Fachbereich Erziehungswissenschaft und Psychologie

der Freien Universität Berlin

The Role of Motivation in Early Mathematics and Science Education

Dissertation

zur Erlangung des akademischen Grades

Doktorin der Philosophie (Dr. phil.)

Vorgelegt von

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Berlin, 2017

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Tag der Disputation: 14.02.2018

ACKNOWLEDGEMENTS

First and foremost, I wish to express my immense gratitude to Prof. Dr. Yvonne Anders for her continuous guidance and support throughout this dissertation project. Her feedback and great expertise were indispensable over the last four years. I also appreciate the opportunity to be part of, what I consider, one of the most interesting research projects and the challenges and numerous opportunities that I was provided with. Thank you!

I am also deeply grateful to Prof. Dr. Martin Brunner, who supported, challenged and advised me during every phase of this dissertation and, in fact, before I even started as a Ph.D. student. I greatly benefited from his expertise and his efforts in promoting my work not just methodologically but in every part of the process.

Special thanks go to Prof. Dr. Jacquelynne S. Eccles for the opportunity to spend a very interesting research stay in Irvine and for all her advice, encouragement, and support before, during, and after this stay.

I would like to thank Prof. Dr. Steffi Pohl for her interest, time and effort put into the lecture and critique of my thesis and her willingness to be part of my dissertation defense committee. Moreover, I am grateful to Prof. Dr. Felicitas Thiel and Dr. Franziska Cohen for – rather spontaneously – agreeing to be part of the dissertation defense committee.

The EASI Science project, which is the basis for two of the three studies, was only possible as a team effort. I am grateful that I have been able to work in a team with Prof. Dr. Yvonne Anders, Julia Barenthien, Prof. Dr. Ilonca Hardy, Prof. Dr. Miriam Leuchter, Prof. Dr. Mirjam Steffensky, Dr. Päivi Taskinen, Timo Tresp and Tobias Ziegler. Many other people helped in successfully conducting this project, including Maria Kleinert and Nadine Michels among other student assistants. I would also like to acknowledge that the EASI Science project was funded by the “Little Scientists’ House Foundation” together with the German Federal Ministry of Education and Research.

Furthermore, I would like to thank my colleagues over the last four years, namely Dr. Itala Ballaschk, Dr. Franziska Cohen, Hande Erdem, Prof. Dr. Axinja Hachfeld, Theresia Hummel, Csaba Kurucz, Elisabeth Resa, Mareike Trauernicht, Dr. Hannah Ulferts, Juliane Schünke, Nadine Wieduwilt and Katrin Wolf. The shared experiences made the last four years much more enjoyable than they would have been without you. Special thanks go Dr. Itala Ballaschk, Dr. Franziska Cohen, Prof. Dr. Axinja Hachfeld and Juliane Schünke for their continued interest and support during different stages of this dissertation. I am also grateful to Lena Keller for her attentive and critical reading of the final draft of my dissertation.

Finally, I would like to thank my family and friends for all their unconditional support and encouragement. Thank you for believing in me, for supporting me and for distracting me when I needed it.

CONTENT

SUMMARY

Mathematics and science education are becoming increasingly relevant as a consequence of the scientific and technological advances in our society. Math and science competencies are now required for a multitude of professional careers and there is a growing demand for qualified professionals in fields associated with math and science. Attention has therefore grown around the importance of promoting children's motivation to pursue math and science throughout their school education. Yet, children start to engage in math- and science-related activities long before they enter school and consequently develop first motivational beliefs about these subjects early on (Andre, Whigham, Hendrickson, & Chambers, 1999; Fisher, Dobbs-Oates, Doctoroff, & Arnold, 2012; Mantzicopoulos, Patrick, & Samarapungavan, 2008; Saçkes, 2013). Moreover, early motivational beliefs have been found to predict children's future choices and achievement (Eccles, 1999; Leibham, Alexander, & Johnson, 2013). Research and practice have therefore recognized the importance of fostering children's motivation in math and science early on, namely in their preschool years (ages 5-6). However, research has so far failed to provide a thorough understanding of preschool children's motivational beliefs in these subjects and how they can be fostered in preschool. In this regard, preschool teachers are assumed to play an important role. Yet, little is known about teachers' practices and how their practices may be affected by preschool teachers' own motivational beliefs in math and science. In general, the relevance of preschool teachers' motivation in respect to other aspects of their competencies and practices in mathematics and science is not well understood. To fill this gap, the present dissertation examines the role of motivation in early mathematics and science education at the child- and teacher-level in three empirical studies.

Study 1 focused on the child-level and examined the structure, level and individual differences in preschool children's science motivation using a new measure. Results from

confirmatory factor analyses supported the differentiation of children's motivational beliefs into their self-efficacy beliefs and enjoyment in science in line with Eccles et al.'s (1983) expectancy-value-model. On average, children were highly motivated in science. Importantly, older children as well as children with more science experience showed higher motivational beliefs.

Study 2 used the measure of children's science motivation in order to explore the relation to teachers' own self-efficacy beliefs in science and to teachers' science practices. Since over 90% of preschool teachers are female, gendered patterns were also tested. Results showed that teachers' science self-efficacy beliefs were positively related to the frequency of their science practices in preschool. Results further showed that teachers' self-efficacy beliefs were also associated with children's self-efficacy beliefs in science. No relation was found for teachers' practices. Additional analyses revealed, however, that these relations were comprised of gendered patterns: Teachers' science self-efficacy beliefs were more strongly related to girls' motivation, whereas the frequency of teachers' science practices was more strongly related to boys' motivation in science.

Study 3 focused on teachers' self-efficacy beliefs and their professional knowledge in the mathematics domain. Since learning in German preschools is typically play-based and integrated into children's everyday activities, preschool teachers' sensitivity to mathematical elements in children's play is considered an important prerequisite for children's learning gains. Study 3 investigated how teachers' sensitivity related to their professional knowledge and self-efficacy beliefs in mathematics. Results revealed that teachers' mathematical content knowledge (CK) was associated with their sensitivity. However, when teachers' mathematical self-efficacy beliefs were taken into account, only an indirect relation, via teachers' self-efficacy beliefs, remained: The higher teachers' mathematical CK, the more confident they were in mathematics, and the more likely they were to recognize mathematical elements in children's play.

Taken together, the results reveal that (1) basic assumptions underlying the expectancy-value-model (Eccles et al., 1983) can be applied to children ages 5-6 and that (2) individual differences in children's motivation exist at the preschool level. Results further show that (3) teachers' self-efficacy beliefs are related to their practices and children's motivation and that (4) some of these relations are moderated by children's gender. Based on these findings, implications for research and practice are discussed.

ZUSAMMENFASSUNG

Die Bedeutung mathematischer und naturwissenschaftlicher Bildung ist im Zuge des wissenschaftlichen und technologischen Fortschritts in unserer Gesellschaft stark gestiegen. Grundlegende mathematische und naturwissenschaftliche Kompetenzen sind nun für eine Vielzahl an Berufswegen erforderlich. Zudem steigt der Bedarf an Fachkräften im mathematischen und naturwissenschaftlichen Bereich. Vor diesem Hintergrund soll die Lernmotivation der Schülerinnen und Schüler, welche entscheidend für die spätere Berufs- und Studienwahl ist (Eccles, 1999; Simpkins, Davis-Kean, & Eccles, 2006), in Mathematik und Naturwissenschaften vermehrt gefördert werden. Lernen im mathematischen und naturwissenschaftlichen Bereich beginnt allerdings lange vor der Einschulung. Bereits Kinder im Vorschulalter (5-6-Jährige) beschäftigen sich spielerisch mit mathematischen und naturwissenschaftlichen Inhalten und entwickeln dabei erste motivationale Überzeugungen bezüglich der Mathematik und den Naturwissenschaften sowie sich selbst als Lernende dieser Inhaltsbereiche (Andre et al., 1999; Fisher et al., 2012; Mantzicopoulos et al., 2008; Saçkes, 2013). Diese frühen motivationalen Überzeugungen sind wiederum ausschlaggebend für die weitere Beschäftigung mit dem entsprechenden Inhaltsbereich sowie für die spätere Kompetenzentwicklung in der Schule (Eccles, 1999; Leibham et al., 2013). Bisher ist jedoch wenig über die mathematische und naturwissenschaftliche Lernmotivation von Vorschulkindern bekannt. So fehlt es an empirischen Untersuchungen zur Struktur, Ausprägung und den Einflussfaktoren von motivationalen Überzeugungen bei Kindern im Vorschulalter. Zudem bleibt unklar, welchen Einfluss pädagogische Fachkräfte auf die mathematische und naturwissenschaftliche Lernmotivation von Kindern haben. Hierbei ist insbesondere die Rolle der motivationalen Orientierungen bei pädagogische Fachkräften für die Gestaltung mathematischer und naturwissenschaftlicher Lerngelegenheiten und die kindliche Motivation kaum erforscht. Vor diesem Hintergrund beschäftigte sich die vorliegende Arbeit

in drei empirischen Studien mit den motivationalen Überzeugungen von pädagogischen Fachkräften und Kindern in den Fächern Mathematik und Naturwissenschaften.

Die erste Studie untersuchte die Struktur und Ausprägung der Lernmotivation bei Kindern im Alter von 5-6 Jahren, sowie Gruppenunterschiede nach Alter, Geschlecht und Umfang der Erfahrung mit Naturwissenschaften anhand eines neu entwickelten Instrumentes. Die Ergebnisse konfirmatorischer Faktorenanalyse zeigten, dass sich die kindliche Lernmotivation in Selbstwirksamkeitserwartung und Lernfreude differenzieren ließ und somit die Annahmen des Erwartung-Wert-Modells von Eccles et al. (1983) bestätigen. Kinder zeigten im Mittel sehr optimistische Selbstwirksamkeitserwartungen und eine hohe Lernfreude in den Naturwissenschaften. Ältere Kinder, sowie Kinder mit mehr Erfahrungen in den Naturwissenschaften zeigten eine höhere Lernmotivation. Geschlechterunterschiede konnten nicht festgestellt werden.

Die zweite Studie nutzte das Instrument aus Studie 1 und untersuchte, inwieweit die Lernmotivation der Kinder mit der Selbstwirksamkeitserwartung der betreuenden Fachkräfte sowie der Häufigkeit der von Fachkräften initiierten naturwissenschaftlichen Aktivitäten zusammenhing. Da über 90% der Fachkräfte weiblich sind, wurden zudem geschlechterspezifische Zusammenhangsmuster getestet. Die Ergebnisse zeigten, dass Fachkräfte mit einer höheren naturwissenschaftlichen Selbstwirksamkeitserwartung häufiger naturwissenschaftliche Aktivitäten anboten. Mit Blick auf die Motivation der Kinder ließ sich ein Zusammenhang zu der Selbstwirksamkeitserwartung der Fachkräfte feststellen, nicht aber zu der Häufigkeit der Aktivitäten. Ergebnisse weiterer Analysen zeigten jedoch ein geschlechterspezifisches Zusammenhangsmuster: Der Zusammenhang zwischen der Selbstwirksamkeitserwartung der Fachkräfte und der kindlichen Motivation fiel für Mädchen stärker aus, während der Zusammenhang zwischen der Anzahl naturwissenschaftlicher Aktivitäten und der kindlichen Motivation bei Jungen stärker war.

Studie 3 fokussierte auf die Motivation sowie das professionelle Wissen pädagogischer Fachkräfte im Bereich früher mathematischer Bildung. Da Lernen in deutschen Kitas häufig Kind-zentriert und spielbasiert stattfindet, müssen Fachkräfte in der Lage sein, frühe mathematische Bildung in das kindliche Spiel zu integrieren. Hier spielt das Erkennen mathematischer Inhalte im kindlichen Spiel, als Ausgangspunkt für potentielle Lerngelegenheiten, eine wichtige Rolle. Aufgrund dessen untersuchte die dritte Studie, welche Kompetenzen das Erkennen mathematischer Elemente im Spiel begünstigen. Die Ergebnisse zeigten, dass das mathematische Fachwissen mit der Sensitivität der Fachkräfte für mathematische Elemente in kindlichen Spielsituationen zusammenhing. Der Zusammenhang verschwand allerdings, wenn die mathematische Selbstwirksamkeitserwartung berücksichtigt wurde: Je höher das Fachwissen im Bereich der Mathematik, desto höher die mathematischen Selbstwirksamkeitserwartungen und desto eher erkannten Fachkräfte mathematische Inhalte im kindlichen Spiel.

Insgesamt lassen sich aus den Ergebnissen wichtige Erkenntnisse (1) über die Struktur der kindlichen Lernmotivation in den Naturwissenschaften sowie (2) über Gruppenunterschiede in der Motivation ziehen. Die Ergebnisse verdeutlichen ferner (3) die Bedeutsamkeit der Selbstwirksamkeitserwartung von Fachkräften für das Erkennen und die Gestaltung mathematischer und naturwissenschaftlicher Lerngelegenheiten und zeigen, dass (4) bereits im Vorschulalter geschlechterspezifische Zusammenhangsmuster existieren. Implikationen für die Forschung sowie die pädagogische Praxis werden diskutiert.

GENERAL THEORETICAL BACKGROUND

1. Introduction

In recent years, attention has grown around the importance of early math and science education in Germany (KMK, 2009; B. Thomas & Watters, 2015). Math and science were implemented in the national guidelines for early childhood[1] education and care (ECEC) (JMK & KMK, 2004) and an increasing amount of early math and science programs has been established. The aim of these initiatives is to foster early math and science learning in preschool[2] in order to promote children's competencies as well as their motivation in these subjects. Motivation refers to individual's self-confidence and enjoyment in a subject and has been shown to predict individual's effort, persistence, and performance (Wang & Degol, 2013; Wigfield, 1994). In fact, motivational beliefs are often better predictors of children's future engagement and effort in a subject than their achievement (Eccles, Wigfield, Harold, & Blumenfeld, 1993; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005). Domain-specific motivational beliefs of young children[3] are thus considered to be important precursors of their future engagement in these domains as well as their achievement and achievement-related choices. Specifically, it is assumed that when young children are confident in math and science and enjoy engaging in these subjects, they are more likely to pursue math and science in the future and persist when facing obstacles. Despite the importance of these early motivational

[1] *Early childhood* refers to a stage in human development from birth to the age of 8 years.

[2] In Germany, the term *preschool* describes early childhood institutions for children ages 3-6 years. However, because this dissertation focuses mainly on children ages 5-6, the term *preschool children* will be used to refer to children ages 5-6 who attend preschool. Since over 95% of children aged 3-6 attend preschool (Autorengruppe Bildungsberichterstattung, 2016), this includes nearly all children of this age group in Germany. *Preschool teachers* consequently refers to the pedagogical staff in preschool.

[3] In this dissertation, the term *young children* will be used to describe children ages 5-6. Because this dissertation focuses entirely on the preschool environment and nearly all children that age attend preschool, the terms *preschool children/preschooler* and *young children* will be used interchangeably.

beliefs, we currently know very little about young children's motivational beliefs in math and science and how they can be promoted. Preschool teachers are assumed to play an important role in children's learning and development, but teachers' influences on children's motivation have not been examined. In this regard, further research is required to investigate which competencies preschool teachers need in order to provide the best possible environments to foster children's motivation in math and science. The present dissertation tackles these questions based on three empirical studies. The first study focuses on the child-level and investigates the motivational beliefs of preschoolers, ages 5-6, in science, using a new measure. Study 2 builds on these insights and explores how teachers' own motivational beliefs, as well as their practices, are related to children's motivation. The third study focuses on the teacher level and further examines different aspects of preschool teachers' competencies as prerequisites of their ability to offer early learning opportunities.

This dissertation is structured in the following way: The theoretical background presents the relevant research literature for the three empirical studies and aims at situating these studies within their broader research context. The theoretical background starts with chapter 2, which gives a short overview of the societal and economic relevance of math and science education more generally, as well as the importance of motivation in math and science for children's educational pathways. Chapter 3 discusses the development of children's competencies and their motivation in preschool and thus highlights the importance of early learning experiences for the development of their motivational beliefs. Children's early learning experiences in German preschools are described in more detail in chapter 4, which gives a comprehensive overview of the German ECEC system as well as typical math and science learning arrangements in preschool. Chapter 5 introduces prevalent theoretical models and empirical findings on motivation and discusses the applicability of these insights to the preschool level and, more specifically, to preschoolers in Germany. Moreover, existing findings on young children's motivational beliefs and math and science are reviewed. After the theoretical assumptions and empirical findings in young children's motivation have been discussed, chapter 6 describes the mechanisms through which preschool teachers can influence and shape children's motivation. These include the quality and frequency of teachers' math and science practices as well as more subtle processes, such as teachers' feedback and encouragement as well as their exemplary behavior. Chapter 7 consequentially focuses on the teacher level and introduces the existing research literature on preschool teachers' math and science competencies and their relevance for teachers' behavior. Finally, the objectives of the three empirical studies are described in chapter 8.

The theoretical background is followed by a short summary of the research insights gained by the three empirical studies. The manuscripts for the three studies can be found in the Appendices I-III)

The general discussion summarizes the findings obtained by the three studies and integrates these into the theoretical background. Specifically, major contributions of the three studies are described. These include insights on the development of motivation throughout childhood as well as determinants of children's motivation, gender differences in children's motivation and findings on the relevance of preschool teachers' competencies. Finally, limitations and directions for further research as well as implications for educational policy and practice are discussed.

2. Math and science education

The importance of mathematics and science, as two central areas of STEM fields (science, technology, engineering, and mathematics), has increased considerably over the last decades as a consequence of the scientific and technological advances (Breiner, Harkness, Johnson, & Koehler, 2012; Laugksch, 2000). In light of this development, scientists and policymakers have emphasized the vital importance of STEM literacy for the individual as well as the society as a whole (Zollman, 2012). There is now a general consensus that each individual in western societies should be “STEM literate” (Zollman, 2012). STEM literacy refers to “the ability to identify, apply, and integrate concepts from science, technology, engineering, and mathematics to understand complex problems and to innovate to solve them” (Balka, 2011, p. 7) and is thus is a synergy of science, technology, engineering and mathematics literacy. Literacy in STEM subjects, such as math and science, is thus seen as a multifaceted construct that includes cognitive aspects, e.g. knowledge and reasoning, as well as non-cognitive aspects, e.g. beliefs and motivation (Bybee, McCrae, & Laurie, 2009; OECD, 2006). Together, they enable individuals to achieve their goals, participate fully in the society and develop and broaden their knowledge (UNESCO, 2008). STEM literacy among the general public also benefits society as a whole because it enhances the human capital by enriching the cultural and intellectual health, promoting democratic practices as well as technological innovations (G. Thomas & Durant, 1987). Moreover, it is beneficial to science itself by achieving greater support among the general public (Laugksch, 2000).

In addition to the aim to educate the general public, the demand for scientists, engineers, and technically trained personnel grows at a relatively rapid rate (Laugksch, 2000). In order to maintain its global competitiveness, more qualified STEM professionals are required in Germany but also in most other western countries (BMBF, 2012). In fact, governments have raised concerns regarding a lack of qualified personnel in STEM (KMK, 2009; National Science Board, 2007; Osborne & Dillon, 2008; Plünnecke & Klös, 2009).

Unfortunately, educational statistics report that STEM subjects are unpopular in school as well as later in postsecondary education (Osborne & Dillon, 2008; Osborne, Simon, & Collins, 2003; Robinson, 2003). For instance, in Germany and the U.S., STEM subjects are failing to attract enough students to ensure an adequate supply of professionals required in our technology- and science-based societies (Anger, Geis, & Plünnecke, 2012; Bundesagentur für Arbeit, 2011; Osborne & Dillon, 2008). This “drop out” of students has been described as the “leaky pipeline towards STEM“ by Watt and Eccles (2008). This trend is not only detrimental for ensuring our future generation of scientists, technologists and engineers; but student's tendency to drop out of STEM early on is also worrying with regard to the mission to educate the general public. The unpopularity of STEM is particularly striking among to female students.

2.1. Gender and STEM

Women are still underrepresented in study fields and careers associated with STEM (Lörz & Schindler, 2011; National Science Foundation, 2011; OECD, 2016). According to the most recent OECD report, German men are 4 times more likely to choose a tertiary education in engineering than women (OECD, 2016). With regard to science, the discrepancy still amounts to 1.6 times the likelihood for men compared to women – despite the fact that women are now overrepresented in tertiary education in general (OECD, 2016). Across Europe only 31% of all STEM graduates are female (Directorate General Education and Culture, 2005). A similar pattern has been reported for other western countries, such as the U.S. (National Academy of Sciences, 2006), Austria, Switzerland (OECD, 2016). Despite efforts of educational policy to increase the number of women in STEM fields nationally and internationally over the last decades, women in STEM remain a minority. Since student's career choices typically develop in the course of their school years (Maltese & Tai, 2011), precursors of these trajectories can be found in school. Boys are more likely than girls to enroll in math courses during middle and high school (Simpkins et al., 2006). Similarly, in Germany, more boys than girls choose math, chemistry, and physics majors in school (acatech & Körber-Stiftung, 2014). In addition, there are differences in boys' and girls' participation in optional sciences learning opportunities: Middle school male students participate more in STEM-related extracurricular activities than female students (acatech & Körber-Stiftung, 2014; Jones, Howe, & Rua, 2000). Thus, gender[4] plays a central role in students' choices throughout school.

[4] In this dissertation *gender* refers to the social-cultural category, which must be distinguished from the purely biological category *sex* (see Sauer, 2016). This distinction implies

2.2. Student's choices throughout their educational pathway

One of the most comprehensive frameworks to explain student's STEM choices in general, as well as gender differences in particular, is the expectancy-value theory of achievement motivation by Eccles et al. (1983). The expectancy-value model conceptualizes students' STEM pathway as a series of choices that commence in childhood and adolescence (Wang & Degol, 2013). These choices can be explained by a persons' expectancy and value beliefs (Eccles et al., 1993). Expectancy beliefs relate to individuals' perception of their own ability to succeed in a task (*"Can I do this task?"*), whereas task value describes the personal value attributed to the choice, such as the personal importance or interest (*"Why should I do this task?"*) (Eccles et al., 1983).

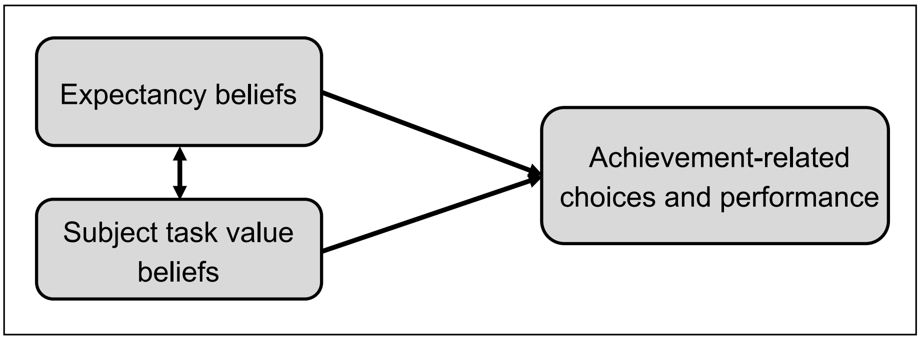

Figure 1. Simplified version of the expectancy-value theory of achievement-related choices (see Eccles & Wigfield, 2002)

In line with the assumptions underlying the expectancy-value model by Eccles et al. (1983), domain-specific expectancy and value beliefs have been shown to be important predictors of achievement and achievement-related choices throughout primary and secondary school (Wang & Degol, 2013; Wigfield, Tonks, & Klauda, 2009). For example, Simpkins et al. (2006) found in their longitudinal study that students' expectancy and value beliefs predicted their future math and science course choices in high school, controlling for their math and

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that gender-specific cognition and behavior is not biologically determined, but socially constructed and thus malleable.

science achievement. Similarly, a study by Maltese and Tai (2011) showed that the majority of students who concentrated on STEM made their choice largely based on their interest in math and science rather than their achievement.

The same framework can be applied to explain gender differences in math and science-related educational choices. In line with the gender differences in student's choices, research repeatedly finds severe differences in boys' and girls' expectancy beliefs and values, with boys rating their ability in mathematics and science higher than girls, controlling for their actual abilities (Eccles et al., 1993; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Jones et al., 2000; Marsh et al., 2005; Nagy et al., 2010). Moreover, boys attach more personal value to doing well in math and science (Andre et al., 1999; Steinmayr & Spinath, 2008) and they report higher interest in math and science (Eccles et al., 1993; Steinmayr & Spinath, 2008). Results from a longitudinal study also show that girls' interest in STEM careers decreased during their high school years whereas boys' STEM interest remained stable (Sadler, Sonnert, Hazari, & Tai, 2012).

Thus, motivational constructs, more specifically students' expectancy and value beliefs in math and science, can explain a substantial amount of students' choices to pursue STEM as well as gender differences in these choices throughout school. In order to understand the patterns in students' beliefs, however, it is important to know when and how motivational beliefs in STEM develop. According to the expectancy-value model, domain-specific expectancy and value beliefs are shaped by children's previous experiences, e.g. their experiences with math and science learning and their interpretation of these experiences (Eccles, 1994; Eccles & Wigfield, 2002). The development of expectancy and value beliefs in STEM subjects, such as math and science, thus begins when children first engage in them, namely in early childhood.

3. Child development and early math and science learning

Learning in STEM, and predominantly in math and science, starts long before children enter school. Young children engage in math and science in a playful way in their everyday life and also more formally through early math and science education in preschool. These early experiences shape the way children see math and science and themselves as math and science learners. In fact, evidence from neurobiological brain research has documented impressively that most of the brain development occurs in the very first years of life and that these early experiences have lifelong consequences (Winter, 2010). Children's learning and development can thus be influenced most effectively early on, which has lead economists to argue that investing in early education will have long-term monetary and non-monetary benefits (Heckman, 2006; Knudsen, Heckman, Cameron, & Shonkoff, 2006). In line with this argument, longitudinal studies have documented the positive effects of early learning for children's future competencies in primary school and beyond (Anders, 2013; Anders, Grosse, Rossbach, Ebert, & Weinert, 2012; NICHD ECCRN, 2005; Sammons et al., 2008). Similar mechanisms are assumed for the development of children's motivation. Specifically, it is assumed that when children's first experiences with math and science are enjoyable, they will develop more positive motivational beliefs about these subjects. Thus, it is important to understand what kind of experiences children gather with math and science before they enter school and how children's motivation in math and science is shaped as a consequence of these experiences. Young children engage in math and science in their everyday lives at home, during potential leisure activities, and in preschool. Although the home learning environment and children's leisure activities are certainly important for the development of their motivation, the present dissertation focuses on children's experiences in preschool. As this dissertation is situated in Germany, the following chapter will outline the characteristics of early math and science education in German preschools and thus provide an overview of the math and science experiences that children draw on when developing their motivational beliefs in these subjects.

4. Early math and science education in Germany

In light of the accumulating evidence on the importance of early learning experiences, Germany has witnessed an increasing emphasis on early math and science education in educational policy and practice (KMK, 2009; B. Thomas & Watters, 2015). This development is reflected in several aspects including (1) the ECEC curriculums, (2) teachers' education and training in math and science, as well as (3) math and science initiatives and programs.

(1) "Math, science and technology" as well as "nature and cultural environments" were defined as two out of six learning areas in the national framework for early childhood education, which was established in 2004 by the Conference of the Ministers of Education and Cultural Affairs (Jugend- und Kultusministerkonferenz (JMK & KMK), 2004). This more general national framework is meant to be further specified in the state curriculums. The German federal states (Bundesländer) have since developed their own ECEC curriculums based on this recommendation, leading to different specifications of math and science education in each state (Anders, 2014). For instance, the Thuringian curriculum clearly defines math and science as central learning areas and it even provides sample learning activities, whereas in Baden-Wuerttemberg math and science are not defined as educational areas at all. Across the federal states, the ECEC curriculums are generally rather unspecific as they mention educational areas but do not define how these areas should be implemented (Leuchter & Möller, 2014) and which competencies, in particular, children should acquire in preschool (Anders, 2014).

