Wissen**	**Gesamt-punktzahl**
Fragen formulieren	Formuliert eine Frage	Formuliert eine passende Frage zum Modell		
Punkte bei sichtbarer Handlung	1	2		0-2
Vermutungen	Lässt Kinder Vermutungen aufstellen			
Punkte bei sichtbarer Handlung	1			0-1
Prüfen	Prüft selbst	Lässt Kinder prüfen	Achtet darauf, dass alle Kinder prüfen	
Punkte bei sichtbarer Handlung	1	2	3	0-3
Beschreiben	Beschreibt den Vorgang selbst	Lässt Kinder den Vorgang beschreiben		
Punkte bei sichtbarer Handlung	1	2		0-2
Interpretieren	Interpretiert selbst	Interpretiert gemeinsam mit den Kindern		
Punkte bei sichtbarer Handlung	1	2		0-2

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