(2) In addition to the curricular recommendations, the German KMK has recently published a revised version of nation-wide guidelines for teacher education, including a statement that preschool teachers should be adequately prepared for their task to trigger children's curiosity in math, science and technology early on (KMK, 2017). However, these

recommendations are not mandatory and preschool teacher education in Germany remains very diverse: There are different pathways to become a preschool teacher, including vocational training, training at technical colleges and different study fields at university, and these pathways also differ between the German federal states (Autorengruppe Fachkräftebarometer, 2017). Moreover, math and science do not play a central role in many of the state curriculums for teacher education (e.g. LISUM Berlin-Brandenburg, 2014; Ministerium für Bildung, Wissenschaft und Kultur Mecklenburg-Vorpommern, 2009; Niedersächsisches Kultusministerium, 2016) and no national standards for teacher education in math and science exist.

(3) Besides the changes implemented by educational policy, Germany has witnessed an immense increase in initiatives and projects that offer more practical examples and support for the implementation of math and science education in preschool[5] (Pfenning, Hiller, & Renn, 2012). In this regard, it is important to distinguish between short-term projects and more long-term oriented initiatives. Short-term projects are, for example, one-day courses or excursions for preschool children, that simply aim at triggering curiosity for future engagement. Long-term initiatives aim at implementing math and science education in preschool in a more enduring way by offering professional development and additional support for preschool teachers. For instance, the “Little Scientists’ House” foundation offers professional development courses for preschool teachers in math and science as well as additional materials and ideas for implementing math and science education. Other successful examples include “Leuchtpol” and “TransKIGs”. There is a large variety of initiatives, but no external quality assurance or monitoring system is in place to ensure the quality of these initiatives.

In summary, despite the increasing attention on early math and science education in Germany, the implementation of these learning areas in preschool is hardly regulated by

[5] Some of these projects are also financially supported by educational policy. However, the funding of these initiatives is not assumed to be relevant for children’s learning experiences.

educational policy. There are few curricular guidelines, which vary between federal states. Moreover, no standards for teacher education exist with regard to math and science. As a response, early math and science programs, which provide much-needed support for preschool teachers, are becoming increasingly popular. However, there is a large variety of programs to choose from and the different programs are typically not evaluated. As a consequence of these characteristics, early math and science education in German preschools is very inconsistent, as it is largely dependent on the federal state, the preschool centers' educational focus and the teachers' educational background and interest in a math or science programs. This also affects children's learning experiences and the development of their competencies: Because there are no mandatory standards, math and science learning situations may differ tremendously between preschool centers and even classrooms, leading to diverse learning experiences among the children. Thus, German preschool children cannot be expected to have a certain amount of early math and science learning experiences by a certain age.

In addition to the characteristics describe above, which affect "what" and how often children learn in math and science, the instructional approach inherent in most German preschools affects the nature children's learning experiences with these subjects. ECEC in Germany follows a social-pedagogical tradition in that child-centered and play-based learning is emphasized (Anders, 2014; OECD, 2011). Learning in German preschools is typically informal and based on children's daily experiences and interests. Thus, learning situations are rarely planned but instead evolve spontaneously from children's questions or teachers' initiatives (Anders, 2014). Moreover, children's implicit and self-guided learning in free play situations is emphasized. As a consequence, children's math and science learning experiences in German preschools are likely to be very informal and partially based on unguided free play. In fact, children are unlikely to be familiar with math and science as subjects, but they may rather draw on their play-based everyday math and science experiences.

Taken together, German preschool children's experience will vary between preschools and even classrooms in terms of the frequency and content of math and science education. Moreover, their experiences are likely to be rather informal and based on the everyday math and science content they encounter during play. In both respects, children's learning experiences differ considerably from the experiences of older children in school or children in other countries with different curricular and pedagogical approaches, such as the U.S. (OECD, 2011). For instance, the U.S. states clearly define learning areas as well as learning goals in math and science and learning situations are typically more structured and teacher-oriented (OECD, 2011). Thus, children in U.S. preschools are likely to have more regulated and structured math and science learning experiences. Since the development of children's motivational beliefs is largely grounded in their experiences, these characteristics are important to take into account when reviewing the international research literature from countries like the U.S. and Germany. The following chapter will introduce the theoretical and empirical research literature on achievement motivation more generally and subsequently discuss the applicability of these theories to young children in Germany.

5. Young children's math and science motivation

Achievement motivation energizes and directs learning-related behavior and is therefore a key determinant of academic effort, academic choices, and academic success (Pintrich, 2003; Schiefele, 1991; Schunk, Pintrich, & Meece, 2008). As mentioned in chapter 2.2, the expectancy-value model by Eccles et al. (1983), is one of the most comprehensive and most widely studied frameworks for achievement motivation. The model assumes that task performance, persistence, and choice is most directly influenced by children's beliefs about their capabilities to succeed in a task and the value related to that task (see Figure 2). Expectancies and values themselves are assumed to be influenced by children's goals and self-schemata, which are in turn influenced by children's perceptions of their environment.

Children's perceptions and of their environment are influenced by a broad array of social and cultural factors, such as the cultural milieu in which they live and their socializers' (parents', teachers', and peers') beliefs and behaviors. In addition, the model includes a feedback-loop through which achievement-related experiences and children's interpretation of these experiences feed back into children's affective memories and lastly their expectancy and value beliefs regarding future tasks. This thesis focuses mainly on the right part of the model, i.e. the expectancy and value components. So far, these components have only been investigated with regard to older children and adolescents, but not among young children. Therefore, it remains unclear whether fundamental assumptions underlying expectancy and value beliefs can be applied to young children. The following chapter will describe the theoretical assumptions of the expectancy-value model in greater detail and subsequently discuss their applicability to the preschool level and more specifically to preschool children in Germany. Then, existing research on young children's motivation in math and science is presented and discussed.

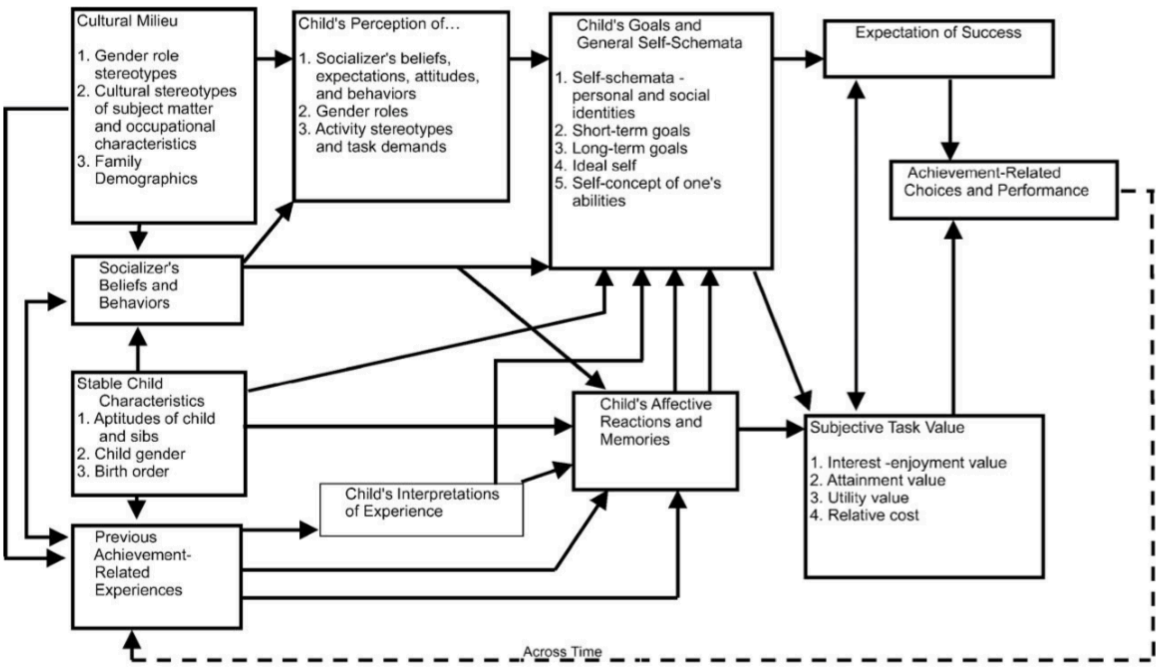

Figure 2. Expectancy-value theory of achievement-related choices (from Eccles & Wigfield, 2002)

5.1. Assumptions underlying the expectancy-value model

As can be seen in figure 2, the right part of the expectancy-value model comprises several assumptions that may not be applicable to young children. These include (1) the differentiation within expectancy and value beliefs, (2) the assumptions that expectancy and value beliefs are positively related, as well as (3) the assumption that both beliefs are subject-specific.

5.1.1. Differentiation within expectancy and value beliefs

The expectancy-value model distinguishes not only between expectancy and value beliefs but also between different components of these beliefs. Since the model integrates other theories on achievement motivation, many of these components conceptually overlap with constructs from other theories, which are labeled differently, but measure similar aspects of motivation. When reviewing and discussing existing studies on achievement motivation, it is therefore important to understand how these constructs are related and what exactly they refer to. The following chapter will therefore define expectancy and value beliefs, and discuss their relation to conceptually similar theories in the research literature. After these different theoretical strands are clarified, the empirical research literature on these concepts will be introduced and discussed with regard to the generalizability of these theoretical assumptions to young children.

Expectancy beliefs. In the expectancy-value model, expectancy beliefs are explicitly distinguished from more general ability beliefs. Expectancy beliefs are defined as individuals' beliefs about how well they will do in a task in the immediate or long-term future (Eccles & Wigfield, 2002) and are thus conceptually related to Bandura's (1977a, 1989) self-efficacy beliefs: Both constructs capture individual's beliefs about how well they will perform on a task (Eccles & Wigfield, 2002) and are typically measured in a similar way (Wigfield & Cambria, 2010). Consequently, the terms expectancy and self-efficacy beliefs will be used interchangeably in this dissertation. These more task-specific beliefs are distinguished from general ability beliefs, which are also referred to as self-concept by other authors (Marsh, 1990; Marsh & Shavelson, 1985; Shavelson, Hubner, & Stanton, 1976). The difference between outcome expectancy beliefs (or self-efficacy beliefs) and more general ability beliefs (or self-concept) is not well defined in the expectancy-value model, but has been discussed in detail by Bong and Skaalvik (2003). They identify 10 comparison dimension on which these constructs differ. For example, academic self-concept relates to individual's more general confidence in a domain, it is past-oriented and stable whereas self-efficacy beliefs are context- and task-specific, future-oriented and malleable (Bong & Skaalvik, 2003). These conceptual differences also manifest themselves in the way these constructs are assessed: Academic self-concept is typically measured with regard to a domain, e.g. *"Math is easy for me."* (Marsh, Craven, & Debus, 1991). In contrast, self-efficacy is typically measured in a more task- and context-specific way: *"If I show you a drawing of a shape, will you be able to tell if the shape is a triangle?"* (Tirosh, Tsamir, Levenson, Tabach, & Barkai, 2013). Although this distinction between individual's more general and task-specific ability beliefs has been supported theoretically as well as empirically for adolescents and adults (Bong & Skaalvik, 2003; Skaalvik & Skaalvik, 2006), it may not be applicable to young children. In fact, Bong and Skaalvik (2003) have argued that the differentiation between self-concept and self-efficacy beliefs evolves with age as children learn to distinguish between their more general ability perceptions in a given domain and their expectations to do well on a task in that domain. In line with this, empirical findings show that ability beliefs and expectancies for success are highly correlated among children in the early elementary school grades (Eccles et al., 1993), which is why research using the expectancy-value framework typically either collapsed these constructs or used them interchangeably for children (Eccles & Wigfield, 1995; Eccles et al., 1993). The indistinguishability between these beliefs is likely to be even stronger among even younger children. Consequently, the concepts of children's more general ability beliefs/self-concept, and their self-efficacy/expectancy beliefs will be used interchangeably with regard to young children in this dissertation.

Value beliefs. Value refers to qualities of different tasks and how those qualities influence the individual's desire to do the task, hence the term task value (Eccles et al., 1983; Eccles & Wigfield, 2002). Eccles and Wigfield (2002) distinguish between four aspects of value: attainment value, intrinsic value, utility value, and cost. Attainment value refers to the personal importance of doing well on the task. Intrinsic value refers to the enjoyment of engaging in a task and utility value describes the usefulness of a task, e.g. for future plans. Cost refers to what the individual has to give up to do a task as well as the effort that will be required to pursue the task (Eccles et al., 1983). All four aspects are assumed to jointly contribute to the total value of a task (Eccles et al., 1983; Eccles & Wigfield, 2002). Since Eccles and Wigfield (2002) integrated a number of existing theories into their model, the four value components are, in part, closely related to other motivation theories and have been studied in similar ways. For instance, intrinsic value and utility value overlap to some degree with intrinsic and extrinsic motivation in the self-determination theory (Deci & Ryan, 1985; Ryan & Deci, 2000). Specifically, when children pursue an activity because it is inherently interesting or enjoyable to them, they are intrinsically motivated (Ryan & Deci, 2000). The concept of intrinsic value is also somewhat related to interest as defined by Hidi and Renninger (2006) as well as Krapp (2002). Interest is conceptualized as a multifaceted construct that includes an emotional component, i.e. positive feelings or enjoyment associated with a topic, a value component, i.e. personal significance of the topic, and a cognitive component, i.e. knowledge about a topic (Krapp, 2005; Renninger, Ewen, & Lasher, 2002). Intrinsic value as defined in the expectancy-value theory is somewhat related to the emotional component of interest (Wigfield & Cambria, 2010). These aspects are also measured a similar way: *"How much do you like doing math?"* (see Eccles et al., 1993); "*Being involved with the subject matter of my major affects my mood positively*" (see Schiefele, 2009). Thus, despite the differences in the roots and labels of different motivation theories, there are some overlaps between the value components as defined in the expectancy-value model (Eccles & Wigfield, 2002), intrinsic and extrinsic motivation in the self-determination theory (Deci & Ryan, 1985; Ryan & Deci, 2000) as well as the concept of interest (Krapp, 2005; Renninger & Hidi, 2011; Schiefele, 2009). The present dissertation therefore draws on all three theories when reviewing the research literature on young children's value beliefs.

But to what degree are the different value components empirically distinguishable and does that depend on children's age? A recent longitudinal study by Frenzel, Pekrun, Dicke, and Goetz (2012) documents structural shifts in student's mathematical interest. Specifically, they find that interest among younger students (5^{th} grade) was more strongly influenced by the emotional component, whereas among older students (9^{th} grade) the concept was more strongly influenced by the cognitively oriented. In line with this, Renninger and Hidi (2011) argue that as individuals grow older and interest develops and deepens, the knowledge and value components become more pronounced, whereas the early stages of interest are characterized by a strong emotional component (Renninger & Hidi, 2011). Thus, among young children, interest may actually be more closely related to intrinsic value as defined by Eccles and Wigfield (2002) than among older students. This is in line with developmental differences that were proposed by Wigfield (1994) and Wigfield and Eccles (1992), who suggest that the intrinsic value component may be especially salient among younger children, where it is most relevant for their activity choices. In fact, Eccles et al. (1983) found for the early elementary school years that among the four value components, intrinsic value was most strongly related to children's expectancy beliefs. Thus, children's intrinsic value, i.e. their enjoyment of a task, may also be most relevant at the preschool level, since it seems unlikely that preschool children choose to engage in math and science activities because of the importance of these activities for their future goals, but rather because they simply enjoy engaging in them. Consequently, the present dissertation focuses on the intrinsic value component of children's motivation.

5.1.2. Relation between expectancy and value beliefs

The expectancy-value model for achievement-related choices makes not just assumptions about the structure of expectancy and value beliefs, but also about the relation between these beliefs (Eccles & Wigfield, 2002). Specifically, it assumes that expectancy and value beliefs are positively related (Eccles & Wigfield, 2002). With that, Eccles et al.'s (1983) model explicitly breaks from Atkinson's (1964) original expectancy-value theory, which assumed an inverse relation. The assumption of a positive relation has been empirically supported in numerous studies (Ferla, Valcke, & Cai, 2009; Goetz, Cronjaeger, Frenzel, Lüdtke, & Hall, 2010; Jacobs et al., 2002; Marsh et al., 2005). But can the same assumptions be applied to younger children? Eccles et al. (1993) found that among first graders within the domains of math, reading, music, and sports, children's expectancy beliefs and values formed clearly distinct factors, thus confirming the assumption that expectancy and value are distinct – at least for children in early primary school. Wigfield (1994) further argues that, initially, young children's expectancy and value beliefs are likely to be relatively unrelated, but as they grow older and more experienced, they may begin to attach more value to domains in which they feel competent. This rationale has also been empirically supported in a study by Denissen, Zarrett, and Eccles (2007), who showed that the relation between expectancy beliefs and value increased with age among a sample of 6- to 17-year-olds. Several reasons for this increasing relation have been proposed. Wigfield (1994) argues that through processes related to classical conditioning, children will associate the positive affect that occurs when one succeeds in a task with that task, leading to higher value beliefs. Moreover, children may attach less value to activities in which they do not do well as a way to maintain a positive global sense of self-esteem (Eccles, Wigfield, & Schiefele, 1998; Harter, 1990). Similarly, Schiefele (2009) notes that children are likely to become more interested in domains in which they have a higher self-concept of ability than others. The rationale that children learn to value what they are good at, as an explanation for the increasing association between expectancy and value beliefs, has also been empirically supported in a study by Jacobs et al. (2002), who followed students from first through 12th grade and found that competency beliefs accounted for much of the age-related changes in value beliefs. Thus, there seems to be a consensus that children's expectancy and value beliefs are positively related and that this relationship becomes more pronounced as they grow older. Nevertheless, the current body of knowledge is limited to school-aged children and, so far, little is known about these relations among even younger children. Children as young as 5 to 6 years old have just begun to develop expectancy and value beliefs in different content areas, such as math and science, and these assumptions mentioned above may therefore not apply to children this young. Specifically, it may be that young children have so little experience with math and science that they have not yet developed distinct expectancy and value beliefs in these subject areas. Thus children's motivation at that stage may represent rather undefined motivational tendencies and the two components of children's motivation may be indistinguishable. Alternatively, in line with Wigfield's (1994) prediction, children may have distinct expectancy and value beliefs, but they may not yet care about their (perceived) ability and thus not adjust their value beliefs accordingly. In this case, expectancy and value beliefs would be even less strongly related among young children. Mantzicopoulos et al. (2008) investigated the motivational beliefs of kindergarten-aged children in science. They found that children's science motivation could be distinguished into science self-confidence and science liking and that the two components were moderately to strongly correlated (r = .47). Although insightful, the findings from Mantzicopoulos et al. (2008) were limited to a selected sample of children who participated in an extensive science program and thus had more and also more formal experiences with science than the average preschooler – particularly compared to German preschool children. Since the developmental changes proposed by Wigfield (1994) occur as a consequence of accumulated experience, the findings from the Mantzicopoulos et al. (2008) study may not be generalizable to preschoolers with less experience. Hence, further research is required to investigate the structure of children’s motivation among a more heterogeneous sample of young children.

5.1.3. Subject specificity

Expectancy and value beliefs are conceptualized as content- or task-specific beliefs (Wigfield et al., 1997). In line with this, research on older students has demonstrated that expectancy and value beliefs are highly domain-specific; that is, beliefs in different subjects show relatively low correlations (Bong, 2001). But are these results transferable to young children? With regard to children’s ability beliefs, Marsh et al. (1991) found distinct ability self-concepts in different domains for the 5-year-olds in their sample. Children’s self-concept became more differentiated from age 5 to 8, as indicated by lower latent correlations among the factors (Marsh et al., 1991). Thus, existing research indicates that young children’s ability beliefs are distinguishable between subjects, but grow more specific with age. In line with this, Harter (1990) discussed that children first have broad understandings of their general ability, i.e. being “smart” or “dumb”, and later develop a more specific sense of their competence in different activities. However, these findings are based on a sample of young children in preschools where clearly defined subject areas exist, and it remains unclear how specific children’s ability beliefs are when they have less experience with subject-specific instruction. Further research is therefore required to investigate the domain-specificity of children’s motivation among a sample of preschoolers with less structured learning experiences, such as the young children in Germany.

With regard to children’s intrinsic value/interest, Todt (1990) as well as Eccles et al. (1998) argued in their review of the literature that children have general or universal interests at first, which become more specific relatively quickly. The increasing differentiation of interest with time was documented in a recent longitudinal study Epstein and Eccles (2014), who showed that students’ interests in different subjects gradually become more specialized as they progress through school. However, even among first graders, Eccles et al. (1993) found distinguished value beliefs between the subjects of math, reading, music, and sports. Yet, these results may not be transferable to even younger children, particularly to those with very little formal math and science experience. Moreover, little is known about the development of children's motivational beliefs within subjects. For instance, one common classification within the science domain is the distinction between physical science and life science. This distinction is also inherent in the different school subjects (biology, chemistry, physics) and study fields. However, is has not been studied when children start to think in these categories. Thus, further research is required to determine how specific children's motivational beliefs are at the preschool level.

5.2. Existing findings on children's motivation in math and science

The previous chapter has looked at the development of children's motivational beliefs and fundamental assumptions underlying these concepts. Now that the applicability of these fundamental assumptions to young children is established, the few research findings that exist on young children's math and science motivation will be introduced and discussed.

With regard to mathematics, a recent study by Tirosh et al. (2013) investigated 5-6 year olds' self-efficacy beliefs in various math tasks. Results show that all children exhibit high self-efficacy beliefs, which were not always in line with their actual performance on these tasks (Tirosh et al., 2013). Regarding the value domain, Fisher et al. (2012) studied 3-5 year olds' math interest using various observational measures, including the duration of children's math-related play and their observed enjoyment. They found that older children rated higher than younger children on all measures of interest (Fisher et al., 2012). This is in contrast to results obtained by Eccles et al. (1993), who report that children's math motivation decreases with age between grades 1 and 3. Similar results have been obtained by Wigfield et al. (1997) for grades 1 to 6. However, Eccles et al. (1993), as well as Wigfield et al. (1997), looked at the elementary years, whereas Fisher et al. (2012) studied even younger children in preschool, which may explain the inconsistent results. Specifically, learning experiences in preschool are likely to be different from the experiences children gather in primary school, which will affect children's motivation. Unfortunately, Fisher et al. (2012) did not report information about the amount and the kind of math experience among the children in the sample. Thus, one can only speculate that these conflicting findings result from different experiences.

Much less research exists for the science domain. Mantzicopoulos et al. (2008) investigated the motivational beliefs of US kindergarteners who participated in a 5- to 10-week science program. They found very high ability beliefs and high interest in science among the children in their sample (Mantzicopoulos et al., 2008). Moreover, results showed that children who participated in a more extensive science program had higher motivational beliefs in science (Mantzicopoulos et al., 2008). Although these results are promising, it remains unclear whether the beneficial effects were specific to that science program or whether these findings are generalizable to children with varying degrees of science experiences in preschool.

In summary, very little is known about the state of young children's motivational beliefs in math and science and the role of different math and science experiences. Thus, more research is required to investigate these aspects.

5.3. Gender differences in young children's math and science motivation

It is well documented that gender differences in children's math and science motivation exist among primary and secondary school children (Andre et al., 1999; Eccles et al., 1993; Simpkins et al., 2006). For instance, primary school-aged girls show less positive attitudes toward science and science careers than do boys (Cvencek, Meltzoff, & Greenwald, 2011) and have lower ability beliefs in math and science (DeWitt et al., 2011; Jacobs et al., 2002; Wigfield et al., 1997). But when exactly do these differences emerge and how do they develop over time? A longitudinal study by Herbert and Stipek (2005) measured 300 children's academic ability beliefs from kindergarten or 1st grade through 5th grade. They found that, starting in 3rd grade, girls rated their math ability lower than boys, despite the fact that there were no differences in children's achievement in mathematics (Herbert & Stipek, 2005). Similarly, Andre et al. (1999) found significant gender differences in the physical science ability beliefs of children in 4-6th grade, in favor of boys, which were not observed among a sample of children in kindergarten through 3rd grade. Research findings for even younger children are inconsistent. Mantzicopoulos et al. (2008) found no gender differences in children's science motivation among their sample of kindergarten children, whereas Leibham et al. (2013) found significant differences in science interest among children aged 4-6 years, in favor of boys. However, as mentioned before, Mantzicopoulos et al. (2008) drew on a sample of children who participated in an extensive science project in kindergarten and thus have comparatively rich experiences with science, whereas Leibham et al. (2013) measured children's everyday play activities at home among children who did not explicitly participate in any science project. Moreover, Mantzicopoulos et al. (2008) assessed both, children's interest and their ability beliefs, using self-report measures, whereas Leibham et al. (2013) relied on parental reports of children's science interest. The inconsistent findings of the two studies might therefore result from a variety of factors that differed in these two studies, such as the amount of experience with science, the measures and the environment children were studied in (home vs. kindergarten). Thus, further research is required to study gender differences among a heterogeneous sample of young children and investigate how children's early experiences with math and science may affect children's gender-specific motivational beliefs.

5.4. Summary

The previous chapters gave an overview of the applicability of the assumptions underlying the expectancy-value model to young children. Moreover, based on these more general characteristics, previous findings on young children's motivational beliefs in math and science were discussed. The main insights gained from the literature review can be summarized as follows: (1) The differentiation within expectancy and value beliefs, which is inherent in the expectancy-value model (Eccles et al., 1983), cannot be empirically supported for young children. Expectancy beliefs and more general ability beliefs are typically found to be indistinguishable among young children and are thus used interchangeably in this dissertation. Similarly, the value components are not clearly distinguishable at this age, with intrinsic value being the most salient component. (2) Existing studies show that older children's domain-specific expectancy and value beliefs are positively related, in line with Eccles et al.'s (1983) prediction. For younger children, a weaker relation is assumed, which should become stronger with more experience. This assumption, however, has not been sufficiently tested. In fact, very little is known about the relation between expectancy and value beliefs among young children. (3) Children's expectancy and value beliefs are assumed to become more subject-specific with experience as children develop higher confidence and interest in some domains compared to others. Although studies find distinguishable motivational beliefs even among 5-7 year olds (Eccles et al., 1993; Marsh et al., 1991), it remains unclear whether subject-specific motivational beliefs exist among young children with less structured experiences and whether their beliefs can be further distinguished into content areas within subjects. (4) Young children are typically found to be very interested and highly confident in their abilities in math and science. Some studies find that children's math and science motivation decreases during the elementary school years, however, little is known about the motivation of even younger children. (5) Lastly, gender differences are consistently found in older children's math and science motivation but research findings on younger children are scarce and inconsistent.

Taken together, existing findings indicate that most, but not all of the assumptions underlying the expectancy-value model can be supported for as early as 1st grade. Moreover, children's motivation starts to change and develop during the elementary years, with individual differences slowly emerging. Yet, few studies have so far investigated children's math and science motivation among even younger children. As a consequence, it remains unclear if results obtained for primary and secondary school children regarding the structure, and individual differences in children's motivation are transferable to the preschool years. Moreover, based on the notion that experience is crucial for the development of children's math and science motivation, studies are required to investigate whether children's motivational beliefs differ as a function of their experiences with math and science in preschool. Factors that influence the development of expectancy beliefs and values in preschool will be discussed in more detail in the following chapter.

6. Determinants of children's math and science motivation

Motivation researchers have long been interested in how achievement motivation is shaped by societal influences. With regard to ECEC, it is assumed that teachers play a central role in children's learning and development. For instance, Bronfenbrenner's (1977) ecological systems theory posits preschool teachers in the close proximity to the children, i.e. the micro-system. The micro system is assumed to have the largest influence on children's development (Bronfenbrenner, 1977). Consistent with Bronfenbrenner's (1977) emphasis on the proximity of processes, this dissertation takes the view that the most crucial preschool influences on children's motivation are the interactions among children and teachers. The importance of interactions is also inherent in the sociocultural theory which posits that children learn through social interactions (Vygotsky, 1978). Children interact with their preschool teachers on a daily basis and thus, preschool teachers' may affect the development of children's motivational beliefs in math and science through a variety of mechanisms. The following chapter will introduce different theoretical and empirical approaches to explain the influence of preschool teachers on children's motivation in more detail and discuss the applicability of the approaches to the context of early math and science education.

6.1. The quality and quantity of educational processes

One of the most prominent concepts to explain children's development in general as well as their subject-specific learning is the quality of ECEC. Quality is often referred to as "process quality", which describes the nature of the pedagogical interactions between preschool teachers and children, but also includes the interactions among children and the interaction of children with space and materials (Anders, Rossbach, & Kuger, 2017; Kluczniok & Rossbach, 2014). Process quality is assumed to directly influence child outcomes, including their motivational beliefs (see figure 3) (Kluczniok & Rossbach, 2014; Pianta et al., 2005; Roux & Tietze, 2007; Tietze et al., 1998). According to the structural-process model (see figure 3, Anders et al., 2017; NICHD-ECCRN, 2002; Pianta et al., 2005; Roux & Tietze, 2007), the quality of the educational processes is, in turn, influenced by structural characteristics, e.g. teacher-child-ratio, formal staff qualification level and materials provided, as well as the teachers' beliefs and orientations (orientation quality; Anders et al., 2017; Kluczniok & Rossbach, 2014; Pianta et al., 2005). In the research literature, process quality is further differentiated into global aspects such as a warm climate or child-appropriate behavior (Harms, Clifford, & Cryer, 1998; Pianta et al., 2005) and domain-specific stimulation in learning areas such as literacy, mathematics, and science (Kluczniok & Rossbach, 2014). Global aspects, particularly the emotional quality of teacher-child relationships, are considered crucial for children's social-emotional competencies (Birch & Ladd, 1997; Hamre & Pianta, 2010; Ladd, Birch, & Buhs, 1999). For instance, empirical findings suggest that high emotional quality is associated with children's early school adjustment indicators, including academic skills, frustration tolerance, work habits, social skills and prosocial behaviors, emotional positivity, behavior problems, school avoidance, and disciplinary actions (Birch & Ladd, 1997; Hamre & Pianta, 2010; Ladd et al., 1999), but not children's achievement (Buyse, Verschueren, Verachtert, & Van Damme, 2009). With regard to children's domain-specific learning and development, domain-specific process quality, e.g. in math and science, is deemed most important. But what exactly is considered high process quality in math and science?

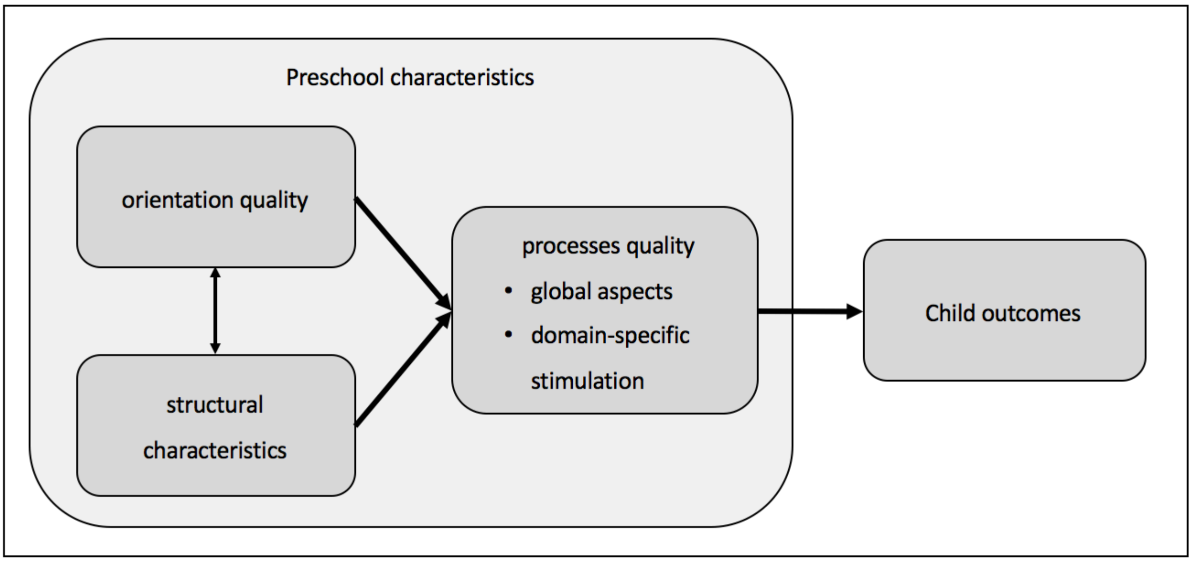

Figure 3. Slightly simplified version of the structure-process model (see Kluczniok & Rossbach, 2014; Roux & Tietze, 2007; Tietze et al., 1998)

The effects of different instructional approaches on children's outcomes have been thoroughly discussed in the research literature. The general consensus seems to be that children profit from cognitively stimulating verbal interactions with their preschool teachers (Hopf, 2012; Siraj-Blatchford, Sylva, Muttock, Gilden, & Bell, 2002; Sylva et al., 2004). These learning situations are characterized by a child-centered approach, in which teachers are sensitive to children's interests and facilitate children's learning by providing them with guidance and support in order to direct children's own exploration (Schweinhart & Weikart, 1988; Stipek & Byler, 1997). Both, teachers and children, play an active role in the learning situation and "work together in an interrelated way to solve a problem, clarify a concept, evaluate an activity, extend a narrative etc. Both parties must […] contribute to the thinking and it must develop and extend the understanding" (Sylva et al., 2004, p. 6). These kinds of interactions were labeled "sustained shared thinking" (SST) by Sylva et al. (2004). The beneficial effects of SST as well as similar high-quality practices are well documented for mathematics (Anders, Grosse, et al., 2012; Anders, Rossbach, et al., 2012; NICHD ECCRN, 2005; Sammons et al., 2008), language literacy (Ebert et al., 2013; NICHD ECCRN, 2003, 2005; Peisner-Feinberg et al., 2001), and children's general cognitive and social-emotional outcomes (Peisner-Feinberg et al., 2001; Sammons et al., 2008; Sylva et al., 2004; Vandell et al., 2010). For the science domain, Peterson and French (2008) identified teachers' involvement and conversation with children during scientific learning as a central element that characterized classrooms where children benefited most from a 5-week science program.

Less research exists with regard to motivational outcomes. A study by Stipek, Feiler, Daniels, and Milburn (1995) found that children who were enrolled in child-centered programs rated their abilities higher, had higher expectations for success on academic tasks and claimed to worry less about school than children in the didactic programs. Similarly, Lerkkanen et al. (2012) found that a child-centered approach was positively associated with the development of children's interest in reading and mathematics, while a teacher-directed approach had a negative effect on children's interests. Thus, existing findings indicate that a child-centered approach, which is characterized by teachers' involvement and sensitivity to children's interests, is also beneficial for children's motivation – although no study has so far looked at children's math and science motivation in particular.

Unfortunately, research shows that high-quality instructional practices are rare in preschool. A study by König (2009) documented 60 hours of everyday practices in German preschools and found only one sequence that met the criteria for SST. Moreover, even the sequences that could be characterized as interactions between teachers and children – although not SST interactions – were typically not related to any educational content (König, 2009). With regard to early science education, Hopf (2012) observed the interactions among teachers and children in a pre-constructed early science setting where teachers were advised to practice science together with a small group of children. Even in this ideal setting, she found that only 23.1% of all interactions could be characterized as SST. Moreover, not all children were equally included in these interactions: Children with lower cognitive abilities as well as girls were less often involved in SST interactions (Hopf, 2012). These results demonstrate that many children might not regularly engage in high-quality math and science practices. Thus, at this stage, it might be more important to establish how often children get a chance to engage in math and science learning together with their preschool teachers – regardless of the quality of these learning situations – and whether the frequency is related to young children's motivation.

A few studies have investigated the frequency of teachers' math and science practices, although no study has so far looked at children's motivation as an outcome variable. Studies on the frequency of teachers' math practices largely vary in their findings, with results ranging from weekly/monthly to daily. For instance, results by Wadlington and Burns (1993) showed that U.S. kindergarten and preschool teachers reported to teach math from weekly to monthly. In contrast, more recent findings by Hindman (2013) found that U.S. preschool teachers reported to engage in mathematics almost daily. Thus, it may be that over the last 20 years the frequency of math instruction has increased. Yet, Hindman (2013) compared self-report data to observational data collected in one morning and finds that half of the teachers who stated that they taught math were never directly observed teaching math. However, an observational study by Boonen, Kolkman, and Kroesbergen (2011) found for a Dutch sample of preschool teachers that the amount of mathematical relevant language input was actually quite high: On average, 154 instances of math talk could be observed in an hour of teacher-child interactions during circle time. Thus, math education may be more pronounced in preschool than 20 years ago, however, there are likely to be regional differences.

Findings for the science domain are scarce, but consistent: A study by Saçkes, Trundle, Bell, and O'Connell (2011) found that about half of the U.S. preschool teachers in their sample taught science once or twice a week and only 15% reported to teach science daily. This is consistent with more recent findings by Spektor-Levy, Baruch, and Mevarech (2013) who showed that the majority of U.S. preschool teachers in their sample engage in science only weekly (62%) and that 27% engage in science activities once or twice a month or even less often (11%).

Regular math and science learning opportunities are, in turn, assumed to be important for the development of children's motivation. However, only two studies have investigated this relation. A study by Arnold, Fisher, Doctoroff, and Dobbs (2002) showed for the mathematics domain, that children who engaged in everyday math activities more often had higher enjoyment than children in the control group. Similar results have been found for children's engagement in an intensive science program (Mantzicopoulos, Patrick, & Samarapungavan, 2013): Children who participated in the program showed higher interest and more positive beliefs about their own ability in science than the control group. Yet, it remains unclear whether children's participation in less intensive science education, e.g. as part of the regular preschool curriculum, is also beneficial for their motivation.

In summary, most studies report that math and science education does not happen daily, although there is a large variation in the results. However, nearly all of these studies are based on U.S. samples and thus the frequency of guided math and science learning activities may be different in Germany, where learning is typically informal and unguided free play makes up a large amount of children's daily activities. Moreover, no study has so far investigated the importance of regular learning experiences for children's motivation among a more heterogeneous sample of preschoolers.

6.2. Socialization processes

So far the effects of teachers' instructional practices on children's motivation in math and science have been discussed. Yet, verbal and non-verbal teacher-child-interactions are characterized by more than just the quality and quantity of teachers' math and science practices. From a social-cognitive perspective, motivation emerges from the interaction between individuals within a social context and is thus influenced by a variety of factors including teachers' verbal and non-verbal feedback and encouragement as well as available social comparison information, i.e. role models (Bandura, 1986; Schunk, 1987; Urdan & Schoenfelder, 2006). Eccles and Wigfield (2002) also suggest that teachers act as socializers, who communicate their own attitudes and beliefs, including their expectations towards the child, through their feedback and encouragement as well as their exemplary behavior (Eccles et al., 1993; Wang & Degol, 2013) (see also figure 2). Over time, this information accumulates to inform the development of children's subject-specific ability beliefs and task values (Wang & Degol, 2013). Thus, taken together, the expectancy-value model and the social-cognitive theory suggest two processes through which teachers may pass their own beliefs to the children: Teachers' feedback and encouragement as well as their exemplary behavior as role models.

With regard to teachers' feedback and encouragement, Eccles and Wigfield (1985) propose that teachers communicate their own expectations towards the children verbally and non-verbally, which shapes children's view of their abilities. For instance, when teachers hold high expectations towards a child, they may support and encourage that child more, who may, in turn, develop a greater sense of competence as learner (Eccles, 2007). This assumption also neatly aligns with the self-determination theory (SDT), which assumes that teachers' underlying beliefs about children's competencies and the malleability of these competencies are communicated to the children through teachers' differential practices, including verbal communication (Dweck, 2006). Similar to Eccles and Wigfield's (1985) prediction, the SDT assumes that teachers' behaviors and beliefs (e.g., beliefs about children's competency) can be transformed into internal beliefs through "internalization" (Davis, 2003). Supporting these assumptions, Parsons, Kaczala, and Meece (1982) found that teacher expectancy was related to students' motivational beliefs in school, and this effect was not mediated by teachers' instructional practices. In a similar pattern, Heyman, Dweck, and Cain (1993) found that 5-6 year old children's self-evaluations were particularly susceptible to evaluative comments by teachers. Thus, in line with the theoretical assumptions proposed by Eccles and Wigfield (1985) as well as the SDT, children seem to perceive and internalize teachers' expectations as early as at 5-6 years. In fact, teachers' feedback might actually be more relevant to preschool children than to older children in school, since normative evaluations are rare in preschool and children thus rely on deducing feedback information from the behavior of their preschool teachers.

In addition to teachers' feedback, teachers may act as role models and thus communicate their own beliefs through their exemplary behaviors to the children. Socialization through observation and behavioral enactment as a central mechanisms was originally proposed in the social cognitive theory (Bandura, 1986). Particularly for young children, modeling is seen as an important process through which children acquire essential skills, beliefs, and behaviors (Schunk, 1987; Zimmerman & Ringle, 1981). Eccles et al.'s (1983) expectancy-value model also suggests that children's perception of socializers' beliefs in a domain shapes children's own beliefs. For instance, if children perceive their teachers to be confident and enthusiastic in math and science, children might learn that these subjects are fun and easy to do and thus may be more likely to approach math and science in a similar fashion. In line with this, research on older students suggests that they adapt teacher's beliefs. For instance, Midgley, Feldlaufer, and Eccles (1989) followed students across school transitions in junior high school and found that students, who moved from high- to low-efficacy math teachers, ended the year with the lowest ability beliefs and the highest perceptions of task difficulty. However, it remains unclear whether these findings can be transferred to the preschool level. In fact, very little is known about preschool teachers' potential role as models of beliefs and behavior, since most of the research focuses on older students or on parental influences (Eccles, Jacobs, & Harold, 1990; Jacobs, Davis-Kean, Bleeker, Eccles, & Malanchuk, 2005). Yet, teachers' exemplary behavior may be particularly relevant for very young children because they rely more heavily on teachers' guidance. This may be particularly the case for teachers of the same gender, since children tend to imitate same-sex models more than opposite-sex ones due to perceived similarity (Bandura, 1977b; Basow & Howe, 1980; Perry & Bussey, 1979). These gender-specific patterns will be discussed in more detail in the following chapter.

6.3. Gendered patterns in educational and socialization processes

The previous chapter discussed several mechanisms through which teachers may influence and shape children's motivational beliefs in math and science, i.e. the quality and quantity of teachers' math and science practices, teachers' verbal and non-verbal feedback, and teachers' exemplary behavior. These processes are assumed to influence individual children's motivation and might thus contribute to individual differences in their motivational beliefs. Since research repeatedly finds gender differences in older children's math and science motivation, it seems an important endeavor to understand how teachers may influence the development of gender-specific motivational beliefs in math and science. The following chapter will therefore review the research literature on gendered patterns in teachers' educational practices as well as their feedback and exemplary behavior.

One of the most obvious mechanisms through which teachers may contribute to gender differences is through the quality and quantity of their practices. Specifically, teachers may not offer the same amount and quality of early math and science education to girls and boys. For the school level, most of the existing studies point to quantitative differences in teachers' interactions with girls and boys (Altermatt, Jovanovic, & Perry, 1998; Becker, 1981; Oakes, 1990). Teachers interact with boys more frequently than with girls and encourage boys more in both science and mathematics classes (Becker, 1981; Dart & Clarke, 1988; Duffy, Warren, & Walsh, 2001; She, 2000). With regard to the preschool level, only very few studies exist. Brandes, Andrä, Röseler, and Schneider-Andrich (2015) compared teacher-child-interactions by gender using 82 video sequences in preschool classrooms. They found that preschool teachers, particularly female teachers, communicate with boys in a more factual, object-related way than with girls (Brandes et al., 2015). Kuger, Kluczniok, Sechtig, and Smidt (2011) also document differences in the learning opportunities that preschool teachers offer girls and boys in language, arts, and hygiene – but they did not find any significant differences in the amount of teacher-initiated activities in math or science. Similarly, Saçkes et al. (2011) found no gender differences in the availability or frequency of science learning opportunities in preschool. In contrast, Greenfield (1997) reported that girls received less attention from their teachers during sciences classes in kindergarten and primary school. Thus, some evidence points to quantitative and other evidence to qualitative differences in teachers' instructional practices. Yet, the research literature for the preschool level is scarce and findings are inconsistent. More studies are required to investigate these relations.

The teacher-child interactions are not just characterized by its quantity and quality, but also by a number of other processes including teachers' verbal and non-verbal feedback and their exemplary behavior. Since gender differences in children's motivation in math and science are in accordance with socially-prevalent stereotypes, socialization in preschool might be particularly powerful with regard to the development of these differences. For instance, teachers may communicate their own stereotypical beliefs through their feedback and encouragement as well as their modeling behavior. Indeed, studies show that school teachers have higher expectancies for boys in math (Keller, 2001; Tiedemann, 2000) and science (Shepardson & Pizzini, 1992) than for girls. For instance, Tiedemann (2000) reported that elementary math teachers judge mathematics to be more difficult for girls than for equally achieving boys. Moreover, teachers attributed failure among girls more often to low ability than to effort and believed that girls would profit less in than boys from additional effort (Tiedemann, 2000). These expectations may have important implications: If teachers expect boys to be better at math or science, they may encourage them more to persist in the face of difficulties and provide more frequent and more positive feedback. In line with this, Dweck, Davidson, Nelson, and Enna (1978) showed that the feedback that boys received focused more on conduct rather than on ability. This is an important finding, since teachers' perceptions and attributions may be "internalized" by the children (Davis, 2003): If girls receive less encouragement and more negative feedback that focuses on their ability in math and science, rather than on their effort, they are likely to adapt these beliefs and they consequently might lose interest in pursuing math- and science-related activities. In fact, several studies have documented that ability perceptions and attributions of success predict motivational beliefs (Eccles & Wigfield, 1985; Grant & Dweck, 2003). Thus, teachers' own (gender-role) beliefs may be communicated to the children through teachers' differential feedback and encouragement behavior, which shapes children's own motivational beliefs. In line with these assumptions, a recent study by Upadyaya and Eccles (2014) showed for the early primary school level that teachers rated boys' math ability higher than girls', controlling for children's actual performance, and these perceptions of ability predicted children's future ability self-concepts. Very little research has been conducted with regard to the preschool context. A study by Cahill and Adams (1997) found that preschool teachers' more general gender role attitudes strongly correlated with their attitudes toward children's gender roles, and child-rearing practices (e.g., encouragement of gendered behaviors). More recently, Wolter, Braun, and Hannover (2015) found for the reading domain that boys were significantly less motivated to read when their teacher endorsed traditional gender beliefs, whereas teachers' gender beliefs had not effect for girls. Thus, the literature for the preschool context indicates that teachers gendered beliefs affect the children they engage with, but the evidence is limited to other areas than math and science. Moreover, it is not clear whether these relations were indeed mediated by teachers' differential feedback and encouragement, or by other mechanisms, such as modeling.

According to the social cognitive theory, observational learning is one of the ways through which children adapt socializers' (teachers', parents', and peers') beliefs – especially those associated with gender-appropriate qualities of behavior (Bandura & Walters, 1963). Specifically, it was proposed by Bussey and Bandura (1984) that young children acquire knowledge about gender categories early on and subsequently start to act in accordance with these categories (see also Martin & Ruble, 2004). In fact, children's rigidity to gender categories peaks at ages 5 to 7 (Martin & Ruble, 2004) and thus, during these years, children will be particularly sensitive to the beliefs and behaviors of same-gender models. Since over 90% of preschool teachers are female, girls may be more likely than boys to notice and adapt teachers' beliefs. For example, if female teachers consider math and science as too hard, girls would be more likely than boys to copy these negative beliefs, due to perceived similarity to the model (Gunderson, Ramirez, Levine, & Beilock, 2012). A study by Beilock, Gunderson, Ramirez, and Levine (2010) found for the primary school level, where also over 90% of teachers are female, that teachers' math anxiety predicted girls', but not boys' math achievement one year later: The higher teachers' math anxiety, the lower girls' math achievement. Competent female role models, on the other hand, can also promote children's own motivation and achievement (Marx & Roman, 2002; Midgley et al., 1989). For instance, Marx and Roman (2002) showed in an experimental design that female students own mathematical ability beliefs could be increased by a competent female experimenter as a role model. Similarly, Smith and Erb (1986) as well as Evans, Whigham, and Wang (1995) demonstrated that the introduction of female role models in high school science classrooms improved girls interest in science-, math- and technology-related careers. These effects may have long-lasting consequences: Zeldin and Pajares (2000) interviewed successful women in STEM about the sources of their self-efficacy beliefs. Their findings indicate that competent female role models were one of the primary sources that motivated women in these traditionally male-dominated domains. Thus, learning through modeling seems to be a powerful mechanism with potentially long-lasting effects. Yet, despite the fact that modeling has been found to be particularly effective among very young children (Schunk, 1987; Zimmerman & Ringle, 1981), little is known about these relations at the preschool level.

6.4. Summary

Teachers play an important part in the development of children's motivational beliefs. This chapter has identified and discussed several mechanisms through which preschool teachers influence and shape children's motivation: The quality and quantity of early education as well as socialization processes. There is also some evidence that these are the mechanisms through which teachers affect the development of gender-specific motivational beliefs. Yet, few of these mechanisms have been studied in the context of early mathematics and science education, particularly with regard to gender. Further studies are therefore required to investigate the processes linking teachers' beliefs and practices, and children's motivation as well as gendered patterns in these relations. Studies that include several aspects of the mechanisms described above will be particularly fruitful as they can compare different influences on girls' and boys' mathematics and science motivation.

7. Preschool teachers' competencies

The previous chapter has demonstrated that preschool teachers play a central role in the development of children's motivational beliefs. Teachers are expected to offer frequent and high-quality mathematics and science education, to provide motivating feedback as well as embody positive role models. These are challenging tasks that requires a number of competencies related to preschool teachers' knowledge, attitudes, and beliefs (Anders, 2012; Mischo, Wahl, Hendler, & Strohmer, 2012). Competencies in this context refer to malleable skills (Weinert, 1999) that allow teachers to handle these kinds of pedagogical situations. By definition, the construct "competency" is multidimensional and domain-specific (Anders, 2012), i.e. teachers' math and science competencies are considered particularly relevant for their math and science practices. But which competencies do preschool teachers require in particular?

Different competency models exist in the literature and most of these consider knowledge as well as teachers' orientations, attitudes, and motivation as important for teachers' practices (Anders, 2012; Fröhlich-Gildhoff, Nentwig-Gesemann, & Pietsch, 2011). For instance, Fröhlich-Gildhoff et al. (2011) propose that teachers' knowledge, as well as their motivation, affects their perception of the pedagogical situation at hand, predicts how they plan to act and subsequently their actual behavior (see figure 4).

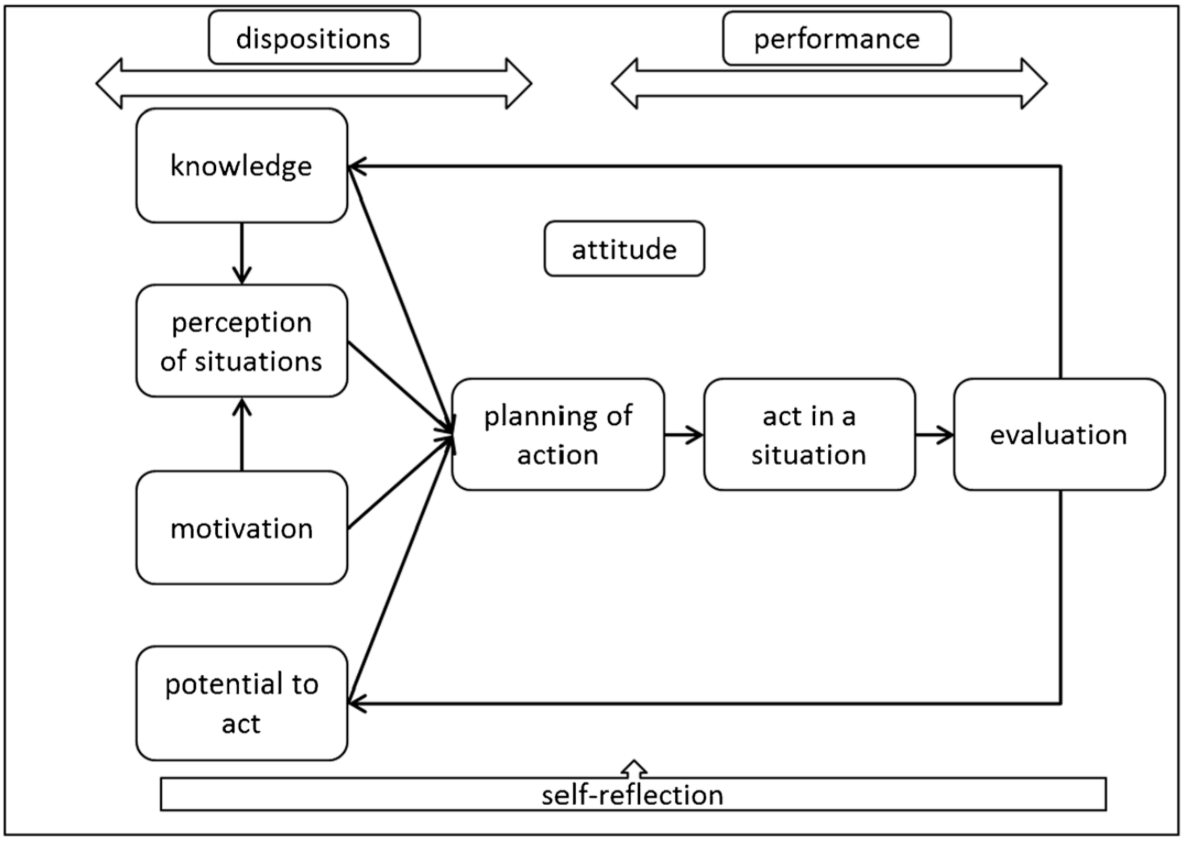

Figure 4. Teachers' competences according to Fröhlich-Gildhoff et al. (2011), translated by Dunekacke, Jenßen, and Blömeke (2015).

The structural-process model (see figure 3), focuses largely on teacher's orientations, i.e. their attitudes and motivational beliefs, assuming that these directly influence the process quality of teachers' practices (Kluczniok & Rossbach, 2014; Roux & Tietze, 2007; Tietze et al., 1998). The present thesis therefore focuses on teacher's professional knowledge and their motivation in math and science.

7.1. Preschool teachers' professional knowledge

Preschool teachers' professional knowledge is considered a prerequisite for their ability to offer regular and high-quality learning opportunities (Anders, 2012). Following prevalent competency models in the school context (Shulman, 1987), the research literature distinguishes between content knowledge (CK), i.e. knowledge about the subject teachers are required to teach, and pedagogical content knowledge (PCK), i.e. knowledge about pedagogical and didactical approaches to effectively teach the subject (Dunekacke et al., 2013; McCray, 2008; Siraj-Blatchford et al., 2002). Thus, with regard to early math and science education, it is assumed that teachers require sufficient knowledge in math and science (CK) and need to be able to communicate this knowledge to the children in an age-appropriate, engaging, and didactically stimulating way (PCK). Since learning in preschool typically takes place in play-based situations, teachers' ability to recognize teachable moments in children's play activities is considered an important aspect of their PCK (McCray, 2008). In fact, McCray and Chen (2012) showed that teachers' ability to recognize mathematical elements in children's play, as one aspect of teachers' mathematical PCK, predicted the process quality and children's learning gains in mathematics. Moreover, findings by Dunekacke et al. (2015) showed that preschool teachers' mathematical CK predicted their ability to recognize mathematical learning opportunities. Similarly, Barenthien, Lindner, Ziegler, and Steffensky (2017) found for the science domain that preschool teachers' CK and PCK were highly correlated. Thus, in line with Shulman's (1987) proposition, CK seems to be a prerequisite for teachers' PCK. Yet, it is largely unclear what level of mathematical and science CK preschool teachers require. It is generally assumed that teachers' level of knowledge should be above the level that they are trying to teach (Garbett, 2003; Krauss et al., 2008). Thus, for 5-6-year-old children, who will enter school the following year, teachers would require knowledge equivalent to primary school math and science. Garbett (2003) investigated preschool and primary school teachers' content knowledge in biology, chemistry, physics and astronomy. Results showed that preschool teachers' science knowledge was below that of primary school teachers (Garbett, 2003). Similar results have been obtained by Kallery and Psillos (2001), who found that preschool teachers' science CK was below what they considered necessary for early science education. Teachers were aware of their limited knowledge: Only 22% of preschool teachers felt that they possessed adequate knowledge to teach science (Kallery & Psillos, 2001). Because of their perceived lack of sufficient knowledge, preschool teachers are reportedly more reluctant to seize teachable moments for early mathematics and science education (Copley, Clements, & Sarama, 2004; Erden & Sönmez, 2010; Harlen & Holroyd, 1997). In fact, they prefer teaching literacy over mathor science (Copley & Padrón, 1998). If teachers feel unconfident in math and science and consequently prefer other subject areas, it seems unlikely that they will be able to offer regular and high-quality learning opportunities in math and science. It is therefore crucial to take teachers' motivation to teach math and science into account.

7.2. Preschool teachers' motivation

Motivational beliefs are assumed to be highly relevant for teachers' educational practices as they facilitate and direct teachers' behavior (Baumert & Kunter, 2013). Teacher motivation is a multidimensional and domain-specific construct (Kunter, Klusmann, & Baumert, 2009) and numerous studies have explored different aspects of teacher motivation for their instructional practices, i.e. teachers' enthusiasm (Kunter, Frenzel, Nagy, Baumert, & Pekrun, 2011), interest (Schiefele, 2017; Schiefele, Streblow, & Retelsdorf, 2013), and ability beliefs, i.e. their self-concept and self-efficacy beliefs (Bitto & Butler, 2010; Tschannen-Moran & Woolfolk-Hoy, 2001). Studies based on school teachers show that all of these aspects are relevant for teachers' instructional practices (Bitto & Butler, 2010; Goddard, Hoy, & Hoy, 2000; Schiefele et al., 2013). For instance, Kunter et al. (2008) showed that secondary school teachers' enthusiasm for teaching predicted the instructional quality of their teaching behavior.

Teacher interest was also positively associated with instructional quality in a study by Schiefele and Schaffner (2015). A study by Keller, Neumann, and Fischer (2017) further showed that teachers' interest in teaching physics predicted student' interest in physics, mediated by enthusiastic teaching practices.

Particular emphasis has been placed on teachers' self-efficacy beliefs (Maguire, 2011). Teacher self-efficacy is conceptually based on Bandura's (1977a) more general definition of self-efficacy beliefs (see chapter 5) but extended to teacher's practices, such as teachers' ability to perform those teaching behaviors that bring about student learning even when students are difficult or unmotivated (Klassen, Tze, Betts, & Gordon, 2011). In that, they are conceptually closely related to more general self-concept (Guskey, 1988). These two concepts, i.e. self-efficacy and self-concept, are both subject-specific, but they differ in their task- and content-specificity (Bong & Skaalvik, 2003). Specifically, self-efficacy refers to the conviction to successfully perform in a given task, such as teaching science, whereas self-concept comprise more general perceptions of one's ability in a subject (Ferla et al., 2009; Pajares, 1996). Nevertheless, both beliefs refer to teachers' perception of their own ability, thus the term "ability beliefs". Teachers' self-efficacy beliefs are assumed to be particular powerful predictors of their teaching practices (Goddard et al., 2000; Justice, Mashburn, Hamre, & Pianta, 2008; Kahle, 2008; Lohse-Bossenz, Zimmermann, Janke, & Müller, 2015; Schiefele, 2009). This is based on the assumption that the strength of teachers' self-efficacy helps determine how much effort they will invest in an activity and how resilient they will be when faced with adversity (Bandura, 1997; Pajares, 1996). Similarly, Eccles and Wigfield (1985) proposed that effective teachers are those who perceive themselves to have control over the students' progress and consider it as part of their responsibility to ensure that all children learn. In line with this, studies on school teacher self-efficacy beliefs typically show positive associations to teachers' instructional practices (Harlen & Holroyd, 1997; Justice et al., 2008; Relich, 1996). But can these results be transferred to the preschool level?

Teaching in preschool differs from teaching in primary and secondary school in that learning situations are typically less planned and less pre-structured, but rather spontaneous and play-based. Thus, preschool teachers are expected to integrate math and science learning into children's everyday (play) activities. Moreover, since there are no mandatory standards for math and science teaching preschool, it is entirely up to the preschool teachers to decide how often they would like to offer early mathematics and science education. Consequently, preschool teachers' confidence in their own ability to teach math and science, i.e. their self-efficacy beliefs, may actually be more important than later in school.

A few studies have investigated the relevance of teachers' self-efficacy beliefs for their practices at the preschool level. Justice et al. (2008) found that preschool teachers' self-efficacy beliefs regarding classroom management and motivating children in their classroom were associated with the quality of early literacy instruction, i.e. teachers' use of techniques to accelerate language growth. A more recent study by Guo, Piasta, Justice, and Kaderavek (2010) found no associations between preschool teachers' self-efficacy beliefs and classroom quality, i.e. instructional and emotional support. Teachers' self-efficacy was, however, related to children's learning gains in print awareness and there was a positive interaction effect of teachers' self-efficacy beliefs and emotional support on children's vocabulary skills (Guo et al., 2010). The authors conclude that high self-efficacy beliefs might lead to a warmer classroom climate, which positively influences children's learning gains in vocabulary. For the science domain, Lohse-Bossenz et al. (2015) found that higher preschool teacher self-efficacy beliefs in science were associated with more cognitive activation and support during early science learning situations. Thus, there is some evidence that preschool teachers' self-efficacy beliefs are relevant for their practices, however, only one study has so far looked at the science domain. Moreover, all of the studies above investigated the influence of teachers' self-efficacy beliefs on the quality of their practices. But the frequency of teachers' math and science practices may be just as relevant as studies indicated that high-quality math and science education is rare in preschool. Further studies are therefore required to investigate these relations.

7.3. Interrelations among teachers' knowledge and motivation

The previous chapters have highlighted the importance of preschool teachers' knowledge as well as their self-efficacy beliefs for their teaching practices. But these two constructs are not independent of each other. By definition, teacher's self-efficacy beliefs are conceptualized as teachers' judgment of their own ability and should thus be related to their knowledge. In line with this assumption, studies for the school level typically find that teachers' self-efficacy beliefs correlate positively with their knowledge, although some results are inconsistent (Newton, Leonard, Evans, & Eastburn, 2012; Schoon & Boone, 1998; Swars, Hart, Smith, Smith, & Tolar, 2007). Specifically, Schoon and Boone (1998) measured science teaching self-efficacy beliefs and science content knowledge among pre-service school teachers. Results indicated that teachers with higher knowledge scores had significantly higher levels of self-efficacy than those with lower scores. Similarly, with regard to mathematics, Newton et al. (2012) found a positive relation between elementary teachers' mathematical CK and their self-efficacy beliefs. In contrast, Swars et al. (2007) found no relation between pre-service elementary teachers' mathematical CK and their mathematical self-efficacy beliefs. Much less is known about the preschool level. A recent study for the science domain by Steffensky et al. (2017) investigated the relation among preschool teachers' science self-efficacy beliefs and a more distal indicator of their knowledge in science, namely teachers' participation in professional development programs. Results reveal a positive relation: The more science-related professional development programs preschool teachers participated in, the higher their self-efficacy beliefs in science (Steffensky et al., 2017). Thus, in summary, most of the studies point towards a positive relation between teachers' knowledge and their self-efficacy beliefs, although some findings are inconsistent and this relation has barely been studied for the preschool level. Consequently, more research is needed to investigate this relation among preschool teachers.

7.4. Summary

Preschool teachers' knowledge and their motivation to teach math and science, particularity their self-efficacy beliefs, are seen as important aspects of teachers' competencies. Yet, little is known about these constructs at the preschool level. Theoretically, teachers' CK and self-efficacy are likely to be related, but this assumption has not been tested. Moreover, both aspects are considered prerequisites for teachers' practices in preschool. This assumption can be partially supported for teachers' CK as well as their self-efficacy beliefs, but the research literature in these constructs is nevertheless scarce. It was discussed above that early math and science learning is typically play-based and teachers therefore need to be able to recognize teachable moments in children's play. However, it remains unclear if and how teachers' CK and their self-efficacy beliefs are related to their ability to recognize mathematical content in children's play, as an important prerequisite for their practices. Teachers are likely to require basic mathematical CK in order to recognize mats. But they may only use their CK to recognize teachable moments if they feel confident enough to teach math. The relation between teachers' sensitivity to mathematical elements in children's play, their mathematical CK and their self-efficacy beliefs in mathematics thus needs to be examined in greater detail. This gap in the research literature seems particularly pressing since guided mathematics and science learning opportunities are found to be rare in preschool. Thus, it is important to understand which competencies are necessary to enable teachers to recognize learning opportunities more often.

8. Objectives of the present dissertation

The previous chapters gave an overview of the research literature on motivation in early mathematics and science education on the child- and teacher-level as well as the interrelations of the two. Starting at the child level, the role of motivation in early math and science learning was discussed and the theoretical assumptions underlying prevalent motivation theories were reflected. The review led to the conclusion that motivation is thoroughly studied among older children, but little is known about young children's math and science motivation. Specifically, basic assumptions regarding the structure and content-specificity of motivation have not been tested for young children ages 5-6. Moreover, it remains unclear whether individual differences in children's motivational beliefs already exist at the preschool level. Specifically, previous studies have found gender differences in older children's motivation. Moreover, the importance of children's age and previous experiences for their motivation was highlighted. Whether similar differences related to age, gender, and previous experiences, can be found at the preschool level, has not been examined.

Based on the notion that motivation is shaped by experience, chapter 6 discussed teacher influences on children's motivation, i.e. teachers' practices, feedback, and exemplary behavior. The importance of the quality of teachers' practices is well documented in the research literature, but little is known about the frequency of teachers' practices in math and science, at least in the German context, and its relevance for children's motivation. In addition, learning through modeling is considered a powerful mechanism through which children acquire teachers' beliefs and behaviors, particularly for children of the same gender. Yet, no study has so far investigated these relations with regard to preschool teachers' and young children's motivation in math and science.

Teachers' practices and behavior are, in turn, assumed to be predicted by their competencies. Specifically, the relevance of teachers' self-efficacy beliefs, as one aspect of their motivation, as well as teachers' knowledge were discussed in greater detail. The discussion revealed that teachers' professional knowledge is comparatively well studied, whereas little is known about teachers' self-efficacy beliefs in math and science, their interrelation with teachers' knowledge, and their relevance for teachers' ability to recognize mathematical elements in children's play.

The present dissertation aims to address these research gaps in three separate studies based on the following research questions:

1. Do fundamental assumptions underlying the expectancy-value theory of achievement motivation apply to 5-6-year-olds? Are there individual differences in children's motivation as a function of age, gender and previous experiences in preschool?
2. How is children's motivation related to their preschool teachers' own motivational beliefs and the frequency of their practices? Are there gendered patterns in these relations?
3. How are teacher's motivation and knowledge interrelated and how do they influence teachers' sensitivity to mathematical elements in children's play?

In doing so, the present thesis addresses several levels of preschool education, as illustrated in figure 5: Teachers' motivation as an important prerequisite, their educational practices and children's motivation as one aspect of child outcomes.

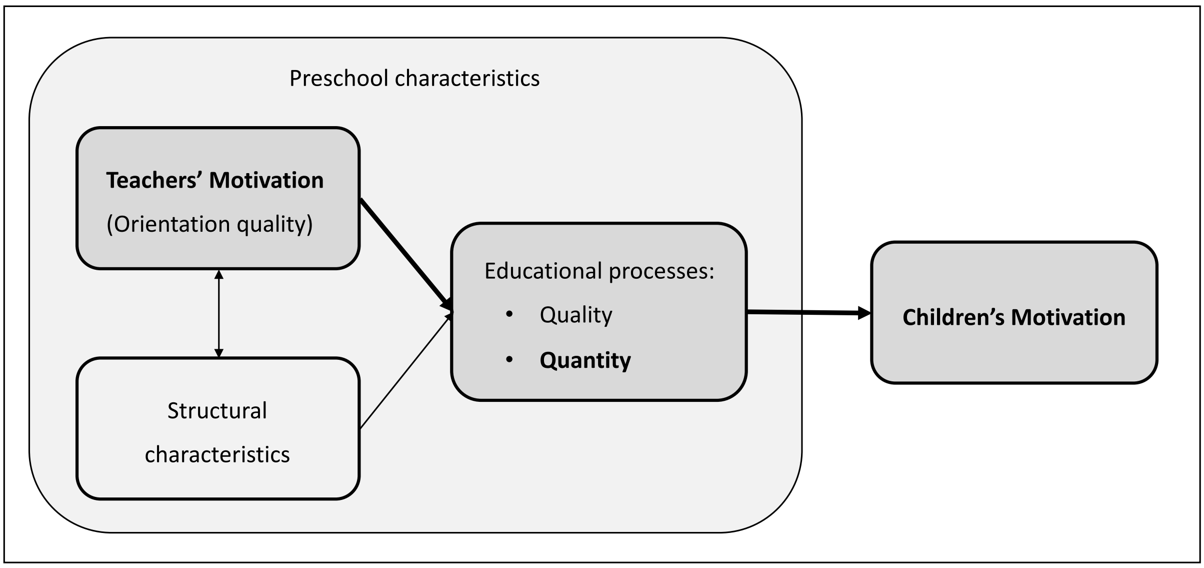

Figure 5. Overview of research aims, based on the structural-process model by Roux and Tietze (2007); Tietze et al. (1998). Research focus is highlighted in bold.

The research questions above are investigated using two different data sets: Studies 1 and 2 draw on data that was collected in 5 federal states of northern Germany in 2015/2016 as part of the research project EASI Science[6]. Study 3 uses data that was collected as part of a study conducted by H.-G. Rossbach and Y. Anders at the University of Bamberg, Germany in 2012. It is important to note that the dataset for studies 1 and 2 focus on science and the dataset for study 3 focuses on math only.

[6] The research project EASI Science (Early Steps into Science) examines the effects of early science education on both teaching staff and children. The project is funded by the "Little Scientists' House" Foundation together with the German Federal Ministry of Education and Research.

SUMMARY OF THE THREE STUDIES

The present dissertation explores the role of motivation in early math and science education at the child- and the teacher-level. Based on the theoretical background on this topic, three empirical studies were conducted to answer the research questions listed above (see chapter 8). In the following, each of the three empirical studies will be summarized (please see the Appendices I-III for the full manuscripts of the three studies).

9. Study 1

Study 1 aimed to shed light on the motivational beliefs of young children, aged 5-6. Because basic assumptions underlying the expectancy-value model by Eccles et al. (1983) have not been tested for children this young, the study investigates (a) the differentiation between young children's expectancy and value beliefs in science as well as (b) the content-specificity of these beliefs. In addition, study 1 explored whether individual differences as function of children's age, gender and previous science experience are already present. In both respects, study 1 was exploratory in nature, since very little is known about young children's science motivation. One of the reasons for this gap in the research literature on young children's science motivation is that it is hard to measure, because children this age cannot yet read or write and may not be familiar with central concepts and terms used in the measurement of these beliefs among older children. Consequently, a new measure for children's science motivation was developed and subsequently used to answer the research questions. Measurement development was based on an extensive review of existing instruments as well as several pilot phases. The main study was based on a new sample of 277 children aged 5-6 years in 55 preschool centers in 5 federal states in Germany. The structure of children's science motivation was investigated by confirmatory factor analyses (CFA). Gender differences were tested using one-way analyses of variance and the relation to age and children's science experiences were investigated using regression analyses. The preschool centers' educational focus on science was used as a proxy of children's science experience.

CFA results showed that, in line with the expectancy-value-model by Eccles et al. (1983), children's science motivation could be differentiated empirically into their self-efficacy (= expectancy) beliefs and enjoyment (= value) ($\chi^2 = 226.99$, $df = 208$; RMSEA = 0.03; CFI = 0.94; SRMR = 0.08; significant increase in model fit compared to the single factor solution: $\Delta\chi^2 = 63.48$, $p < .001$). The two latent factors were moderately correlated ($r = .41$, $p < .001$). However, they could not be further distinguished into content areas within science, i.e. life science and physical science, as the latent factors were highly correlated ($r \geq .91$, $p < .001$). Based on these results, two scales were formed, representing children's self-efficacy beliefs and enjoyment. Reliability results for the scales capturing children's self-efficacy beliefs and enjoyment in science were good ($\alpha = .87$ and $\alpha = .86$, respectively). Descriptive statistics showed that children were on average confident in their own ability in science and enjoyed learning about science (range = 1-4; $M = 3.00$, $SD = 0.66$ and $M = 3.55$, $SD = 0.54$ respectively). Regarding individual differences, results revealed significant age differences, with older children reporting higher self-efficacy beliefs in science ($\beta = .12$, $p < .05$). No significant gender differences were found in children's motivation. Importantly, children in preschools with an explicit science focus showed higher motivational beliefs than children in preschools without a science focus ($\beta = .36$, $p < .01$ for children's self-efficacy; $\beta = .28$, $p < .05$ for children's enjoyment). Taken together, study 1 provides further research and practice with a reliable, validated, and economic assessment of young children's science motivation. Moreover, the findings have important practical implications, as they reveal that early science experiences in preschool are associated with higher motivation in science among the children.

10. Study 2

Study 2 built on study 1 and investigated teacher-level influences on children's motivation. The review of the literature revealed two processes which are considered important for children's learning and development, but have not been previously studied with regard to children's science motivation: The frequency of teachers' practices and teachers' exemplary behavior. Study 2 aimed to address this research gap and investigated the interplay between preschool teachers' motivational beliefs, i.e. their self-efficacy beliefs, the frequency of teachers' practices and children's motivational beliefs in science.

It was assumed that the frequency of teachers' science practices would be positively related to children's motivation, since children require regular learning situations in order to be able to develop positive motivational beliefs about science and themselves as science learners. Moreover, based on the notion that teachers function as role models for the children in their classroom, teachers' science self-efficacy beliefs were assumed to be positively related to children's own motivational beliefs in science. This relation may be stronger for girls than for boys, since > 90% of preschool teachers are female and children tend to imitate same-sex models more than opposite-sex ones due to perceived similarity (Bandura, 1977b; Basow & Howe, 1980; Perry & Bussey, 1979). These mechanisms and their gendered patterns were examined based a sample of 277 children and 348 teachers for the descriptive and regression analyses, and a limited sample of 234 preschool children, nested in 88 preschool teachers for the analyses linking teachers' motivation and practices, and children's motivation.

Descriptive results for the child level revealed significant gender differences in children's science self-efficacy, favoring of boys ($F(1,275) = 7.45$, $p < .01$). Descriptive results for the teacher level showed that teachers engaged in science-related activities together with the children in their classroom about 1-3 times a month, on average. Only 1.9% of preschool teachers engage in science daily and 11.9% never engage in science activities. Regression results revealed that preschool teachers' science self-efficacy beliefs were positively related to the frequency of their science activities: ($\beta = .31, p < .01$). Results from two-level path analysis also showed that teachers' self-efficacy beliefs in science were related to children's science self-efficacy beliefs ($\beta = .31, p < .01$). No significant relation was found for the frequency of teachers' activities and children's motivation. Further analyses of these relations revealed that they are comprised of gendered patterns: The relation between teachers' science activities and children's self-efficacy beliefs was significantly stronger for boys than for girls ($\Delta\beta = .31, p < .05$). In contrast, the relation between teachers' and children's self-efficacy beliefs in science was significantly stronger for girls than for boys ($\Delta\beta = -.29, p < .05$). A similar pattern existed for children's enjoyment: Teachers' self-efficacy beliefs were more strongly related to girls' than boys' enjoyment ($\Delta\beta = -.24, p < .05$), whereas teachers' science activities tended to be more strongly related to boys' than girls' enjoyment. However, this latter relation was not statistically significant ($\Delta\beta = .31, p > .05$).

The second study provides empirical evidence on the interplay between preschool teachers' self-efficacy beliefs in science, their instructional practices, and boys' and girls' motivation to learn in science. In line with previous studies (Appleton & Kindt, 1999; Harlen & Holroyd, 1997), results indicated that preschool teachers' science self-efficacy beliefs mattered for the frequency of their science practices: The more confident teachers were in teaching science, the more often they engaged in science activities with the children in their classroom. Moreover, findings revealed gendered patterns in the relation between teachers' science self-efficacy beliefs, their science activities, and children's motivation: Teachers' science activities seemed to be more strongly related to boys' motivation, whereas teachers' self-efficacy beliefs were more strongly related to girls' motivation. Although previous research has documented gendered patterns in the association between teachers' own beliefs, their practices, and children's motivation for the primary and secondary school level (e.g. Beilock et al., 2010; Dweck et al., 1978), this is the first study to reveal that similar patterns exist at the preschool level.

11. Study 3

Study 3 focused on the teacher level and investigated the interrelations between preschool teachers' motivation and their professional knowledge in math. Since learning in preschool typically takes place in play-based situations, teachers' ability to recognize mathematical elements in children's play is an important prerequisite for their practices and children's learning gains (McCray & Chen, 2012). Study 3 investigated which other competencies teachers require in order to be sensitive to mathematical elements in children's play. It was assumed that content knowledge (CK) in math is required to recognize mathematical elements in children's play. Yet, whether or not teachers recognize mathematics may also depend on their confidence in math. Teachers' mathematical ability beliefs, i.e. their mathematical self-concept and mathematical self-efficacy beliefs, were therefore also assumed to be relevant for teachers' sensitivity to math. Study 3 examined both, teachers' CK as well as their ability beliefs with regard to teachers' sensitivity to mathematical elements in children's play. The study was based on a sample of 221 preschool teachers from 29 preschool centers in two federal states in Germany.

Regression results revealed a positive relation between preschool teachers' mathematical CK and their sensitivity to mathematics in children's play ($\beta = .29$, $p < .001$): The higher preschool teacher's mathematical CK, the better they recognized mathematical content in children's play. Structural equation modeling (SEM) results further revealed that preschool teachers' mathematical CK was positively related to both, teachers' mathematical self-efficacy ($\beta = .43$, $p < .001$) and their mathematical self-concept ($\beta = .28$, $p < .001$). Mathematical self-efficacy and mathematical self-concept were moderately correlated, thus indicating that they represent different facets of preschool teachers' ability beliefs ($r = 0.43$, p

< .001). Mathematical self-efficacy ($\beta = 0.34$, $p < .001$), but not mathematical self-concept ($\beta = -.04$, $p > .05$), was positively related to teachers' sensitivity to mathematics in children's play. Moreover, the direct relation between teachers' mathematical CK and their sensitivity was non-significant in the SEM model. Instead, an indirect relation via teachers' self-efficacy beliefs remained: The higher teachers' mathematical CK, the higher their mathematical self-efficacy beliefs and the more sensitive they were to mathematical content in play-based situations. These findings demonstrate the relevance of teachers' self-efficacy beliefs for their ability to recognize mathematical content in children's play situations. As teachers' sensitivity to mathematics has been shown to predict pedagogical practice (McCray & Chen, 2012), the results also underline the importance of self-efficacy beliefs for their practices.

GENERAL DISCUSSION

12. Major contributions of the present dissertation

Based on the summary of the research findings, the following chapter will discuss the more general insights gained by the three studies in light of the theoretical background introduced in chapters 1-8. Subsequently, general limitations and directions for future research and practice will be pointed out.

12.1. Theoretical assumptions about young children's motivation

Children's motivation in math and science is considered a key determinant of their future academic effort, academic choices, and academic success in these subjects (Wang & Degol, 2013; Wigfield, 1994). Eccles et al.'s (1983) expectancy-value theory is one of the most prevalent models that synthesized multiple factors affecting achievement motivation in a comprehensive model. Although the model is widely tested and validated for school-aged children and adolescents (Denissen et al., 2007; Ferla et al., 2009; Goetz et al., 2010; Jacobs et al., 2002; Marsh et al., 2005), we do not know if the assumptions underlying the model also hold for younger children. The present dissertation draws on a sample of preschool children aged 5-6 years and can therefore provide insights on the applicability of these assumptions to younger children. Specifically, two of the main assumptions could be tested for children aged 5-6 years: (1) The assumption that expectancy and value beliefs are distinguishable but positively related and (2) the content-specificity of expectancy and value beliefs within the science domain.

(1) The expectancy-value model distinguishes between expectancy beliefs, which refer to individual's confidence or self-efficacy beliefs in a task, and value beliefs, which include the enjoyment of the task among other aspects (Eccles & Wigfield, 2002). It is assumed that expectancy and value beliefs are positively related (Eccles & Wigfield, 2002). However,

Wigfield (1994) suggests that the correlation between children's expectancy and value beliefs may not be the same across all ages. He argues that the relation may grow stronger with age and more experience, as children begin to attach more value to domains in which they feel competent (Wigfield, 1994). This assumption has also been empirically supported by a number of studies for school-aged children (Denissen et al., 2007; Jacobs et al., 2002; Marsh et al., 2005). Yet, these results may not be transferable to the preschool level. Children aged 5-6 years may lack sufficient experience with a subject, such as science, in order to develop distinct beliefs about their own ability and their enjoyment in that subject. Alternatively, in line with Wigfield's (1994) prediction, children may have distinct expectancy and value beliefs, but these beliefs may not be related at all since children this young may like a subject regardless of their ability perceptions. Study 1 investigated the structure of children's motivation among 5-6-year-olds in science. Results showed that children's self-efficacy beliefs and enjoyment in science represented separate factors, which were moderately correlated (latent $r = .41$). The magnitude of the correlation was similar, although smaller, than in an earlier study of kindergartener's science motivation by Mantzicopoulos et al. (2008). The difference in the strength of the correlation may be explained by the fact that Mantzicopoulos et al. (2008) drew on a sample of children who participated in a 5-10-week science program and thus have, on average, more experience with science than the children in study 1. The fact that Mantzicopoulos et al. (2008) found a higher correlation in their sample of more experienced kindergarteners also supports Wigfield's (1994) prediction that expectancy and value beliefs become more closely related with experience. In line with this, studies on older children and adolescents typically find even higher correlations around $r = .4\text{-}.6$ (see Ferla et al., 2009; Marsh et al., 2005). Thus, the results of study 1 can be interpreted as supportive of the theoretical distinction between expectancy and value beliefs as suggested by the expectancy-value model (Eccles et al., 1983). Moreover, the strength of the correlation is in a range that would be expected based on Wigfield's (1994) proposition of the development of these beliefs and given earlier findings for older and more experienced children. These are important findings for future research, as they confirm that the assumptions underlying the expectancy-value model hold for children this young and can thus be applied in subsequent studies with children of similar ages.

(2) A second assumption underlying the expectancy-value model is domain-specificity: Expectancy and value beliefs are assumed to be highly domain-specific beliefs, i.e. specific to math, science, reading etc. (Eccles & Wigfield, 2002). This assumption has been empirically supported even for children in the early elementary school years (Eccles et al., 1993; Marsh et al., 1991; Wilson & Trainin, 2007). Thus, it is well established that even younger children distinguish between different domains when judging their ability and value. What is not well studied is the differentiation of motivational beliefs between content areas within a domain. Because the instrument used in study 1 draws on content- rather than on domain-specific items, it is suitable to investigate the content-specificity of children's science motivation. Results showed that young children's self-efficacy beliefs and enjoyment could not be further distinguished into the areas of life and physical science. The most likely explanation for this finding is that children simply do not have enough experience with the adult-made categories "physical science" and "life science" to distinguish between these areas in their motivational beliefs. In line with this, Harter (1990) argues that children first have a broad understanding of their general ability, e.g. being "smart" or "dumb", and later develop a more specific sense of their competence in different activities. Research on the developmental trajectories of ability beliefs and enjoyment/interest also shows that these beliefs become more refined as children get older and thus more experienced with different content areas (Epstein & Eccles, 2014; Marsh et al., 1991). The results of study 1 thus indicate that children's science motivation has not yet begun to differentiate into these content areas within the science domain. This is an important finding for future studies, specifically regarding the measurement of children's science motivation. It is also highly relevant for future research on the developmental trajectories of children's motivation because it shows that longitudinal studies starting in the

late preschool years should be particularly informative since the transition to school is a period where children gather a lot of new experiences with science in a short period of time – which should then be visible in the structure of their motivational beliefs.

12.2. Influencing factors of children's motivation

The development of children's motivation is grounded in their experience in preschool and it is therefore important to get a better understanding of influencing factors at different levels of preschool education. The present dissertation provides insights on two levels, namely the preschool level and the teacher level with regard to early science education. Study 1 focused on the preschool level and revealed that the preschool centers' focus on early science education was positively associated with children's science motivation: Children in preschools centers that focus on science showed higher motivational beliefs than children in preschool centers with a different educational focus. Similar findings have been obtained by Mantzicopoulos et al. (2008), who found that children who engaged in a science program for a longer period of time reported higher motivational beliefs in science. Thus, children with, presumably, more experience in science seem to have higher science motivation. Consistent with this conclusion, findings for study 1 also showed that older children, who are likely to have more experience with science, reported higher motivational beliefs in science. Taken together, study 1 provides a first indication that early science learning experiences in preschool may be beneficial for children's science motivation, however alternative explanations for this finding cannot be excluded (see chapter 13.1). Moreover, study 1 used a rather distal indicator of children's science learning experiences, namely the preschools' science focus, and thus cannot explain which mechanisms account for this association.

Preschool teachers are assumed to be in children's more proximal environment (Bronfenbrenner, 1977), since they interact with the children on a daily basis and may thus influence children's motivation directly. In the theoretical background of this dissertation two major processes through which teachers may influence children's motivation were discussed in greater detail: (1) The quality and quantity of teachers' practices and (2) socialization processes including teachers' feedback and exemplary behavior. The empirical part of this dissertation investigated two of these processes, namely the frequency of teachers' practices and teachers' exemplary behavior in the science domain.

(1) Based on the assumption that children's subject-specific motivation is grounded in their experiences with that subject, regular science learning opportunities are assumed to be essential for children to be able to develop positive motivational beliefs in science. In this regard, the research literature has underlined the importance of teachers' involvement during these learning opportunities for children's motivation (Lerkkanen et al., 2012; Stipek et al., 1995). Yet, it remains unclear how often teacher engage in science learning activities together with the children. Responding this lack of research, particularly in the German context, study 2 investigated the frequency of teachers' science practices and their relevance for children's motivation. Results revealed that teachers engaged in science-related activities together with the children in their classroom about 1-3 times a month and less than 2% of them offered daily science activities. Thus, most children rarely engage in science-related learning activities together with their preschool teachers. Study 2 also provides some novel insights on the relation between the frequency of teachers' science activities and children's science motivation. Findings showed no relation in the whole sample. However, there was a positive relation for boys. Because the associations differed by gender, the findings will be discussed in greater detail in chapter 12.3.

(3) In addition to teachers' responsibility to offer regular (and high-quality) learning opportunities, teachers' also act as socializers for the children in their classroom. The social cognitive theory (Bandura, 1986; Schunk, 1987; Urdan & Schoenfelder, 2006) as well as the expectancy-value model (Eccles et al., 1993; Wang & Degol, 2013) propose several mechanisms through which preschool teachers' may shape children's learning and

development. These include (a) teacher's verbal and non-verbal communication of feedback as well as (b) teachers' exemplary behavior as role models. Study 2 investigated the second of these processes, i.e., the relevance of teachers as role models for children's motivation in the science domain. Specifically, the study examined the relation between preschool teachers' science self-efficacy beliefs and children's self-efficacy and enjoyment in science. Results revealed a positive relation, which was comprised of gendered patterns: Preschool teachers' self-efficacy beliefs were more strongly related to girls' than to boys' motivation in science. Because these relations were comprised of gendered patterns, they will be discussed in greater detail in the following chapter.

12.3. Gender differences and gendered patterns

Studies on older children's and adolescents' achievement motivation typically find gender differences with boys being more confident and reporting more enjoyment in areas associated with math and science (Eccles et al., 1993; Simpkins et al., 2006). Findings for younger children, however, are inconsistent: Some studies found no significant gender differences (Andre et al., 1999; Mantzicopoulos et al., 2008), whereas other studies that focus on children's interest found gender differences in favor of boys (Alexander, Johnson, Leibham, & Kelley, 2008; Leibham et al., 2013; Nölke, 2013). Studies 1 and 2 of this dissertation investigated gender differences in children's motivation among a sample of 5-6 year olds for the science domain. The results from these studies seem to be conflicting: Study 1 found no gender differences and study 2 revealed significant differences in children's science self-efficacy beliefs, with boys being more confident in their science ability than girls. It is important to note that, although both studies draw on the exact same sample of 277 preschool children, the analyses differed in terms of the control variables. Study 1 controlled for children's science experience as indicated by the center managers' report of the preschools' science focus, children's receptive vocabulary skills, their numerical and general cognitive abilities as well as children's age and language spoken at home. Study 2 did not control for any of these variables. Thus, the inconsistent findings may result from an interaction of one of the control variables with the children's gender. This would only affect control variables that are related to the outcome, which is the case for children's age and the preschools' science focus. However, the age distribution was similar among boys and girls and the age range was only 1 year. It therefore seems more likely that the preschool's science focus acted as a moderating variable. But in what way? There are two alternative constellations in which gender differences may vary in preschools with and without a science focus. First, gender differences may be stronger in preschools without a science focus than in preschools with a science focus. This would imply that children start out with gender differences when they have little experience with science education, such as in preschools without a science focus, and that these differences are reduced with the right interventions. Contrary to this assumption, a study by Sadler et al. (2012) on the development of gender differences throughout school revealed that gender differences become more, not less, pronounced as children progress through school and gather more experiences with science. Thus, a second explanation seems more likely: Gender differences may be stronger in preschool centers with a science focus because of children's experiences. For instance, preschool centers with a science focus may implement early science education by offering more frequent science activities. Results from study 2 showed that frequent science activities were more strongly related to boys' than to girls' motivation. This may indicate that boys somehow benefit more from these activities than girls, leading to larger gender differences in preschools with a science focus than in preschools with a different educational focus. The possibility that gender differences in favor of girls produce the inconsistent findings can be eliminated because results from study 2 revealed gender differences in favor of boys in the entire sample. Thus, the most likely explanation for the inconsistent results in studies 1 and 2 is that gender differences are larger in preschool centers with a science focus and controlling for the preschool's science focus in study 1 partly accounted for these differences. Future studies are required to test this conclusion and investigate the underlying mechanisms. If more frequent science activities in preschools with a science focus indeed benefit boys more than girls, this finding would have important practical implications (see chapter 14).

Gendered patterns were also found with regard to the relation between teachers' science self-efficacy beliefs and children's motivation: Teachers' self-efficacy beliefs were more strongly associated with girls' than with boys' motivation. Although the mechanisms underlying this association were not studied, role modeling is one of the most likely explanations. Observational learning through modeling is considered an important process through which children adapt teachers' beliefs and behaviors (Bandura & Walters, 1963). This mechanism is particularly powerful for models of the same gender due to the perceived similarity to the model (Gunderson et al., 2012). In fact, competent female role models in STEM have been discussed for a few decades and there is a large body of empirical evidence that supports the effectiveness of this approach among older children, adolescents, and adults (e.g. Evans et al., 1995; Marx & Roman, 2002; Smith & Erb, 1986). For instance, Marx and Roman (2002) showed in an experimental design that female students' own math ability beliefs could be increased by a competent female experimenter as a role model. Results from study 2 indicated that similar relations may exist at the preschool level. This is an important finding as role modeling may present one way through which teachers can foster girls' science self-efficacy beliefs, which is particularly crucial in light of the fact that gender differences seem to exist this early on. Nevertheless, since the mechanism underlying this association cannot be determined, further investigation is warranted.

12.4. Preschool teachers' competencies and practices

Preschool teachers seem to play an important role for children's motivation in science. It is their responsibility to offer regular and high-quality math and science learning opportunities and embody confident role models for the children in their classroom. In order to offer the best possible learning environment, preschool teachers require a number of competencies, including motivational beliefs and professional knowledge in the subjects they teach (Anders, 2012; Fröhlich-Gildhoff et al., 2011). For instance, preschool teachers' pedagogical content knowledge (PCK) in math, and particularly their ability to recognize mathematical elements in children's play, has been shown to predict the quality of their instructional practices and children's learning gains in math (McCray & Chen, 2012). Teachers' mathematical content knowledge (CK) was identified as an important prerequisite for teachers' ability to recognize mathematical learning opportunities (Dunekacke et al., 2015). Less is known about the influence of preschool teachers' motivation. Research based on school teachers indicates that teacher motivation, and particularly teachers' self-efficacy beliefs, are a strong predictor of their teaching practices and children's learning gains (Goddard et al., 2000; Justice et al., 2008; Kahle, 2008; Schiefele, 2009). Yet, few studies have investigated preschool teachers' self-efficacy beliefs. The present thesis therefore examined the self-efficacy beliefs of preschool teachers in the math and science domain. Specifically, study 2 investigated the relation between preschool teachers' science self-efficacy beliefs and the frequency of their practices in science, whereas study 3 focused on the interrelations between teachers' mathematical self-efficacy beliefs and their professional knowledge in math. Results for study 2 revealed that teachers' self-efficacy beliefs in science were positively associated with the frequency of their science practices. Thus, more confident teachers engaged in science more often. Results from study 3 showed that preschool teachers' self-efficacy beliefs in math were also associated with teachers' ability to recognize mathematical elements in children's play: The more confident teachers were in their own ability in math, the better they were at recognizing mathematical elements. Thus, the combined findings from study 2 and 3 showed that preschool teachers' self-efficacy beliefs were associated with their ability to recognize and initiate early learning opportunities in the mathematics and science domain. These results are in line with previous findings for school teachers (Goddard et al., 2000; Justice et al., 2008;

Kahle, 2008; Schiefele, 2009) and thus indicate that teachers' self-efficacy beliefs are highly relevant at all levels of education. Yet, whereas school teachers' self-efficacy beliefs have been thoroughly studied for the last decades, the research literature on preschool teachers' self-efficacy beliefs remains scarce. In fact, research has largely focused on preschool teachers' professional knowledge and attitudes. The findings of the present dissertation should therefore encourage further research, as they indicate that knowledge alone may not be sufficient. Specifically, it seems that preschool teachers need to be confident enough in their ability in order to use that knowledge for their practices. Results from study 3 also indicate how teachers' confidence may be fostered: Teachers' mathematical CK was positively related to their self-efficacy beliefs, i.e. the higher teachers' mathematical CK, the more confident they were in math. Thus, teachers' self-efficacy beliefs may be fostered by improving teachers' knowledge, e.g. through professional development.

13. Limitations and directions for future research

Study-specific strengths and limitations are discussed in the discussion section of each study (see Appendices I-III). In the following, general limitations of the thesis as a whole will be highlighted and, subsequently, directions for future research will be discussed.

13.1. Validation of the findings obtained in this dissertation

The present dissertation consists of three studies, all of which are based on cross-sectional data. As a consequence, the findings obtained in this dissertation are of correlative nature and cannot be interpreted in a causal manner. In order to validate the found associations in this dissertation and to investigate the directions of the associations, future longitudinal studies are required. Ideally, future studies allow for more than two time points and include the preschool level, teacher level, the educational processes, and the child level, in order to investigate the direction of the identified mechanisms in greater detail.

For instance, study 1 of this dissertation indicated that the preschool centers' focus on science was associated with higher science motivation among the children. Yet, longitudinal data is required to replicate these findings and to determine the direction of these associations. Specifically, at least two time points are required in order to determine whether an increase in children's motivation from time 1 to time 2 can be explained by the preschools' science focus. In addition, potential selection effects would need to be examined in more detail. For instance, parents may choose to send their child to a preschool center with a science focus because their child shows a particular interest in science or because the parents themselves consider science important (and also foster children's science motivation at home). Thus, children in preschools with a science focus may be more motivated in science than children in preschools with a different educational focus to begin with. However, a study by Alt, Heitkötter, and Riedel (2014) showed that a much larger percentage of parents chose preschool centers because of its proximity to their home (86%) or opening hours (78%) than because of their preference for the educational focus of the preschool (22%). Moreover, due to the shortage in preschool places, many parents may not have much choice at all. Nevertheless, these and additional factors, including structural characteristics of the preschool, would need to be controlled.

Furthermore, studies 2 and 3 revealed that teachers' self-efficacy beliefs in math and science were related to their ability to recognize mathematical elements in children's play, to the frequency of teachers' science practices and to children's science motivation. Again, longitudinal data would be required to clarify the direction of these associations. Specifically, at least three time points would be necessary in order to determine whether teachers' self-efficacy beliefs indeed predict their practices, and whether teachers' practices predict children's motivation. Longitudinal data could also test whether the direction of the relation found between teachers' self-efficacy beliefs and children's motivation, particularly among girls, is consistent with the role modelling hypothesis. In addition, assumed causal relations should be explicitly tested using an experimental design. This may be hard to do for teachers' self-efficacy beliefs, however, the effects of more frequent science activities on children's motivation could be tested using a pretest-posttest experimental design.

Regarding the validity of the measures, it is important to note that all three studies draw on self-report data. Although self-reports are necessary to assess motivational beliefs, observational measures are required to validate some of the findings of this dissertation as well as to investigate the extent to which these motivational variables translate into behavior. For instance, observational measures of children's motivation, such as the amount and duration of their engagement in science-related activities, would provide further validation of the young children's science motivation scale (Y-SCM) introduced in study 1. Moreover, the measure of teachers' ability to recognize mathematical content in children's play (study 3) should be validated using observational data in order to test whether higher scores are associated with a better recognition of mathematical learning opportunities in practice. In addition, observational measures could provide a more in-depth understanding of the gender-specific relations between teachers' self-efficacy beliefs, their practices and children's motivation found in study 2. Specifically, with regard to the gendered patterns linking the frequency of teachers' science activities and children's motivation, it was argued that this relation may be stronger for boys because these is a qualitative or a quantitative difference in teachers' interactions with boys and girls during these learning opportunities. Since the research literature on qualitative and quantitative differences in teacher-child-interactions is scarce and findings are inconsistent, this topic warrants further empirical investigation. For instance, future studies could combine an observational measure of the quality of teacher-child-interactions, such as the CLASS (Pianta, La Paro, & Hamre, 2008) and/or SSTEW (Siraj-Blatchford, Kingston, & Melhuish, 2015) with an observation of the number of teacher- and child-initiated interactions in the classroom during early science activities, and compare these findings by children's gender.

13.2. Generalizability

One central aspect that should be investigated in future studies is the generalizability of results across subjects. Although this dissertation provides insights on two central STEM subjects, mathematics and science, each of the studies investigated only one of the two subjects instead of both subjects simultaneously. Thus, it remains unclear whether the results obtained for math can be transferred to science and vice versa. For instance, early math education might be more established in practice than early science education, which may lead to different findings by subject. In this case, the association between the frequency of teachers' practices and child outcomes may be stronger in science than in math simply because there is more variation in teachers' science practices. In a similar pattern, Simpkins, Davis-Kean, and Eccles (2005) compared parental influences on elementary school children's participation in math, science and computer activities and found that the influences were strongest for children's computer activities. The authors argue that this may be due to the fact that computer activities are less common in elementary school compared to math and science and consequently parental influences may be more powerful. Future studies should therefore compare the found associations by subject.

A second limitation relates to the regional generalizability of findings. It is important to note that findings may not be generalizable to all German preschools. Although northern, eastern, western, and southern Germany, as well as urban and rural areas, are represented if all three studies are combined, participation in the studies was optional and thus preschool centers and preschool teachers with an educational focus or interest in early math and science education may be overrepresented compared to the German average. This may be particularly the case in studies 1 and 2, which were part of a larger research project that aimed to compare children in preschools with and without a focus on science education and thus deliberately oversampled preschool centers that focus on science. As a consequence, the sample might be selective in that children's and teachers' motivation may be more positive and teachers' practices more frequent than in the average German preschool. However, this would only affect the generalizability of the central tendencies found in the present dissertation but not the generalizability of the associations. With regard to the generalizability of the findings to other countries, similar limitations apply. All studies were based on a sample that may be subject to selection bias and may thus not be representative. In addition, one central characteristic of German preschools is that they follow a child-centered and play-based approach. Thus, findings may not be generalizable to countries that follow more didactic, teacher-directed approaches. This may affect the central tendencies of the measures as well as the associations found in the three studies. Specifically, the young children's science motivation scale (Y-SCM) used in study 1, the measure of teachers' self-efficacy beliefs and practices in study 2 as well as the measure of teachers' sensitivity to mathematics in study 3 are all based on a pedagogical approach that emphasizes play-based learning which is grounded in children's everyday activities. The central tendencies obtained for these measures may therefore not be generalizable to countries with other pedagogical approaches. The associations found for these measures may also differ depending on the pedagogical approach. For instance, study 1 found that children's motivational beliefs could not be distinguished into the areas of physical science and life science. This pattern of results may be different in countries where early science learning is more structured and teacher-directed, and children may thus be familiar with these categories. Similarly, teachers' sensitivity to mathematical content in children's play, which is a central element in study 3, may be more relevant in countries where learning is typically play-based than in countries where mathematical learning situations are pre-planned because it is more important for teachers in these countries to recognize teachable moments in children's play. Future studies should therefore investigate the generalizability of the findings obtained in this dissertation across countries with different pedagogical approaches.

13.3. Areas for further research

In addition to the strategies to further validate and generalize the found associations, future studies should broaden and extend the focus of this dissertation.

First, study 2 found significant gender differences in children's science motivation and it was argued above that children's early science experiences may contribute to these differences. Thus, future studies should compare gender differences among children with more and less science experiences in preschool. In addition, longitudinal studies are required to investigate the developmental trajectories of gender differences in children's science motivation. It is well documented that girls show lower motivational beliefs in science by the time they are in primary school (Cvencek et al., 2011; DeWitt et al., 2011; Jacobs et al., 2002; Wigfield et al., 1997) and later in secondary school (e.g. Jones et al., 2000; Marsh et al., 2005; Nagy et al., 2010), and these differences eventually contribute to women being underrepresented in STEM careers (Lörz & Schindler, 2011; National Science Foundation, 2011; OECD, 2016). Study 2 reveals that gender differences already occur among children ages 5-6. Thus, future studies should move to even earlier ages in order to investigate when these differences emerge and how they develop until primary school.

Second, future studies should broaden the focus of the present dissertation with regard to teachers' practices. Whereas this dissertation provides first insights into the interrelations between the frequency of teachers' practices and children's motivation in science, it might be fruitful to include other aspects of teachers' practices and compare their relation to children's motivation. For instance, the quality of early learning situations is considered an important predictor of children's learning gains and might thus also be relevant for children's motivation. In fact, Lerkkanen et al. (2012) found that child-centered approaches, which are conceptually closely related to high-quality instruction (Hopf, 2012; Siraj-Blatchford et al., 2002; Sylva et al., 2004), were more beneficial for children's motivation in the long run than didactic, teacher-directed strategies. Yet, quality alone may also not be sufficient. Steffensky et al. (2017) showed in a recent study that neither the quality nor the quantity of early science learning situations were related to children's knowledge in science. Instead, there was a significant interaction effect: Quality was only relevant given a certain quantity of early science practices and vice versa. Similar mechanisms may exist with regard to children's motivation. Thus, future studies should investigate and compare the influence of the quantity and the quality of teachers' practices on children's motivation.

Third, results of the present dissertation underline the relevance of teacher's self-efficacy beliefs in mathematics and science for their practices, which is in line with previous findings for the primary and secondary school (Harlen & Holroyd, 1997; Relich, 1996). Nevertheless, it would be interesting to include other aspects of teachers' motivation in addition to their self-efficacy beliefs. The expectancy-value model considers two aspects of motivation as predictors of individuals' choices and performance: Their expectancy (self-efficacy) beliefs and their subject task value (Eccles et al., 1983). Similarly, Schiefele et al. (2013) proposed that teacher interest is highly relevant for their practices: They found that primary and secondary school teachers with higher interest used more cognitively stimulating instructional practices. Thus, teachers' interest (intrinsic value) may also play a central role for their practices in math and science and, consequently, for children's motivation. Moreover, study 2 revealed that the relation between teachers' science self-efficacy beliefs and children's – and particularly girls' – motivation was much lower for children's enjoyment than for children's self-efficacy. In this regard, teachers' interest may be more relevant for children's enjoyment than teachers' self-efficacy beliefs. Future studies should therefore investigate how teachers' self-efficacy beliefs, as well as their interest in math and science, relate to their practices and children's motivation.

Lastly, teachers' professional knowledge and their self-efficacy beliefs should be investigated in greater detail. Specifically, study 3 revealed that teachers' ability to recognize mathematical content in children's play, as one aspect of teachers' PCK, is related to preschool teachers' mathematical self-efficacy beliefs. Both competency aspects, i.e. teachers' self-efficacy beliefs and their PCK, are considered important predictors of teachers' practices (Guo, Dynia, Pelatti, & Justice, 2014; McCray, 2008; McCray & Chen, 2012). Yet, no study has so far investigated both aspects simultaneously. In fact, these two competency aspects may not act independently with regard to teachers' practices. For instance, teachers' may recognize mathematical elements in children's play, but they may only make use of this knowledge if they feel confident enough to teach math. Similarly, teachers may feel confident in math, but if they do not recognize teachable moments, they will nevertheless offer too little learning opportunities. Future studies should therefore explore preschool teachers' PCK and their self-efficacy beliefs, as well as the interactions between the two, with regard to teachers' practices and child outcomes.

14. Implications for educational policy and practice

Although future research is required to validate and extend the findings obtained in the present dissertation, a number of implications for educational policy and practice can be derived. One central finding of the present dissertation is that young children, aged 5-6 years, are highly motivated to learn in science. Moreover, children in preschool centers with a science focus were even more motivated than children in preschools with a different educational focus. Although it cannot be determined whether this difference was caused by the preschools' science initiatives or by selection effects, these results nevertheless provide a first indication that early science education in preschool does not seem to harm children's motivation – and may even promote it. This result is particularly promising in light of the fact that research on older children and adolescents documents a severe drop in their science motivation throughout primary and secondary school (Andre et al., 1999; Osborne et al., 2003; Sáinz, Upadyaya, & Salmelo-Aro, 2016). If the findings obtained in study 1 can be validated, early science education may be one way to promote children's motivation early on, in order to buffer this drop later in school. Nevertheless, the effectiveness of each science project or initiative in preschool should be evaluated in greater detail. As stated in the theoretical part of this thesis, there is a large diversity of early science programs in Germany. Although the increasing attention on early science education can, in itself, be viewed as a positive development, the quality and effectiveness of these initiatives should be empirically tested. Specifically, projects and programs should undergo scientific evaluations that determine their output and more long-term outcomes in order to ensure that these initiatives are indeed beneficial for children's outcomes. The present dissertation provides a valuable tool for measuring one important aspect of children's outcomes, namely their science motivation. In fact, one of the main goals of most of these initiatives is to arouse and maintain children's interest and self-confidence in science (e.g. Stiftung Haus der kleinen Forscher, 2015), which is exactly what the young children's science motivation (Y-CSM) scale measures. Moreover, the scale is invariant to age and gender and suitable for children who are not familiar with *science* as a term and concept, which makes it ideal for assessing and comparing the outcomes of different early science projects.

Results from the present dissertation also indicate that, within preschools, girls' and boys' may not profit from early science education in the same way: Although regular science practices are certainly a prerequisite for any beneficial effects, results may be interpreted as a first indicator that frequent science activities may be more beneficial for boys' motivation, whereas girls may profit more from confident teachers as role models. These findings need to be further validated using longitudinal data, ideally, combined with an experimental design. However, if supported, they would imply that an increase in the quantity of science education through educational policy and practice may benefit boys more than girls. More attention should therefore be paid to how these learning situations are carried out and how teachers may communicate their own motivational beliefs to the children in their classroom.

With regard to teachers' motivation, results from the present dissertation underline the relevance of teachers' self-efficacy beliefs: Teachers' self-efficacy beliefs were related to their pedagogical practices in science, their sensitivity to mathematics in children's play, as well as to children's motivation. Thus, fostering teachers' self-efficacy beliefs through teacher education and training programs may be beneficial on several levels. Recent findings by Steffensky et al. (2017) showed that teachers' participation in professional development in science was associated with higher self-efficacy beliefs in science. Similarly, findings for the mathematics domain showed that preschool teachers' participation in mathematical training increased their mathematical self-efficacy beliefs (Ciyer, Nagasawa, Swadener, & Patet, 2010; Rosenfeld, 2012). Thus, more frequent participation in professional development seems to be beneficial for teachers' self-efficacy beliefs in math and science, and potentially for their practices and children's motivation. Professional development may also provide more concrete guidance to teachers regarding the implementation of early mathematics and science education in their day-to-day routines, which may positively affect the frequency and quality of their practices. Yet, as of now, very few teachers participate regularly in professional development: Beher and Walter (2012) showed that teachers are generally interested in professional development, but the preschool centers lack sufficient staff to compensate their absence. The lack of qualified staff in the German ECEC system has also been noted by the Bertelsmann Stiftung (2016), which found that the staff-child-ratio was less than ideal in all of the German federal states – particularly so in the eastern states. In order to provide preschool teachers with more time and resources for their own professional development, educational policy is required to increase investments in the early childhood sector that would alleviate the staff shortage. Another important strategy may be to address and improve teacher education. Only a small percentage of preschool teachers attend higher education whereas most preschool teachers get their training in vocational education (Statistisches Bundesamt, 2017). As a consequence, teacher qualification is very inconsistent. Moreover, even for those teachers who do attend higher education, training in math and science during teacher education may not be sufficient. In fact, a survey by the Weiterbildungsinitiative Frühpädagogische Fachkräfte (2011) revealed that preschool teacher education at colleges and universities qualifies the teachers for their general pedagogical work, but there is a lack of courses on domain-specific education, including mathematics and science. Moreover, the educational curriculums for higher education are quite diverse between federal states, leading to different levels of qualification. Educational policy should therefore implement nation-wide teacher education and qualification standards in order ensure a sufficient training in math and science among preschool teachers all over Germany. In turn, the better teachers' education and training, the more confident they will be in math and science. When teachers are more confident in math and science, they are more likely to recognize and seize math and science learning opportunities as well as embody confident role models for our future generation of scientists.

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STUDY 1

Uncovering Young Children's Motivational Beliefs About Learning Science

Oppermann, E., Brunner, M., Eccles, J. S., & Anders, Y. (2017). Uncovering young children's motivational beliefs about learning science. *Journal of Research in Science Teaching*, 24(2), 195-217. https://doi.org/10.1002/tea.21424

This research was supported by the "Little Scientists' House" Foundation together with the German Federal Ministry of Education and Research.

Abstract

Young children, ages 5–6 years, develop first beliefs about science and themselves as science learners, and these beliefs are considered important precursors of children's future motivation to pursue science. Yet, due to a lack of adequate measures, little is known about young children's motivational beliefs about learning science. The present two-part study explores the motivational beliefs of young children using a new measure – the Young Children's Science Motivation (Y-CSM) scale. Initial measurement development involved a thorough literature review of existing measures, and an extensive piloting phase until a final instrument was reached. To establish scale reliability, measurement invariance as well construct and criterion validity, the final instrument was administered to a new sample of 277 young children, ages 5–6 years, in northern Germany. Results reveal that children's motivational beliefs can be empirically differentiated into their self-confidence and enjoyment in science at this young age. Older children were more motivated in science, but no significant gender differences were found. Importantly, children in preschools with a science focus reported significantly higher science motivation. This finding stresses the importance of early science education for the development of children's motivational beliefs about science.

Keywords: early childhood, science motivation, assessment, science education

Science is becoming increasingly important in our technology-based society. Basic science competencies are now essential for the majority of professional careers as well as many areas of everyday life. However, science, and particularly physical science, is not a very popular subject and many students do not feel confident about their science abilities (Aschbacher, Li, & Roth, 2010; Osborne, Simon, & Collins, 2003; Vedder-Weiss & Fortus, 2012). In fact, beginning in primary school, children express beliefs that science is difficult and that they prefer learning about language and arts (Andre, Whigham, Hendrickson, & Chambers, 1999). These findings are alarming, as children's motivation to learn is considered an important predictor of their future achievement as well as their achievement related choices (Beghetto, 2007; Britner, 2008; Britner & Pajares, 2006; Eccles & Wigfield, 2002; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005 Welch, Walberg, & Fraser, 1986). If primary school children already express negative beliefs about science, they are unlikely to pursue science in the future (Simpkins, Davis-Kean, & Eccles, 2006). To prevent this sequence of negative beliefs, research, and practice has moved to earlier ages. Young children, aged 5–6 years, accumulate experiences with science long before they enter school and these early experiences shape the way children see science and themselves as science learners (Eshach & Fried, 2005; Monteira & Jiménez-Aleixandre, 2016; Saçkes, Trundle, Bell, & O'Connell, 2011). In fact, young children's early motivational beliefs about science have been shown to predict their engagement and future interest in primary school (Leibham, Alexander, & Johnson, 2013; Valeski & Stipek, 2001). Attention has therefore grown around the potential benefits of early science education for the development of children's science motivation (French, 2004). This recent trend is reflected in a significant increase of science programs and initiatives (e.g., French, 2004; Greenfield et al., 2009; Pahnke & Rösner, 2014). Whether these programs actually increase children's motivation to learn about science, however, has not been sufficiently studied. In general, we know very little about children's science motivation and how it is shaped by early science experiences. One reason for this gap in the research literature is a lack of adequate measures. Unlike knowledge, motivational beliefs cannot be directly tested because they represent children's subjective judgments about their confidence in and enjoyment of learning in science. Existing self-report measures of children's science motivation require an understanding of science as a term and concept and thus might not be suitable for all preliterate children. A new measurement approach is therefore required in order to gain a better understanding of young children's motivational beliefs in science. This paper addresses the present gap in the research literature in two sequential parts. In Part 1, we describe the development and validation of a new measure of early science motivation, operationalized by children's self-confidence and their enjoyment, and is suitable for young children aged 5–6 years. Part 2 of the study investigates how young children's motivational beliefs about science are influenced by early science education and explores young children's science motivation in different groups (i.e., age and gender).

1. Literature Review

1.1. Early Science Learning and the Development of Motivational Beliefs

Typically, young children are curious about the world around them and highly motivated to learn (Raffini, 1993). Children are often called "natural scientists" (Raffini, 1993), as they approach nature with a sense of wonder and excitement. These early playful experiences with scientific phenomena[1] in preschoo1 build the foundation for children's beliefs about science as a subject and themselves as science learners (Leibham et al., 2013; Saçkes et al., 2011). Developmental psychologists and motivation researchers both have emphasized the significance of early experiences for the development of self-beliefs, such as science motivation (Aschbacher et al., 2010; Daniels & Meece, 2007; Wigfield et al., 1997). It is therefore important to take into account the kind of experiences children encounter in preschool when investigating children's science motivation. Although early science education has recently

[1] In this paper, *preschool* refers to child care institutions for young children aged 5–6 years. This study was situated in Germany, where child care institutions for this age group are called *preschool*, however, the authors are aware that the terms may differ between countries.

received more attention and was integrated in the preschool curriculums in many countries (French, 2004; Greenfield et al., 2009), the type of early science learning opportunities that children encounter largely varies between preschool centers and even countries. Whereas some preschools offer formal science education with planned and instructed learning situations, others offer more informal and play-based learning. The latter type is particularly common in countries that emphasize child-centered learning in their curriculums, such as Australia, Canada, Germany, Korea, Norway, Sweden, and Poland (Bulunuz, 2013; OECD, 2011). Specifically, in preschools that follow a child-centered approach, science learning situations are more play-based and thus typically not labeled as such. Children therefore have no way of knowing that they are engaging in science and might not be familiar with the term science. In fact, a study by Tu (2006) found that even among US preschools, only 4.5% of the activities were related to formal science instruction, whereas 8.8% of the activities were related to informal science learning. Moreover, Mantzicopoulos et al. (2008) showed, also in a US sample, that preschool teachers do not typically label science topics explicitly as science. Thus, even in formal and teacher directed science instruction, young children are unlikely to have a comprehensive understanding of the term science, as teachers do not typically label their science-related activities as such. This has important practical implications as it is important to account for children's knowledge and previous experiences. In the following, we systematically review existing measures of children's motivational beliefs and discuss their suitability for adaptation to early science motivation.

1.2. Review of Existing Measures of Children's Motivational Beliefs

A systematic review of existing self-report measures of motivational beliefs for children aged 5–6 years identified 21 self-report measures for children aged 5–6 years (see the appendix A, Table A1 for a tabular summary of the literature review). The majority of these instruments are carried out in one-to-one personal interviews and many use graphical tools such as pictures (Baroody & Diamond, 2013; Harter & Pike, 1984; Nicholls, 1978) or puppets (Edens & Potter, 2013; Mantzicopoulos, Patrick, & Samarapungavan, 2008; Measelle, Ablow, Cowan, & Cowan, 1998). For instance, Harter and Pike (1984) presented children with pictures of children who are good and not so good at certain activities and then asked them to compare themselves to the two children in the pictures and indicate which child they are more like. Unfortunately, only a few instruments exist for the science domain, as most measures focus on subject areas such as mathematics or reading (Baroody & Diamond, 2013; Edens & Potter, 2013; Measelle et al., 1998; Tirosh, Tsamir, Levenson, Tabach, & Barkai, 2013). One of these, which was developed by Andre et al. (1999), is a questionnaire that uses smiling and frowning emoticons as response options, asking the children to indicate which emoticon represents their confidence in and enjoyment of physical science and life science. Unfortunately, they used single item scales and do not indicate any reliability or validity data. Moreover, it remains unclear whether the children were familiar with the concepts of physical science and life science. More recently, Mantzicopoulos et al. (2008) published the Puppet Interview Scale of Competence in and Enjoyment of Science (PISCES). In this questionnaire-type interview children are presented with two puppets that state opposing motivational beliefs about learning science and are asked to indicate which puppet is more like themselves. The psychometric properties and the results from the validation study are promising. PISCES was the first instrument that reliably measured children's motivational beliefs about learning science. Moreover, Mantzicopoulos et al. tackle the issue of children's potentially limited knowledge of the term science by introducing the term to the children before the interview. When asked about science, 81% of the children who Mantzicopoulos et al. interviewed, correctly named science content. These very promising results are, however, limited to a sample of children who participated in a science workshop for a total of 10 weeks before the interview. Accordingly, Mantzicopoulos et al. report that 92% of children's responses referred to science content that was part of the workshop curriculum. Thus, children's knowledge of science was largely based on the workshop. Yet, the large majority of children do not typically participate in such extended workshops. In fact, science learning opportunities are alarmingly rare in preschool (Tu, 2006). It therefore remains unclear to what extent all other children are familiar with science, particularly if science learning experiences in many countries are somewhat informal and thus not labeled as science. Thus, young children's motivational beliefs about science might not be linked to the term science but rather to their experiences with the everyday science content that they engage in. For instance, children might believe that they are good at experiments and that they enjoy learning about animals, but they might not be aware that these are areas of science. Thus, we propose a different measurement strategy, which draws on children's science-related beliefs based on their experiences with everyday science content.

1.3. Theoretical Assumptions: The Structure of Children's Motivation

Multidimensionality. The development of our measure of young children's science motivation was guided by the respective research literature on the structure of children's motivational beliefs. Based on the expectancy-value model of achievement motivation as a theoretical framework (Eccles & Wigfield, 2002), we assume that children's science motivation is two-dimensional, namely, distinguished into outcome expectancy and subject task value beliefs (Eccles & Wigfield, 2002). In line with this theoretical conceptualization, Chapman et al. (2000) found for the literacy domain that 5 and 6-year old children's reading motivation could be differentiated into three separate factors that included beliefs about reading competence, beliefs about reading difficulty, and enjoyment of reading. Similar results have been obtained by Mantzicopoulos et al. (2008) for science: Young children's motivational beliefs about learning science could be differentiated into their perceived competence in doing science, their ease of science learning, and their subjective science liking. In theory, outcome expectancy beliefs are further distinguished into ability beliefs and expectations of success in a specific task (Eccles & Wigfield, 2002). Previous studies, however, have shown that these two beliefs cannot be empirically distinguished for very young children as they are highly related (Eccles &Wigfield, 2002; Eccles, Wigfield, Harold, & Blumenfeld, 1993). In our study, we focus on children's self-confidence in science related activities as one aspect of their outcome expectancy beliefs. With regard to subject task value, four sub-domains are typically distinguished in the research literature: Attainment value, intrinsic value, utility value, and relative cost (Eccles & Wigfield, 2002). In this study, we focus solely on children's intrinsic value because we assume that young children's engagement in science is largely driven by their enjoyment of learning science, rather than their perceived importance of science for their identity, future career, or the relative cost.

Content Specificity. In constructing a measure for children's motivation, we assume that young children's motivation is domain-specific, i.e. specific to science. This assumption is based on a large body of research literature on young children's motivational beliefs, which documents that young children do distinguish between subjects (Andre et al., 1999; Eccles et al., 1993; Gottfried, 1990; Harter & Pike, 1984; Marsh, Craven, & Debus, 1991; Measelle et al., 1998; Valeski & Stipek, 2001). For instance, Marsh et al. (1991) showed that at the age of 5, children distinguishable in their competence perceptions between the subject domains of physical ability, peer relationships, reading, and mathematics. Similarly, Andre et al. (1999) showed that preschool children's interest differs across the subjects math, reading, life science, and physical science. Thus, young children seem to distinguish between different subjects, but it remains to be seen whether they also distinguish between content areas, i.e. life science and physical science, within the subject science.

1.4. The Influence of Early Science Education

We argued earlier that experience is essential for the development of motivational beliefs. Yet it remains unclear how exactly early science experiences, such as science projects and initiatives, influence children's motivation to learn science. Due to the lack of adequate measures, this subject has not been thoroughly studied. It is, however, most relevant to early science initiatives that aim to promote children's science motivation. To our knowledge, only Mantzicopoulos et al. (2008) investigated the influence of formal science education on children's science motivation and found a positive effect: Children who participated in early science courses for a longer period of time showed higher motivational beliefs (see also Patrick, Mantzicopoulos, & Samarapungavan, 2009). Mantzicopoulos et al., however, only looked at differences due to the length of participation in a specific science project (5 vs. 10 weeks). Therefore, their findings might not be generalizable to children who encounter a much larger variety of science education in preschool.

1.5. Age and Gender Differences

Based on the rationale that science experience is essential for children's motivational beliefs in science, this paper explores whether similar mechanisms might exist regardless of age. There is a general consensus that younger children tend to be highly motivated to learn and overly optimistic about their competencies (e.g., Eccles et al., 1993; Harter & Pike, 1984; Mantzicopoulos et al., 2008; Marsh, Ellis, & Craven, 2002). Several reasons for this tendency have been discussed in the research literature. For instance, Stipek and Mac Iver (1989) argue that children's still developing cognitive abilities might lead to overly optimistic judgments. It might also be that preschoolers simply have less opportunities to test and correct their self-evaluations because they receive rare, individualized, and mostly positive feedback. In line with this assumption, studies have shown that children's motivational beliefs gradually decline as they progress through elementary school where normative feedback and evaluation are more pronounced (Chapman & Tunmer, 1995; Leibham et al., 2013). At the preschool level (ages 5 – 6), particularly in countries that follow a child-centered approach, normative evaluation is rare for both comparatively younger and older children. Thus, in preschool we might not see the same decline in children's motivation with age because older children do not receive more normative evaluation. In fact, this unique situation where 5 and 6-year olds receive roughly the same amount of normative evaluation, allows us to investigate age effects by holding the influence of normative evaluation constant.

In addition to age, we investigate whether gender differences in science are already present at the preschool level. Women are still underrepresented in occupational fields associated with physical science (Eccles, 2007) and one of the reasons for this gender gap is that women feel less confident in physical science and show less intrinsic value beliefs (Eccles, 1994; Frome, Alfeld, Eccles, & Barber, 2006). Moreover, they often do not choose the necessary science courses in high school in order to pursue a science career (Eccles, 1994). As gender differences in science motivation are already present in school (Anderman & Young, 1994; Andre et al., 1999; Beghetto, 2007; Eccles, 1994; Meece & Jones, 1996), research needs to move to earlier stages in order to understand the evolution of these differences. Only a few studies have investigated gender differences in preschoolers' science motivation and the results of existing studies are inconsistent. For instance, Leibham et al. (2013) report substantial gender differences in parents' reports of 4-year olds interest in science, in favor of boys. In contrast, Mantzicopoulos et al. (2008) as well as Patrick et al. (2009) report no gender difference in preschoolers' self-reported science motivation. Thus, more research is required to investigate gender differences in children's science motivation.

1.6. Research Objectives

In the present paper we aim to contribute to a better understanding of young children's motivational beliefs in science using a new measure, namely the young children's science motivation (Y-CSM) scale. This was achieved in two sequential parts: a measurement development phase (Part 1) and a study of differences in young children's motivational beliefs about learning science (Part 2). More specifically, in Part 1 we aim at investigating whether young children's motivational beliefs in science can be reliably measured and clearly defined into distinguishable factors. We describe the measurement development process for a long and a short scale version of the Y-CSM, provide evidence of reliability, and construct validity. In Part 2, we aim at examining differences in young children's motivational beliefs with regard to (a) children's previous science experiences as indicated by their preschool center's science focus, as well as (b) children's age and gender.

2. Part 1: Measurement Development

2.1. Methods

Participants and Sample. As part of the scale development process, earlier version of the YCSM scale were tested and gradually improved in four sequential rounds of pilot testing. For the pilot study, 18, 6, 9, and finally 55 children were recruited from eight different preschool centers in Berlin, Germany. In the main study, the final version of the Y-CSM was applied to investigate our research aims. For the study, 55 new preschool centers in five federal states of Germany (Berlin, Hessen, North Rhine-Westphalia, Schleswig-Holstein and Thuringia) were recruited. Data collection in these 55 centers took place as part of the project "EASI Science"[2]. Results regarding other teacher and child variables are not central to this paper and have been published elsewhere (Barenthien, Lindner, Ziegler, & Steffensky, 2017; Ziegler & Hardy, 2015). In order to guarantee heterogeneity with regard to young children's early science learning experiences, the sample included 22 early childhood centers with and 24 centers without an explicit science focus. For nine preschool centers we did not obtain information about the science focus from the center managers. Informed consent was obtained for a total of 283 children, 122 of which were in preschools with and 124 of which were in preschools without an explicit science focus.

Measures.

Development of the Y-CSM Scale. In constructing the young children's science motivation (Y-CSM) scale, we were guided by the research literature on existing measures (Eccles et al., 1993; Mantzicopoulos et al., 2008; Measelle et al., 1998), but adapted these to be suitable for preliterate children who are not necessarily familiar with the term science. In order to ensure that all children are familiar with the science content in our items, we chose early science learning experiences that children typically encounter in their everyday lives based on

[2] The research project EASI Science (Early Steps into Science) examines the effects of early science education on both teaching staff and children.

the preschool science curricula in Germany as well as the research literature on common science activities in preschool (Greenfield et al., 2009; Tu, 2006). Item generation was based on pilot testing where different items were probed and subsequently improved.

The pilot studies were also used to probe different response formats, i.e., a dichotomous response option ("Yes"/"No") versus a 4-point scale. Children's responses to the dichotomous response format matched their responses to the 4-point scale in 85% of the cases in the pilot study. Due to its more beneficial psychometric properties, we used the 4-point scale in the final version of our measure. The final measure consists of a total of 28 items including 8 items on children's self-confidence in life science, 7 items on their self-confidence in physical science, as well as 7 items on children's enjoyment in life science, and 6 items on their enjoyment in physical science (please see appendix B for the entire scale). Response options for items measuring children's self-confidence range from "very well" (4) to "not at all" (1), response options for items measuring children's enjoyment range from "very much" (4) to "very little" (1). The verbal response options were coupled with a diagram of increasing size (see appendix B). Sample items:

"*Have you ever watched what happens to water in a pot while boiling noodles or potatoes? Imagine your preschool teacher asks you why steam rises over a pot with boiling water. Please show me how well you could answer that question: Could you answer it very well* [interviewer points to the largest area of the diagram] *quite well* [interviewer points to the second largest area of the diagram] *not very well* [interviewer points to the second smallest area of the diagram] *or not at all* [interviewer points to the smallest area of the diagram]?"

"Please show me how much you would enjoy learning more about why steam rises over boiling water. Would you enjoy that very much, quite a lot, not that much, or very little?"

The graphical format was inspired by, but not identical to, the one introduced by Eccles et al. (1993) in her study with primary school children. Interviewers were trained to repeat the four response options for every item, while pointing to the corresponding points on the diagram.

Children could respond verbally or by pointing. Children very rarely pointed between two response options. If this happened, the interviewer repeated the question and the response options and asked the child to choose one of the four options.

In addition to the visual response format, small hand puppets were used to guide children through the interview. Children were given opposing statements about the puppets' confidence in and enjoyment of learning in science and were then asked about their own motivational beliefs. The puppets were important props to demonstrate the administration format to the children and help children cope with the unfamiliar interview situation. Moreover, the fact that the puppets stated opposing views about learning science was supposed to reassure children that both views, e.g., positive and negative motivational beliefs, are equally acceptable. In order to prevent children from sympathizing with one of the puppets, we had two identical puppets that matched the child's gender. Furthermore, the statements were counterbalanced so that each puppet had the same amount of positive and negative statements. Similar procedures have been used in previous studies with very young children (see Mantzicopoulos et al., 2008; Mantzicopoulos, Patrick, & Samarapungavan, 2013; Measelle et al., 1998). The entire interview procedure, including practice items, is documented in appendix B.

Interviewer Protocols. After each child interview, interviewers documented the interview situation in a standardized protocol. Specifically, interviewers reported how engaged children were in the interview, whether there were disturbances during the interview (e.g., preschool teachers entering the room) and whether there were any language impairments or comprehension difficulties.

Preschools' Science Focus. Information about the preschool centers' educational focus was collected through center managers' responses to the following multiple choice question in an online questionnaire: "Does your preschool center have any special focus, in addition to your general pedagogical work?" (Response options: no; science; language education; foreign languages; mathematics; physical education; music; health; social-emotional competencies;

religion; others, please specify). Overall 46 of the 55 center managers completed the online questionnaire, 24 of which reported that their preschool has a science focus.

Children's Age, Gender, and Cognitive Abilities. In addition to children's age and language spoken at home, we assessed their language literacy, mathematical, and intellectual abilities. This allowed us to control for important background characteristics in our analysis. Children's receptive vocabulary skills were tested using the German version of the Peabody Picture Vocabulary Test (PPVT-III, Dunn & Dunn, 2004), which has been shown to relate to other measures of language, literacy, and academic achievement (Wing-Yin Chow & McBride-Chang, 2003). The test consists of a series of items where the children are presented with four pictures and asked to point to the picture which corresponds with the word spoken by the examiner. In this study we used a total of 60 items (item sets 3–7), which are recommended for children age 5–9 years old. On average, the children answered 47 out of 60 items correctly ($M = 46.72$; $SD = 7.04$).

Children's early numeracy skills were assessed by the subscale arithmetics of the German version of the Kaufman Assessment Battery for Children, Second Edition (K-ABC, Melchers & Preuß, 2009). The K-ABC is internationally established and commonly used to assess children's early numeracy skills (Anders, Grosse, Rossbach, Ebert, & Weinert, 2012; Mantzicopoulos, 2006). The subscale arithmetics assesses early skills in counting, identifying numbers, and understanding of early mathematical concepts. The entire scale was used in our study, and it consists of a total of 25 items, organized into five sets of increasing difficulty. On average, children answered 18 out of 25 items correctly ($M = 17.61$; $SD = 6.05$).

Children's intellectual abilities were measured using the subscales substitutions and similarities of the German version of the Culture Fair Intelligence Test 1, revised (CFT1-R) (Weiss & Osterland, 2012). The CFT1-R is a well-established test in psychological research and practice, which has been shown to be suitable for children ages 5–9 (Weiss & Osterland, 2012). In the subtest substitutions children achieved, on average, 23 points out of a maximum of 75 points (*M* = 22.79; *SD* = 11.29); in the subtest similarities children answered, on average, 6 out of 15 items correctly (*M* = .40; *SD* = 2.16). The scores for the two subscales were z-standardized and averaged to generate an overall score for each child's intellectual abilities.

Procedure. The pilot study was carried out in Summer 2014. Data collection for the main study took place between Spring 2015 and Spring 2016. The Y-CSM was administered in one-tone personal interviews in separate rooms in the preschool centers. Since preschool centers typically only had one or, rarely, two spare rooms, we could interview only one or a maximum of two children simultaneously, thus leading to a long period of data collection. A complete motivation interview session with one child lasted an average of 20 minutes. Information about the child's birth date was obtained through the parental consent documents. Children were interviewed by undergraduate or graduate students. Fidelity of implementation of the motivation interviews was ensured through extensive training of the interviewers. Interviewer training consisted of two-phases. First, interviewers participated in a 1 day (8 hour) workshop that utilized an interviewer manual and several practical exercises. In the second phase, interviewers carried out one full trial interview with a 5–6 year old child in their circle of acquaintances and filled out a detailed protocol of the trial, which was subsequently discussed in a feedback dialogue with the principal investigator.

Statistical Analyses.

Assumptions and Data Preparation. Previous to the analyses that address our research aims, data were screened for normality and potential outliers. The analyses revealed that nearly all Y-CSM items, with one exception, were negatively skewed (skewness ranges between 2.50 and 0.14). Because of the negatively skewed sample distribution, outliers were detected based on the absolute deviation around the median (MAD), which is more robust to non-normally distributed data than the mean (Ugarte, Militino, & Arnholt, 2015). Altogether 36 potential outliers were detected. After careful examination using interviewer protocols as well as PPVT scores as estimates of children's German language abilities, 6 of the 36 cases were removed from the data because they showed severe comprehension difficulties. The final dataset consisted of 277 children, 48% of which were female, 27% spoke another language than German at home, and the mean age was 71.80 months (5.98 years, median = 72 months; range = 58–85 months/4–7 years).

Psychometric Properties and the Structure of Children's Science Motivation. The structure of children's motivational beliefs was investigated using confirmatory factor analysis (CFA).We compared (1) a g-factor model, where all variables load on a single motivation factor, to (2) a two-factor model, where self-confidence and enjoyment form two separable factors and (3) a four-factor model, where self-confidence and enjoyment are each further distinguished into life and physical science factors. As our data showed severe deviation from normality, all models were estimated using the robust WLSMV estimator, which is recommended for categorical data and a skewed sample distribution (Beauducel & Herzberg, 2006; Curran, West, & Finch, 1996). Due to the pairwise orientation of the weighted least square estimation, we were not able to estimate missing data using full information maximum likelihood (fiml). However, the amount of missing data were not substantial (between 0.00% and 1.44% missing on the observed variables) and the data were missing completely at random (MCAR; $\chi^2 = 653.96$, df = 617, $p > 0.05$). Goodness-of-fit was assessed with reference to several indicators: (1) The chi-square value, (2) the Comparative Fit Index (CFI), as well as (3) the Root Mean Square Error of Approximation (RMSEA). The three nested models were compared by chi-square difference testing with mean and variance adjustments according to Satorra and Bentler (2010), which was implemented in the package "lavaan" in R.

Based on the CFA results, scale scores were formed by computing the average across items loading on the same factor. This procedure was, in our case, preferable to item response (IRT) analyses, because we were primarily interested in the mean scores, which are easier to understand and require smaller sample sizes than more complex IRT methods (Kean & Reilly, 2014). Moreover, the results produced by IRT models and classical test theory (CTT) methods have been found to be highly comparable with regard to item difficulty and person ability estimates (Macdonald & Paunonen, 2002; Pelton, 2002). Thus, in the interest of parsimony, we draw on prevalent CTT methods for scale formation and descriptive analyses of the scale.

Based on these CFA results, we developed two versions of the Y-CSM scale, a long version as well as a shorter and thus more economic version, which can be applied in future studies where testing time or personal resources are limited. The goal of the scale reduction process was to reduce the length of the self-confidence and enjoyment scales to five items each, but simultaneously to ensure that the short scales were theoretically and empirically representative of the longer versions. In line with the recommendations in the research literature, we considered theoretical as well as empirical criteria during the process of item selection (see Gogol et al., 2014; Smith, McCarthy, & Anderson, 2000). The following steps were undertaken: First, items were assigned to the content areas of life science or physical science and, within the content areas, to topics (e.g., animals, plants, magnetism). The categorization of the items to content areas, was guided by the research literature as well as the national science standards (Gelman & Brenneman, 2004; National Research Council, 2012).We then selected five science topics that are most likely to be relevant for children's future learning in primary and secondary school, by cross-referencing the items with the primary and secondary school curriculums. The result was: *animals* and *plants* for life science, and *magnetism, floating and sinking* and *aggregate states* for physical science. Subsequently, one item was selected for each topic based on how well the item measured the construct, as inferred by the factor loadings (Stanton, Sinar, Balzer, & Smith, 2002). Confirmatory factor analysis (CFA) was then rerun using the remaining five items for each scale. Finally, we calculated the correlations between the long and the short version to determine the amount of information that was reproduced by the short version (Gogol et al., 2014). As Pearson's correlation would be artificially inflated due to the replicated, non-independent measurement error that is shared by the short version and the full scale, we corrected for the overlapping error variance according to Levy (1967).

2.2. Results

The robust goodness-of-fit indices for the single-, two-, and four-factor models are presented in Table 1. The results indicate that the single-factor motivation model does not fit the data very well. The CFI value is small and the RMSEA is too large to be considered a good model fit (Hu & Bentler, 1999). In contrast, the two-factor model, with science self-confidence and enjoyment as two separate factors, fits the data quite well: The CFI is above 0.95 and the RMSEA is below 0.05. Moreover, the chi-square difference test statistics suggest a significant increase in model fit in the two-factor model compared to the single-factor model ($\Delta\chi^2 = 63.475$, $p < 0.001$). The two latent factors were moderately correlated ($r = 0.41$, $p < 0.001$), indicating that children's self-confidence beliefs and enjoyment are related, but represent empirically distinguishable aspects of motivation.

In order to test if children's self-confidence and enjoyment in science can be further distinguished into the areas of life science and physical science, we compared the two-factor model to the four-factor model. The four-factor model shows a significantly better fit than the two factor model. However, the latent self-confidence factors in life and in physical science are highly correlated ($r = 0.91$, $p < .001$). Similarly, the two factors representing enjoyment in life and physical science are also highly correlated ($r = 0.94$, $p < .001$). Even though the four-factor model fits the data better, the extremely high correlations between the latent factors indicate that young children's self-confidence and enjoyment can hardly be empirically distinguished into the areas of life science and physical science. In the interest of parsimony, we therefore base the subsequent analysis on the two-factor model.

Table 1

CFA results

Model	$\chi 2$ (*df*)	CFI	RMSEA (90% CI)	Δ $\chi 2$ (*df*)	*p*
g-factor model	1283.892	.746	.098	-	-

	(350)		(.093-.104)		
2-factor model	499.527 (349)	.959	.040 (.031-.047)	63.475 (1)	.000
4-factor model	476.069 (344)	.964	.037 (.029-.045)	14.357 (5)	.003

Notes. N = 277. χ2 = Chi-square value; df = degrees of freedom; CFI = comparative fit index; RMSEA = root mean square error of approximation. The scaled chi-square difference tests statistics (χ2Δ (df)) as well as the corresponding p-values refer to the differences between the model fit of the present row compared to the previous row.

Based on the CFA results, we calculated two scale scores by computing the average across item scores for the items loading on a certain factor. Internal consistency coefficients for both scales were high (see Table 2). The means were above the theoretical average of 2.5 (range 1–4) and the distribution of response scores was negatively skewed on all items except one, indicating that young children, aged 5–6 years, report high self-confidence in and enjoyment of science.

Table 2

Scale descriptives

	Long scale version		Short scale version	
	Self-confidence	Enjoyment	Self-confidence	Enjoyment
Number of items	15	13	5	5
Cronbach's alpha	.87	.86	.68	.74
Mean	3.00	3.55	3.13	3.55
Standard Deviation	.66	.54	.73	.60
Median	3.03	3.64	3.20	3.80
Interquartile Range	[2.53 ; 3.60]	[3.31 ; 4.00]	[2.60 ; 3.80]	[3.40 ; 4.00]
Skewness	-0.34	-1.50	-0.60	-1.52

For the short scale version, five items were selected on each scale (see Table 3). CFA was rerun using the remaining five items for each scale. The model fit indices indicate that the reduced model fits the data well (χ^2 = 61.356, df = 34; RMSEA = 0.05; CFI = 0.97). The latent factors correlated with r = 0.50. Scores for the reduced scales were again computed by averaging the scores for the five items loading on a certain factor. As can be seen in Table 2, the descriptive statistics are very similar to the original scale. The corrected correlations between the original and the shortened scales according to the formula by Levy (1967) were acceptable ($r = 0.54$ for the self-confidence scales and $r = 0.62$ for the enjoyment scales). Importantly, both short forms demonstrated a level of internal consistency that seems appropriate for many research purposes.

Table 3

Short Scale Items

Science Domain	Self-confidence	Enjoyment
Life Science	Can you say where butterflies come from?	How much would you enjoy learning more about butterflies?
	How much you already know about plants?	How much would you enjoy learning more about plants?
Physical Science	How much you already know about magnets?	How much would you enjoy learning more about magnets?
	Can you say which things float in the water and which things do not?	How much would you enjoy learning more about why certain things can float on the water and other things do not?
	Can you say why steam rises over a pot with boiling water?	How much would you enjoy learning more about why steam rises over boiling water?

3. Part 2: Group Differences

3.1. Method: Sample, Measures, and Statistical Analyses

The sample and measures applied in Part 2 were the same as in Part 1.

Statistical Analyses.

The Relation to the Preschools' Science Focus. To investigate the relation between children's science motivation and the amount of science inquiry in preschool, we ran four separate regression models with each science motivation scale as a dependent variable. The center managers' reports of whether or not the preschool specifically focuses on early science was entered as a dichotomous independent variable in the model (0 = no science, 1 = science) at Level 2. The data were clustered by preschools and standard errors adjustments were used to account for the multilevel structure of the data. Standard error adjustments are, in our case, preferable to hierarchical linear modelling because we are primarily interested in the overall, cluster-unspecific effects (McNeish, Stapleton, & Silverman, 2016). Children's age, gender, and language spoken at home, as well as the PPVT and the K-ABC scores as indicators of their vocabulary and mathematical skills, and the CFT as a measure of children's intellectual ability were entered as control variables. As we have 10.83% missing on the center managers' reports of the preschools' science focus, subsequent analyses are limited to a sample size of N = 237 children for whom all information was available. Full information maximum likelihood (fiml) estimation was used to estimate missing data on dependent as well as control variables.

The Relation to Age and Gender. Prior to investigating group differences, we tested for measurement invariance of the short and the long scale CFA models to age and gender. Median split was used to form age groups (older group was aged ≥ 72 months, N = 150, mean = 66.66 months and the younger group was aged < 72 months, N = 125, mean = 76.08 months. Information about children's age was missing for N = 2). For each group, four-factor models with different restrictions were compared, in the most stringent of which the factor loadings, intercepts, and means were constrained equal across groups. Model fit was estimated using the variance adjusted WLSMV estimator, which is recommended for ordered categorical data (Sass, Schmitt, & Marsh, 2014). Goodness-of-fit indices are the chi-square value (x2), the RMSEA, and the CFI. We report the scaled chi-square difference test, where a significant change in the chi-square value from the less to the more restrictive model indicates a lack of invariance (Satorra & Bentler, 2010). As the chi-square value is sensitive to sample size and non-normal data (Sass et al., 2014) we additionally report the differences in the CFI as an alternative fit index, where a CFI change value of 0.02 or higher would indicate a lack of invariance (Cheung & Rensvold, 2002).

After establishing measurement invariance, we investigated age effects using regression analysis for all four scales as described above. Gender differences were investigated using analysis of covariance (ANCOVA), controlling for children's age, language spoken at home, and their German language, cognitive, and mathematics ability.

3.2. Results

Relation to the Preschools' Science Focus. The results of all four regressions of early science education in preschool on children's science motivation are summarized in Table 4 (see Tables C1 and C2 in appendix C for a more detailed report of the results of the four regression models). Science education in preschool significantly explains children's self-confidence in and enjoyment of science. Children in preschools with an explicit focus on science education show higher science self-confidence and enjoyment than children in preschools with a different focus (regression results for the long scale version: $\beta = 0.36$, $p < .01$ for self-confidence and $\beta = 0.29$, $p < .01$ for enjoyment). The pattern of results was similar for the corresponding short forms. There were no significant relations to children's PPVT, K-ABC, or CFT scores as indicators of their vocabulary, mathematical, and general cognitive abilities (see appendix C).

Table 4

Summary of regression of the preschools' science focus explaining children's motivation

Dependent Variable	Beta	*SE*	*p*
Self-confidence (LV)	0.36	0.13	.007
Self-confidence (SV)	0.28	0.12	.020
Enjoyment (LV)	0.29	0.11	.007
Enjoyment (SV)	0.39	0.10	.000

Note. N = 237 LV = Long scale version, SV = Short scale version. All models are controlled for children's PPVT, CFT, K-ABC scores as well as their age, gender and the language spoken at home. Beta represents the standardized mean difference between preschools with vs. without an explicit focus on science education (STDY standardization). Positive values indicate a higher level of motivation for children attending a preschool with an explicit focus on science education.

Age and Gender Differences.

Measurement Invariance. The results of the measurement invariance tests of the two-factor models (short- and long-scale model) for age and gender are displayed in Tables D1 to D4 in appendix D. With regard to age, the goodness-of-fit indices for the least restrictive configural invariance model (M1) to the most restrictive means invariance models (M4) are very similar for the long and the short scale version. Moreover, the chi-square differences are not significant and the changes in CFI are all below 0.02. Similarly, for gender, there are no significant changes in the chi-square values between M1, M2, M3, and M4, and the DCFI are all well below 0.02 for the long and short scale models. We therefore conclude that the factor models for the long and short scale version are invariant to age and gender in terms of their factor loadings, intercepts, and means.

Age Differences. To investigate age differences, we ran four separate regression analyses for the four motivation scales with age as a continuous independent variable, controlling for children's science experience as indicated by the preschool's science focus, as well as the children's PPVT, CFT, K-ABC scores, their gender, and the language spoken at home. The results revealed a small positive effect of age on children's science self-confidence as measured by the long scale (see Table 5). Older children reported more self-confidence in science than younger children ($\beta = 0.12$, $p = 0.03$). The positive relations of age to the other three scales was not statistically significant (i.e., p was larger than 0.05).

Table 5

Summary of regressions of children's age explaining children's motivation

	Beta	*SE*	*p*
Self-confidence (LV)	0.12	0.06	.032
Self-confidence (SV)	0.09	0.06	.148
Enjoyment (LV)	0.13	0.07	.062
Enjoyment (SV)	0.11	0.06	.072

Note. N = 237 LV = Long scale version, SV = Short scale version. Beta represents the change in SD in science motivation with one SD change in Age (STDYX standardization). All models are controlled for children's science experience as indicated by the center managers' report of the preschool science focus, as well as the PPVT, CFT, K-ABC scores, their gender and the language spoken at home.

Gender differences. The results for the analysis of covariance (ANCOVA) to examine gender differences in children's science motivation are displayed in Table 6. On average, boys report higher science self-confidence and girls report slightly higher enjoyment (F = 3.59, p = 0.06). These differences, however, were not significant and the effect sizes were small (Cohen, 1988).

Table 6

Mean differences in children's motivation by gender

	Girls		Boys		F	p	Cohens' d
	M	SD	M	SD			
Self-confidence (LV)	2.89	0.69	3.11	0.62	3.59	.059	0.33
Self-confidence (SV)	3.03	0.78	3.22	0.66	2.13	.146	0.27
Enjoyment (LV)	3.58	0.48	3.52	0.58	0.59	.445	0.11
Enjoyment (SV)	3.58	0.56	3.52	0.64	0.92	.339	0.09

Note. N = 237 LV = Long scale version, SV = Short scale version. All models are controlled for children's science experience as indicated by the center managers' report of the preschool science focus, as well as the PPVT, CFT, K-ABC scores, their age and the language spoken at home.

4. Discussion

Very few measures exist that assess young children's science motivation. These measures (e.g., PISCES) provide rich insights into children's science motivation. However, they require that children have a thorough understanding of the concept of science to give valid answers to the items. Given that science learning opportunities are alarmingly rare in preschool (Tu, 2006), only very few children can be expected to have a thorough understanding of the term science, which may limit the broad applicability of existing measures. The major aim of the present two-part study was to introduce a new measure of children's science motivation, which is adequate for preliterate children and does not require basic knowledge of the term science.

The key findings as obtained by this new measure can be summarized as follows. Young children's science motivation could (a) clearly be differentiated empirically into two components - self-confidence and enjoyment - and (b) both components could be reliably measured even if children are not familiar with the term science. Importantly, (c) early science education in preschool was positively associated with children's science motivation (d) older children had higher motivational beliefs in science, and (e) boys and girls had similar levels of self-confidence in and enjoyment of science. In the following we discuss our findings in light of the relevant research literature and give directions for further research.

4.1. Measurement Development: Psychometric Properties and the Structure of Children's Science Motivation

Part 1 of the present paper introduced a new measure of young children's science motivation, namely the young children's science motivation (Y-CSM) scale. Two versions of the scale, a long, and a shorter and more economic version, were developed and tested using a sample of 277 children aged 5–6 years with varying previous science experiences from 55 preschool centers all over northern Germany. Importantly, the psychometric properties for both scale versions were satisfactory among this heterogeneous sample of children, providing future researchers with two reliable scales, which can be applied in short or long forms depending on the available testing time and resources.

With regard to the structure of children's science motivational beliefs, our findings support the theoretical distinction between self-confidence and enjoyment. Children, aged 5 – 6 years, distinguish between what they think they are good at in science and how much they like learning science. This is consistent with previous findings for primary school children and for young children across different subjects (e.g., Eccles et al., 1993; Harter & Pike, 1984; Mantzicopoulos et al., 2008; Marsh et al., 2002). In line with the expectancy-value theory

(Eccles & Wigfield, 2002), children's self-confidence and enjoyment were positively related. Children who feel confident in learning about science also enjoy learning about it, and vice versa. The moderate size of the correlation between their self-confidence and enjoyment is similar to those reported by previous studies (Mantzicopoulos et al., 2008; Wigfield et al., 1997).

Based on the assumption that children's motivational beliefs are multidimensional, we also investigated whether their self-confidence and enjoyment could be further distinguished into the areas of life science and physical science. We did not find strong evidence for a distinction between life science and physical science, as the latent correlations between life and physical science were close to one, indicating that there is no meaningful distinction between the factors. Thus, young children do not seem to differentiate between life and physical science when judging their motivational beliefs. One explanation for this finding might be that children aged 5–6 years are not yet cognitively able to distinguish between different contents when judging their motivation. Previous studies have, however, consistently shown that children as young as 5 years old do distinguish between different subject areas, i.e. reading, mathematics, and sports (Chapman, Tunmer, & Prochnow, 2000; Eccles et al., 1993). Thus, we believe it is more likely that children are simply not yet familiar with the socially constructed distinctions between life and physical science. When children encounter these (adult made) categories on a more regular basis they should start to think in these categories and develop specific motivational beliefs for different content areas. In line with the assumption that the distinction between life and physical science becomes more prevalent in children's motivation as they become more familiar with these categories, studies document distinguished motivational beliefs in life and physical science later in secondary school (Britner, 2008; Potvin&Hasni, 2014).

4.2. Group Differences: Relationship to the Preschools' Science Focus, Age, and Gender

In Part 2 of the present paper we examined the relation of the new Y-CSM scale to the preschools' science focus as well as children's age and gender.

Relationship to the Preschools' Science Focus. We have previously argued that the development of motivational beliefs is grounded in experience. As a means of establishing convergent validity, we have investigated how children's motivational beliefs in science relate to whether or not their preschool emphasizes science education. The results revealed that children in preschools with an explicit focus on science education show a higher level of self-confidence and more enjoyment of science. This is in line with findings by Mantzicopoulos et al. (2008), who demonstrated that children who engage in science for a longer period of time are more motivated in science. These results have important practical implications: The fact that children in preschool centers with an explicit focus on science education are even more confident and interested in science than children in centers without a science focus stresses the importance of early science education for the development of children's positive beliefs about science and themselves as science learners. These early motivational beliefs matter, because within expectancy value theories of achievement related choices (Eccles &Wigfield, 2002) they are considered important precursors of children's future motivation to pursue science throughout their educational pathway and beyond (Leibham et al., 2013; Simpkins et al., 2006). If children acquire positive experiences and motivational beliefs about science during their time in preschool, they are likely to be more interested in learning and doing science in school. Children, who can draw on positive science experiences and beliefs about themselves as science learners, should also be more confident and persistent in the face of challenges later in school. These mechanisms might be particularly relevant for the science domain: Findings show that, although children's motivational beliefs naturally decline in elementary school (Chapman & Tunmer, 1995; Fortus & Vedder-Weiss, 2014; Leibham et al., 2013; Wigfield et al., 1997), the decline seems to be more severe in science than in other subjects (Andre et al., 1999; Osborne et al., 2003; Sáinz, Upadyaya, & Salmelo-Aro, 2016). Thus, particularly in science, it seems crucial to prevent this downward spiral of motivational beliefs by fostering positive experiences with science early on. Age appropriate science education therefore may not only promote children's early science motivation; it might also have long-lasting positive effects on children's view of science throughout their primary school years. Further research is required to replicate the positive effects of science inquiry on children's science motivation and to investigate whether these effects persist throughout primary and secondary school. Importantly, our findings show that the instrument is invariant to age among children aged 5–6 years and sensitive to differences among children with different ages and experiences, which makes it suitable to investigate the developmental trajectories of children's science motivation.

Relationship to Age and Gender. In line with existing studies, our results demonstrate that young children, aged 5–6 years, are on average very confident about their science abilities and are eager to learn (e.g., Eccles et al., 1993; Harter & Pike, 1984; Mantzicopoulos et al., 2008; Marsh et al., 2002). Yet, in contrast to previous research, we find that older children were more, not less, self-confident in science. One potential explanation for the inconsistency with previous studies might be that both younger and older children receive very little normative evaluation and feedback in preschool. Thus, given that there are no differences in terms of normative evaluation, older children might be more confident because they have more experience with science than their younger peers, which might increase their self-confidence in comparison. An alternative explanation might be that older children are offered more science learning experiences than younger children in preschool and thus have higher motivational beliefs.

With regard to gender, we found that boys report slightly higher self-confidence in science than girls, however, this difference was not significant. This is consistent with previous findings by Mantzicopoulos et al. (2008) showing no significant gender differences in children's science motivation. Thus, although studies find significant differences between girls' and boys' views about science later in secondary school (Anderman & Young, 1994; Andre et al., 1999; Eccles, 1994; Simpkins et al., 2006; Vincent-Ruz & Schunn, 2017), these differences are largely absent in preschool.

4.3. Limitations

There are a number of limitations to the present study that should be noted. First, although the sample was drawn from preschools all over northern Germany, it was not a random selection. Participation in the study was voluntary, so the sample might be affected by self-selection. Moreover, because we were interested in measuring the motivational beliefs of children with different science experiences, we deliberately selected a sample that included a similar number of preschools with and without an explicit science focus. As a consequence, preschool centers with a science focus might be overrepresented in our sample compared to the German average.

Second, the short scale version of our instrument was administered as part of the corresponding full scale and was not additionally validated using a different sample. Although we controlled for an overestimation of the correlations between the short and long scale versions due to shared measurement error using Levy's (1967) approach, future studies should investigate the agreement among the short and long scale versions using different samples.

Third, re-test reliability or predictive validity of the scales could not be estimated because of the cross-sectional data conditions. However, the results show that our measure is invariant to age and gender and thus is suitable to investigate age differences in young children's science motivation. We believe that investigating the long term effects of science education on children's motivation is a crucial next step that should be addressed by future studies.

Fourth, we rely on the center managers' reports of the preschools' educational focus as an indicator of the amount of science education children encountered. Although the significant differences in children's science motivation in preschool centers with and without a science focus show that the center managers' reports are to some degree informative of children's science experience, they are by no means an exact measure of the frequency or intensity of children’s science experiences. Since we cannot control for differences in quantity and quality within preschools, we might be underestimating the effects of science instruction on children’s motivation. More reliable measures, preferably observational measures, are therefore needed for further validation of the instrument.

4.4. Concluding Remarks and Implications for Research and Practice

This study provides future studies with an instrument (Y-CSM) that is adequate for preliterate children with limited knowledge of science. There are several applications of theY-CSM scale for future research and practice. The present study empirically supports these applications for children aged 5 – 6 years. Future research is needed to show whether the instrument is also applicable for younger or older children (in other countries than Germany).

First, because the Y-CSM instrument is suitable for children aged 5–6 years, regardless of gender and previous science experiences, it can be used to evaluate the effectiveness of early science education for the development of children’s motivational beliefs about science in this age group and perhaps even in younger and older children. Many early science initiatives aim to provide young children with early science experiences in order to foster their positive beliefs about science as a subject and themselves as science learners. Being able to measure children’s motivational beliefs as a result of these initiatives and compare them to children who did not participate in the initiative is a fundamental requirement for the optimization of existing programs.

Second, the Y-CSM scale can be used to gain a better understanding of young children’s science motivation in the overall population as well as in different subgroups. We still know very little about potential group differences that emerge before children even enter formal schooling. For instance, to our knowledge, no study has yet looked at differences in young children’s science motivation with regard to different social backgrounds, such as their socioeconomic status or their ethnic background. Yet, research on older students in primary and secondary school has shown severe differences with regard to the science motivation and achievement of students with different ethnic and socioeconomic backgrounds (Muller, Stage, & Kinzie, 2001). Thus, further research is required to examine potential differences among children aged 5–6 years.

Lastly, the Y-CSM scale can be used to investigate the developmental trajectories of children's science motivational beliefs starting in preschool. This is crucial for understanding the development of children's motivational beliefs for their educational pathway and later career choices. In particular, the long term effects of early science education on children's motivation later in primary school are still not well understood.

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Appendix A

Table A 1

Summary of the literature review on self-report measures of motivational beliefs among children aged 5-6 years

Authors	Construct	Age range/ mean age/ Grade	Sample Item	Response formats	Scale Score Reliability
Andre et al. (1999)	Attitudes and beliefs in math, reading, life science, physical science	Kindergarten	"Put an X over how good you feel you are at math."	3-point Likert scale (Frowning to smiling emoticons)	None reported (single item scales)
Baroody and Diamond (2013)	Literacy interest	4 - 5 years	"How often do you look at books by yourself?"	4-point Likert scale (Bar graph: 4 = every day, 3 = lots of days, 2 = few days, 1 = no days)	α = .80
Cimeli, Neuenschwander, Röthlisberger, and Roebers (2013)	Preacademic self-concept	Kindergarten *M* = 6.6 years	"Look, here is a picture of a sequence of children. Imagine these are children in your classroom. This child is the best in counting [points at topmost figure], and this child is the worst in counting [points at lowermost figure]. Which child are you?" (translated from German)	Pictures of a sequence of children	α = .71

Table A 1 Summary of the literature review on self-report measures of motivational beliefs among children aged 5-6 years (continued)

Authors	**Construct**	**Age range/ mean age/ Grade**	**Sample Item**	**Response formats**	**Scale Score Reliability**
Chapman and Tunmer (1995)	Self-concept in reading	5 - 7 years	"I am a good reader"	5-point Likert Scale with double binary response option (1 = no, never, 2 = no, not usually, 3 = undecided or unsure, 4 = yes, usually, 5 = yes, always)	α = .86
Eccles et al. (1993)	Competence and subject task value beliefs	1st to 4th graders	"How good in math are you?"	7-point Likert Scale illustrated with bars of increasing size and labels (1 = not at all good; 4 = ok; 7 = very good)	α = .78 math competence α = .61 math subject task value
Eder (1990)	Self-concept	3 - 7 years	Puppet interview: "I mostly do things that are hard." "I mostly do things that are easy." "How about you?"	Dichotomous	α = .45 (value for 5-year olds)
Edens and Potter (2013)	Academic competence, achievement motivation	4 - 7 years	Puppet interview: "I don't like school work that is hard,' 'I like school work that's hard'. "How about you [child's name]"?	7-point Likert scale	α = .76 academic competence α = .74 achievement motivation

Table A 1 Summary of the literature review on self-report measures of motivational beliefs among children aged 5-6 years (continued)

Authors	**Construct**	**Age range/ mean age/ Grade**	**Sample Item**	**Response formats**	**Scale Score Reliability**
Guay et al. (2010)	Academic motivation	6 - 10 years	"I like maths."	5-point Likert Scale with double binary response option (always yes; sometimes yes; don't know; Sometimes no, always no)	α = .75 Grade 1, intrinsic motivation in math
Harter and Pike (1984)	General self-concept	4.5 – 7.4 years	"The girl/boy on the left is good at puzzles, but the child on the right is not very good at puzzles. Which of the girls/boys are you most like? Are you just pretty good at… or really good at…"	Two opposing pictures of children; 4-point Likert scale with double binary response option (left/right picture, "sort of true" or "really true")	α = .71
Mantzicopoulos (2006)	Perceived competence	*M* = 5.5 years	"This girl isn't very good at numbers. This girl is pretty good at numbers."	4-point Likert Scale with double binary response option	α = .67
Mantzicopoulos et al. (2008)	Science Competence; Science liking: and Ease of Science Learning	Kindergarten	Puppet interview: "I have fun learning science." "I don't have fun learning science."	Dichotomous	α = .79 Science Competence, α =.79 Science Liking, α = .64 Ease of Science Learning

Table A 1 Summary of the literature review on self-report measures of motivational beliefs among children aged 5-6 years (continued)

Authors	**Construct**	**Age range/ mean age/ Grade**	**Sample Item**	**Response formats**	**Scale Score Reliability**
Marsh et al. (1991)	Academic self-concept	Kindergarten *M* = 5 years	"Math is easy for me."	4-point Likert Scale with double binary response format (always yes; sometimes yes; Sometimes no, always no)	α = .76 Reading α = .77 Math α = .89 Academic
Marsh et al. (2002)	Academic self-concept	4 - 5 years	"Do you like playing number games?"	4-point Likert Scale with double binary response format (always yes; sometimes yes; Sometimes no, always no)	ω = .83 Verbal ω = .75 Math
Measelle et al. (1998)	Self-perceptions	*M* = 4.6 years	Puppet interview: "I have lots of friends at school." "I don't have lots of friends at school."	Children's responses were coded on a 7-point Likert scale (1 = very negative; 7 = very positive)	α = .76 Academic competence α = .74 Achievement motivation
Morrow (1983)	Literature interest	Kindergarten	Forces choice survey: children were presented with two activity choices and asked which one they would rather do.	Ranking scales	α = .51
Nicholls (1978)	Self-concept of attainment	5 - 13 years	Children were presented with a row of 30 schematic faces that represent the children in their class. "Can you show me how good you are at reading? Which one is you?"	Position rating 1 - 30	None reported

Table A 1 Summary of the literature review on self-report measures of motivational beliefs among children aged 5-6 years (continued)

Authors	Construct	Age range/ mean age/ Grade	Sample Item	Response formats	Scale Score Reliability
Niklas and Schneider (2012)	Academic self-concept	*M* = 6.4 years	Children were presented with a row of 5 pawns representing their classmates. They were given another pawn and asked to position the pawn according to their own competence (between or next to other pawns).	Position rating 1 - 11	α = .64 Math α = .69 Verbal
Nölke (2013)	Science interest	*M* = 5.6 years	"Which of the following would you prefer to learn?" [how to play an instrument; how to color; which story tells exists; how to experiment" "How much would you enjoy observing a drop of water using a magnifying glass?"	Ranking Scales as well as 3-point Likert Scales	α = .26 Ranking scale for interest in physical science α = .74 Rating scale for interest in science observation (selected reliability measures)
Stipek et al. (1995)	Ability perceptions and enjoyment	*M* = 4.8 years	Ability perceptions: Children were asked how smart they were and how good they were at numbers, letters/reading and art. Enjoyment: Children were asked to indicate how much they liked school and how much they liked their teacher.	Ability perceptions: 5-point Likert Scale (Rows of 1 - 5 stars) Enjoyment: 5-point Likert Scale (Frowning to smiling emoticons)	None reported

Table A 1 Summary of the literature review on self-report measures of motivational beliefs among children aged 5-6 years (continued)

Authors	Construct	Age range/ mean age/ Grade	Sample Item	Response formats	Scale Score Reliability
Tirosh et al. (2013)	Self-efficacy beliefs in mathematics	Kindergarten 5 - 6 years	"If I show you a drawing of a shape, will you be able to tell if the shape is a triangle?"	4-point Likert Scale with double binary response format (Yes / No; "Are you very sure or a little bit sure?")	None reported
Valeski and Stipek (2001)	Perceived competence in math and literacy	Kindergarten 4 - 6 years	"How much do you know about math?"	5-point Likert Scales with 5 bars of increasing size (e.g. for enjoyment 1 = Not at all fun; 5 = very much fun)	α = .68 Math α = .61 Literacy

Appendix B

Methods Supplement

Young Children's Science Motivation Scale (Y-SCM)

Interviewer Instructions

The interviewer is equipped with two pairs of identical puppets. If the interviewed child is female, the interviewer chooses the two female puppets, called Kiki and Kora; if the child is male, the interviewer chooses the two male puppets, called Bodo and Momo. Interviewers are trained to treat both puppets equally and avoid speaking about the puppets outside of the instructions during the interview. They should pronounce both, positive and negative statements in the same way. The response options should be read aloud on each item, with the interviewer pointing to the corresponding points on the diagram (see figure 1).

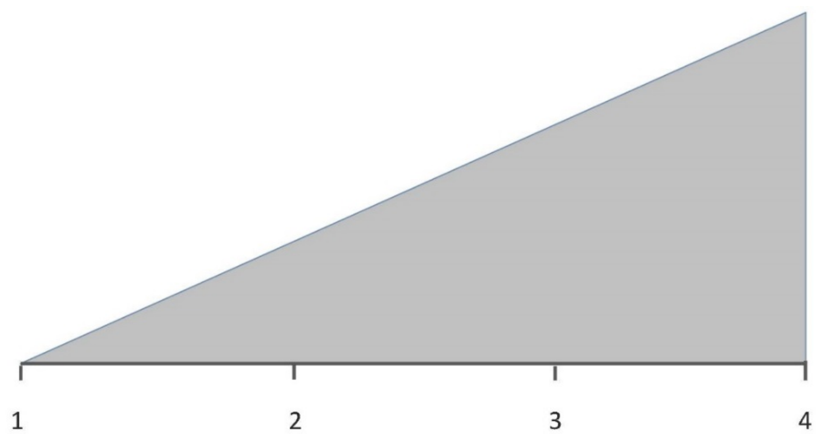


Figure 1. Response format.

B2: Introduction

Hello, my name is __________ and I am __________ years old. Can you tell me how old you are? Age: ____________ Can you tell me when your next birthday is? Date: ____________

I come from the university in _______ and I am a researcher. Research means, that you ask a lot of questions and try to find the answers. My research is about what preschool children like to learn and what they are good at. This is why I would like to ask you some questions.

I brought a paper with me, where I will take notes during our conversation, so that I do not forget your answer.

I also brought these two puppets with me. This one is Kiki/Bodo and this is Kora/Momo. Kiki/Bodo and Kora/Momo are friends and they go to the same preschool. In the next few minutes they are going to talk about things they like doing in preschool and things they do not like so much. Kiki/Bodo and Kora/Momo like different things, but that is okay, because they are different children. It is very normal that different children like different things and that they are also good at different things.

Practice item 1: Kiki/Bodo is very good at drawing. Kora/Momo is not good at drawing. How about you? Are you good at drawing or are you not good at drawing? [child responds verbally] Please show me how good you are at drawing. Are you very good, quite good, not so good, or not good at all? [interviewer indicates each response option on the diagram]

Practice item 2: Kora/Momo is good at playing soccer. Kiki/Bodo is not good at playing soccer. How about you? Are you good at playing soccer or are you not good at playing soccer? [child responds verbally] Please show me how good you are at playing soccer. Are you very good, quite good, not so good, or not good at all? [interviewer indicates each response option on the diagram]

Kiki/Bodo and Kora/Momo are now going to talk about how much they already know about different things in the nature and which things they would like to learn more about. The two of them are good in a different things and they also like different things. Just like before, I will then ask you about yourself. Please feel free to ask if you do not understand a word.

Appendix I – Manuscript for Study 1

Motivation scale

Have you ever watched animals, for example a caterpillar eating a leaf or ants?	
SE_LS1	Kiki/Bodo [point at Kiki/Bodo] already knows a lot about different animals. Kora/Momo [point at Kora/Momo] does not yet know much about animals. Please show me how much you know about animals. Do you know very much, quite a lot, not that much or very little?
EN_LS1	Please show me how much you would enjoy learning more about animals. Would you enjoy that very much, quite a lot, not that much or very little?
SE_LS2	Imagine your preschool teacher asks to tell her how ants live. Please show me how well you could answer this question. Could you answer her question very well, quite well, not very well or not at all?
EN_LS2	Please show me how much you would enjoy learning more about ants. Would you enjoy that very much, quite a lot, not that much or very little?
SE_LS3	Imagine your preschool teacher asks to tell her where butterflies come from. Please show me how well you could explain to your preschool teacher where butterflies come from. Could you answer her question very well, quite well, not very well or not at all?
EN_LS3	Please show me how much you would enjoy to learning more about butterflies. Would you enjoy that very much, quite a lot, not that much or very little?
SE_LS4	Imagine your preschool teacher asks you to tell her how fish can breathe under water. Please show me how well you could explain to her how fish can breather under water. Could you answer her question very well, quite well, not very well or not at all?
EN_LS4	Please show me how much you would enjoy learning more about fish. Would you enjoy that very much, quite a lot, not that much or very little?
Have you ever looked at plants in detail? For example at a leaf, a blossom or a root?	

SE_LS5	Kora/Momo already knows a lot about plants. Kiki/Bodo does not yet know much about plants. How about you? Please show me how much you already know about plants. Do you know very much, quite a lot, not that much or very little?
EN_LS5	Please show me how much you would enjoy learning more about plants. Would you enjoy that very much, quite a lot, not that much or very little?
SE_LS6	Imagine your preschool teacher asks you what plants need in order to grow. Please show me how well you could explain to your preschool teacher what plants need in order to grow. Could you answer her question very well, quite well, not very well or not at all?
SE_LS7	Please show me how well you could explain to your preschool teacher why plants need sunlight in order to grow. Could you answer her question very well, quite well, not very well or not at all?
EN_LS6	Please show me how much you would enjoy learning more about what plants need in order to grow. Would you enjoy that very much, quite a lot, not that much or very little?
SE_LS8	Imagine your preschool teacher asks you where seeds from plants come from. Please show me how good you could answer this question. Could you answer her question very well, quite well, not very well or not at all?
EN_LS7	Please show me how much you would enjoy learning more about the seeds of plants. Would you enjoy that very much, quite a lot, not that much or very little?
Have you ever played with magnets and checked which things stick to them? For example magnets on a fridge or a blackboard.	
SE_PS1	Kiki/Bodo already knows a lot about magnets. Kora/Momo does not yet know much about magnets. How about you? Please show me how much you already know about magnets. Do you know very much, quite a lot, not that much or very little?
SE_PS2	Kora/Momo knows which things stick to a magnet. Kiki/Bodo does not know that yet. How about you? Please show me how well you could explain which things stick to magnets? Could you explain that very well, quite well, not very well or not at all?

EN_PS1	Please show me how much you would enjoy to learning more about magnets. Would you enjoy that very much, quite a lot, not that much or very little?
Have you ever tried out which things swim in the bathtub or in a bucket and which things sink? And have you ever observed which things can swim on a lake and which things sink?	
SE_PS3	Imagine your preschool teacher asks you which things float in the water and which things do not. Please show me how well you could answer her question. Could you answer it very well, quite well, not very well or not at all?
EN_PS2	Please show me how much you would enjoy learning more about why certain things can float on the water and other things do not. Would you enjoy that very much, quite a lot, not that much or very little?
Have you ever watched what happens to water in a pot while boiling noodles or potatoes?	
SE_PS4	Imagine your preschool teacher asks you why steam rises over a pot with boiling water. Please show me how well you could answer her question. Could you answer it very well, quite well, not very well or not at all?
EN_PS3	Please show me how much you would enjoy learning more about why steam rises over boiling water. Would you enjoy that very much, quite a lot, not that much or very little?
Have you ever observed ice melting?	
SE_PS5	Imagine your preschool teacher asks you what exactly happens when ice melts. Please show me how well you could answer her question. Could you answer it very well, quite well, not very well or not at all?
EN_PS4	Please show me how much you would enjoy learning more about what happens when ice melts. Would you enjoy that very much, quite a lot, not that much or very little?
Have you ever talked about how rain is formed, for instance with the preschool teacher or at home with your parents?	
SE_PS6	Imagine your preschool teacher asks you how rain is formed. Please show me how well you could answer her question. Could you answer it very well, quite well, not very well or not at all?

EN_PS5	Please show me how much you would enjoy learning more about how rain is formed. Would you enjoy that very much, quite a lot, not that much or very little?
Have you ever talked about why it is hot in summer and cold in winter, for instance with the preschool teacher or at home with your parents?	
SE_PS7	Imagine your preschool teacher asks you why it is hot in summer and cold in winter. Please show me how well you could answer her question. Could you answer it very well, quite well, not very well or not at all?
EN_PS6	Please show me how much you would enjoy learning more about the seasons, such as summer and winter. Would you enjoy that very much, quite a lot, not that much or very little?

Appendix C

Table C1

Results of regression analyses explaining children's science self-confidence

	Long scale version			Short scale version		
	Beta	*SE* (*B*)	*p*	Beta	*SE* (*B*)	*p*
Science instruction (0 = no science, 1 = science)	0.36	0.13	.007	0.28	0.12	.020
Age	0.12	0.06	.031	0.09	0.06	.148
Gender (0 = female, 1 = male)	0.23	0.13	.071	0.17	0.13	.186
Language spoken at home	0.03	0.08	.693	0.03	0.08	.718
PPVT	-0.09	0.08	.248	-0.09	0.08	.238
K-ABC	-0.06	0.07	.418	0.02	0.08	.823
CFT	-0.00	0.05	.970	0.03	0.06	.577
R^2	0.07			0.04		

Note. N = 237. PPVT = Peabody Picture Vocabulary Test. K-ABC = Kaufman Assessment Battery for Children. CFT = Culture Fair Intelligence Test. Continuous variables, i.e. Age, Language spoken at home, PPVT, K-ABC and CFT, were standardized before the analysis. Beta thus represents the change in the dependent variable with one SD change in the independent variable (STDYX standardization) for the continuous variables. For binary variables, i.e. Science instruction and Gender, Beta represents the standardized mean difference on the motivation scales with between the values 0 and 1 (STDY standardization).

Table C2

Results of regression analyses explaining children's science enjoyment

	Long scale version			Short scale version		
	Beta	*SE* (*B*)	*p*	Beta	*SE* (*B*)	*p*
Science instruction (0 = no science, 1 = science)	0.29	0.11	.007	0.39	0.10	.000
Age	0.13	0.07	.061	0.11	0.06	.072
Gender (0 = female, 1 = male)	-0.16	0.14	.242	-0.18	0.13	.186
Language spoken at home	0.01	0.06	.864	0.04	0.06	.512
PPVT	0.10	0.07	.140	0.08	0.07	.227
K-ABC	-0.06	0.06	.308	-0.08	0.06	.197
CFT	-0.02	0.06	.780	-0.01	0.05	.925
R^2	0.05			0.06		

Note. N = 237. PPVT = Peabody Picture Vocabulary Test. K-ABC = Kaufman Assessment Battery for Children. CFT = Culture Fair Intelligence Test. Continuous variables, i.e. Age, Language spoken at home, PPVT, K-ABC and CFT, were standardized before the analysis. Beta thus represents the change in the dependent variable with one SD change in the independent variable (STDYX standardization) for the continuous variables. For binary variables, i.e. Science instruction and Gender, Beta represents the standardized mean difference on the motivation scales with between the values 0 and 1 (STDY)

Appendix D

Table D1

Fit indices for analyses of invariance across age groups for the long-scale CFA model

	$\chi 2$ (*df*)	CFI	RMSEA	$\Delta\chi 2$ (*df*)	*p*	Δ CFI
Model 1: Configural invariance	785.20 (698)	.953	.044	-	-	-
Model 2: Metric invariance	823.48 (724)	.955	.042	8.508 (26)	.999	.002
Model 3: Scalar invariance	870.43 (778)	.955	.041	18.567 (54)	1.000	.000
Model 4: Means invariance	913.27 (780)	.951	.042	4.165 (2)	.125	.004

Table D2

Fit indices for analyses of invariance across age groups for the short-scale CFA model

	$\chi 2$ (*df*)	CFI	RMSEA	$\Delta\chi 2$ (*df*)	*p*	Δ CFI
Model 1: Configural invariance	70.108 (68)	.970	.055	-	-	-
Model 2: Metric invariance	83.129 (76)	.967	.055	8.758 (8)	.363	.003
Model 3: Scalar invariance	95.670 (94)	.964	.051	14.112 (18)	.722	.003
Model 4: Means invariance	98.531 (96)	.965	.050	1.484 (2)	.476	.002

Table D3

Fit indices for analyses of invariance with regard to gender for the long-scale CFA model

	$\chi 2$ (*df*)	CFI	RMSEA	$\Delta\chi 2$ (*df*)	*p*	Δ CFI
Model 1: Configural invariance	781.64 (698)	.954	.044	-	-	-
Model 2: Metric invariance	827.18 (724)	.955	.043	10.412 (26)	.997	.001
Model 3: Scalar invariance	873.38 (778)	.956	.041	17.971 (54)	1.00	.000
Model 4: Means invariance	918.60 (780)	.951	.043	4.328 (2)	.115	.005

Table D4

Fit indices for analyses of invariance with regard to gender for the short-scale CFA model

	$\chi2$ (*df*)	CFI	RMSEA	$\Delta\chi2$ (*df*)	*p*	Δ CFI
Model 1: Configural invariance	65.29 (68)	.976	.051	-	-	-
Model 2: Metric invariance	82.06 (76)	.970	.054	10.503 (8)	.232	.006
Model 3: Scalar invariance	95.58 (94)	.966	.051	14.567 (18)	.691	.003
Model 4: Means invariance	107.26 (96)	.958	.057	5.440 (2)	.066	.008

STUDY 2

The interplay between preschool teachers' science self-efficacy beliefs, their teaching practices, and girls' and boys' early science motivation

Oppermann, E., Brunner, M., & Anders, Y. (submitted). The interplay between preschool teachers' science self-efficacy beliefs, their teaching practices, and girls' and boys' early science motivation.

This research was supported by the "Little Scientists' House" Foundation together with the German Federal Ministry of Education and Research.

Abstract

Children develop motivational beliefs about science, i.e. beliefs about their own competence and enjoyment in science, in their preschool years and these beliefs are considered important precursors of children's future science motivation. Yet, it remains unclear how children's motivational beliefs in science are shaped by their preschool teachers' own beliefs and their practices. Moreover, with over 90% female teachers, gender may play an important role in the relation between preschool teachers' and children's science motivation. The present study investigates these relations, and their gendered patterns, based on a sample of 277 young children aged 5-6 years and 348 preschool teachers in Germany. Regression results indicate that teachers' science self-efficacy beliefs are related to their practices. Results from multilevel path analyses further show that teachers' self-efficacy beliefs are associated with children's self-efficacy in science. No relation was found for teachers' practices. These relations, however, differed by gender: Teachers' self-efficacy beliefs were more strongly related to girls' motivation, whereas teachers' practices were more strongly related to boys' motivation. These findings provide novel evidence on gendered patterns in the association between teachers' self-efficacy beliefs, their science activities and children's science motivation.

Keywords: early childhood, teacher efficacy, science education, motivation, gender roles, instructional practices

Young children, ages 5-6 years, engage in science long before they enter school and thereby gather first experiences with science as a subject and themselves as science learners. These early experiences with science, i.e. everyday materials and activities related to life science and physical science, build the foundation for children's motivation to pursue science in the future. In fact, studies consistently report that children's confidence in and enjoyment of learning in a particular subject are the two major components of their achievement motivation (Eccles & Wigfield, 2002), and these largely depend on children's previous experiences with that subject (Sonnenschein & Munsterman, 2002; Stipek, Feiler, Daniels, & Milburn, 1995; Valeski & Stipek, 2001).

Preschool[1] teachers may shape these experiences in a variety of ways. First, preschool teachers differ in the extent to which they are capable of creating regular opportunities for science learning in their classrooms. Preschool teachers' confidence in their abilities to teach science—their self-efficacy beliefs—can be expected to be an important predictor of their teaching practices. Previous research has repeatedly demonstrated that teachers' domain-specific self-efficacy beliefs influence their practices in the (preschool) classroom (Ashton & Webb, 1986; Guo, Piasta, Justice, & Kaderavek, 2010; Lohse-Bossenz, Zimmermann, Janke, & Müller, 2015; Spektor-Levy, Baruch, & Mevarech, 2011). Second, preschool teachers act as role models. Teachers may involuntarily communicate their negative or positive beliefs about science in subtle ways to the children in their classroom. In this respect, children's and teachers' gender may interact because social learning theory teaches us that children are more prone to models that are similar (Bandura, 1977b; Perry & Bussey, 1979). Specifically, with gender being a highly salient feature and preschool teachers being almost exclusively female (>90%), girls might be more likely than boys to notice and adapt to teachers' beliefs about science.

[1] In this paper, *preschool* refers to child care institutions for young children aged 5-6 years. This study was situated in Germany, where child care institutions for this age group are called *preschool*, however, the authors are aware that the terms may differ between countries.

Teachers' science practices, one the other hand, should benefit both boys and girls in their classroom. Yet, teachers might not offer the same number amount of early science activities to both genders.

These mechanisms and their gendered pattern, however, have not been studied (a) with respect to science learning and (b) in the preschool context. The overarching goal of this paper is to fill this gap. To this end, we examine the relations between preschool teachers' self-efficacy in teaching science, their practices in science, and children's science-related motivation. In doing so, we analyze the extent to which the pattern of relations differs between boys and girls.

1. Literature

1.1. Early science education and the development of children's motivational beliefs in science

Children's motivation is considered an important predictor of their future effort, persistence and choice (Eccles, 1999; Simpkins, Davis-Kean, & Eccles, 2006). Wigfield & Eccles (2002) distinguish between two aspects of motivational beliefs: Outcome expectancy beliefs, and subject task value beliefs. Outcome expectancy beliefs refer to individuals' confidence in their ability to successfully perform in a task and are thus conceptually related to Bandura's (1977a) self-efficacy beliefs. Subject task value comprises of different components related to the personal value of a task, of which intrinsic value, i.e. enjoyment of the task, is considered the most relevant component for very young children (Eccles et al., 1983; Wigfield & Eccles, 1992). Both, children's subject-specific self-efficacy beliefs as well as their enjoyment are grounded in their previous experience with that subject (Sylva et al., 2013; Wigfield & Eccles, 2002). Attention has therefore grown around the potential benefits of early science education for the development of children's motivational beliefs about science and themselves as science leaners. The demand for scientists, engineers, and technically trained personnel grows at a relatively rapid rate (Laugksch, 2000), and yet science-related subjects, particularly those related to physical science, are failing to attract enough students to ensure an adequate supply of professionals (Osborne & Dillon, 2008). Already at the beginning of primary school, children's motivation to learn science is lower than in many other subjects and continues to decline throughout middle and secondary school (Andre, Whigham, Hendrickson, & Chambers, 1999; Gaspard, Häfner, Parrisius, Trautwein, & Nagengast, 2017; Osborne, Simon, & Collins, 2003). Consequently, many western countries have increased their initiatives to foster children's science motivation early on by promoting enjoyable science learning experiences in preschool (e.g. French, 2004; D. B. Greenfield et al., 2009; Pahnke & Rösner, 2014). The importance of experiences for the development of motivational beliefs is well documented in the research literature (Daniels & Meece, 2007; Jansen, Scherer, & Schroeders, 2015; Lazarides & Watt, 2015; Wigfield et al., 1997). For instance, in the literacy domain, research shows that children who have enjoyable experiences with literacy are more likely to read broadly and frequently in the future (Sonnenschein & Munsterman, 2002). With regard to science, two recent studies show that an increase in the quantity of science education has beneficial effects on children's science motivation (Oppermann, Brunner, Eccles, & Anders, 2017; Mantzicopoulos, Patrick, & Samarapungavan, 2008). Specifically, children in preschools with an explicit focus on science education as well as children who engage in science for a longer period of time were more self-confident and reported higher enjoyment in science learning (Oppermann et al., 2017; Mantzicopoulos, Patrick, & Samarapungavan, 2008). Moreover, young children sustain their science interest over the course of their preschool years (Leibham, Alexander, & Johnson, 2013). Thus, the quantity of science education on the preschool level seems to have positive and potentially long-lasting effects on children's motivational beliefs in science. The importance of the quantity of early learning opportunities, in addition to the process quality, has also been documented in a recent meta-analysis with regard to children's mathematics and language outcomes (Ulferts & Anders, 2015). Yet, the number of science learning opportunities that children are offered might largely depend on the preschool teachers they engage with.

1.2. Preschool teachers' science practices

As a consequence of the increasing emphasis on early science education, preschool teachers have received considerably more responsibility as initiators and supporters of children's engagement and learning in science. Their practices, in turn, are assumed to be highly relevant to children's learning. Teachers' practices include their didactic strategies, the supply of space and materials, and the provision of learning opportunities in general (Institute of Medicine and National Research Council, 2015; Siraj-Blatchford, Sylva, Muttock, Gilden, & Bell, 2002). Thus, with regard to science, it is part of preschool teachers' responsibility offer regular science learning opportunities for the children in their classroom. However, offering regular math and science learning may mean different things depending on the country. Specifically, countries such as Australia, Canada, Germany follow a child-centered approach in their curriculum (Bulunuz, 2013; OECD, 2011). Learning in these countries is typically play-based and not pre-arranged. Instead, learning opportunities evolve spontaneously based on children's questions and interest. Thus, in these countries, preschool teachers are required to recognize, seize and initiate regular science learning opportunities in children's play. This places a lot of responsibility in the hands of the preschool teachers, as it is entirely up to the preschool teachers to seize decide if and how often they would like to offer science learning activities. Thus, the frequency of science learning activities may vary tremendously between preschools and even between classrooms.

Unfortunately, very little is known about the frequency of teachers' science practices in these countries. However, research for the US, where national standards are established, shows that science learning opportunities are quite rare. In an observational study, Tu (2006) videotaped and coded 120 minutes of the free play intervals of 20 preschool teachers in the Midwestern US. Results revealed that altogether only 13.3% of all activities were related to science and these included mainly activities such as playing in the sand box with shovels and making play dough. Moreover, preschool teachers often missed teachable moments. Many centers had science-related materials (plants or sand boxes), but teachers did not use them to engage children in science learning (Tu, 2006). In line with these findings, Saçkes, Trundle, Bell, and O'Connell (2011) report, based on a survey of preschool teachers, that about half of the teachers in their study teach science once or twice a week and only 15% reported teaching science daily. This is consistent with more recent findings by Spektor-Levy, Baruch, and Mevarech (2013) who show that the majority of preschool teachers engage in science weekly (62%), 27% engage in science activities once or twice a month, and 11% even less often. The frequency of science learning activities may be even lower in countries without national standards, as preschool teachers may have more flexibility to actively initiate or avoid science activities. As a consequence, teachers' practices may depend more strongly on their own beliefs, including their self-efficacy beliefs in science. In fact, preschool teachers often report feeling unconfident about their ability in science and teaching science to young children (D. B. Greenfield et al., 2009; Koballa & Crawley, 1985; Saçkes, Flevares, Gonya, & Trundle, 2012; Spektor-Levy et al., 2013). Moreover, they report feeling less confident in science than in other subjects, including mathematics, language, and arts (Torquati, Cutler, Gilkerson, & Sarver, 2013). Preschool teachers' self-efficacy beliefs in science may therefore play an important role in their ability to offer regular science learning opportunities.

1.3. Preschool teachers' self-efficacy beliefs and their science practices

Self-efficacy beliefs are defined as a person's conviction that they can successfully perform a specific task (Bandura, 1977a), In that, self-efficacy beliefs subject- and task-specific, such as teachers' beliefs about the extent to which they can engage children in early science learning. The importance of teachers' self-efficacy beliefs for their practices in the early childhood classroom is well documented in the research literature (Goddard, Hoy, & Hoy, 2000; Justice, Mashburn, Hamre, & Pianta, 2008; Lohse-Bossenz et al., 2015; Schiefele, 2009;

Schiefele & Schaffner, 2015), however, there is little research on preschool teachers' self-efficacy beliefs in teaching science.

Qualitative research by Harlen and Holroyd (1997) revealed that teachers, who described themselves as unconfident, tended to cope with this lack of confidence by teaching as little science as possible as well as avoiding science content that they were not confident with. Similarly, a qualitative study of recently graduated preschool and school teachers by Appleton and Kindt (1999) showed that teachers' self-confidence in science influenced the frequency of their science teaching practices in a positive way.

Previous quantitative research, on the other hand, focused on teachers' science related attitudes rather than their self-efficacy in teaching science. Erden and Sönmez (2010) found a positive association between the frequency of teachers' early science activities and teachers' comfort in science teaching as well as their attitudes regarding the developmental appropriateness of science instruction. Similar results have been obtained in a more recent study of 146 preschool teachers in the US. Teachers' general attitudes towards science teaching affected the extent to which teachers integrated science activities within the preschool teaching program (Spektor-Levy et al., 2013).

Taken together, the qualitative research literature indicates that preschool teachers' science self-efficacy beliefs are highly relevant to the frequency of their science practices. Yet there is hardly any research to determine whether the insights gained by the qualitative research are generalizable to a larger scale when using quantitative methods.

1.4. Preschool teachers as role models

Modeling refers to a process in which "observers pattern their thoughts, beliefs, and behaviors after those displayed by one or more models" (Schunk & Zimmerman, 2007). Particularly for young children, modeling is seen as an important process to acquire essential skills, beliefs, and behaviors (Schunk, 1987; Zimmerman & Ringle, 1981). With regard to children's motivation, studies have shown that children can increase their own self-efficacy beliefs simply by observing self-efficacious models, such as their teachers (Lirgg & Feltz, 1991; Zimmerman & Ringle, 1981). For instance, Stipek, Givvin, Salmon, and MacGyvers (2001) found, for the mathematics domain, that elementary teachers' self-confidence in their mathematical ability was significantly correlated with children's confidence as math learners. Similarly, Midgley, Feldlaufer, and Eccles (1989) showed in a longitudinal study that teachers' self-efficacy beliefs predicted student's motivation in math. The beliefs of students who had low-efficacy teachers became more negative, whereas the beliefs of students who had high-efficacy teachers became more positive over the course of the study. Moreover, teachers' influences on students' beliefs can have long lasting effects. For example, Westerback (1982) investigated the source of preservice elementary school teachers' attitudes towards science and found that teachers cite their own teachers as the most important influence in shaping their current attitudes towards science. These results indicate that modeling may be a powerful mechanism through which teachers' own self-efficacy beliefs in science might affect children's motivation to learn. This influence may be particularly strong for models that are similar, i.e. have the same gender.

1.5. Gender differences

Research repeatedly demonstrates that science is not students' favorite subject in school and that this is especially true for girls (Aschbacher, Li, & Roth, 2010; Osborne et al., 2003). Even in primary school, girls report less interest and lower confidence in their abilities in science (DeWitt et al., 2011; Eccles, Wigfield, Harold, & Blumenfeld, 1993; Saçkes et al., 2011). These differences persist during middle and secondary school and eventually contribute to women being underrepresented in science-related studies and occupational fields, especially in fields related to physical science (Eccles, 1994; OECD, 2016; Wigfield et al., 1997). This pattern is problematic, not just because it limits women's access to prestigious and high-paying careers, but also – from a macro perspective – because it contributes to a diminishing supply of professionals in science, engineering, and technology that are able to meet societal needs.

In light of this gender gap, we consider it a crucial undertaking to gain a better understanding of how these differences emerge right at the beginning of children's educational pathway. Only a few studies have investigated gender differences in some aspects of young children's science motivation, and this research has produced conflicting results. Studies that investigated both aspects of children's motivational beliefs in science, i.e. their enjoyment as well as their self-efficacy beliefs, found no significant gender differences (Andre et al., 1999; Oppermann et al., 2017; Mantzicopoulos et al., 2008). In contrast, studies that investigated only one aspect indicate that boys showed higher interest in STEM-related activities than girls (Alexander, Johnson, Leibham, & Kelley, 2008; Leibham et al., 2013; Nölke, 2013). Moreover, results by Baram-Tsabari and Yarden (2005) reveal gender differences within the different topics of science. Specifically, they analyzed 1535 science-related questions that children submitted to a website and found that girls were more likely to ask questions about biology, and boys dominated all of the remaining fields. These findings mirror results of a meta-analysis documenting large gender differences in adolescents' and adults' interests, with men being more interested in things and women favoring people (Su, Rounds, & Armstrong, 2009). It remains unclear, however, whether gender differences in children's science interest and their self-confidence are already present at the preschool level. Moreover, if gender differences should be present, more research is required to explore whether boys' and girls' motivational beliefs are influenced by teachers' beliefs and practices in the same way. In fact, teachers' practices and modeling have been proposed as important mechanisms to explain gender differences in motivation among older children (see Gunderson, Ramirez, Levine, & Beilock, 2012).

Gendered patterns in teachers' practices. Children's early experiences with science largely depend on teachers' practices and support during science-related learning activities – and these practices might differ for girls and boys. Research indicates that teachers treat girls and boys differently in school (Becker, 1981; Eccles & Blumenfeld, 1985; Fagot, 1977; Serbin, O'Leary, Kent, & Tonick, 1973) as well as in preschool (T. A. Greenfield, 1997; Kuger, Kluczniok, Sechtig, & Smidt, 2011; Wolter, Braun, & Hannover, 2015), however, most of these studies focused on domains other than science. A study by Kuger et al. (2011) documents differences in the learning opportunities that preschool teachers offer girls and boys with regard to language, arts, and hygiene. More recently, Wolter et al. (2015) found that female preschool teachers offer more appropriate early literacy activities to girls than to boys and suggest that this difference might be responsible for the finding that girls scored higher than boys on early literacy. Similarly, Brandes, Andrä, Röseler, and Schneider-Andrich (2015) report that female preschool teachers behave more as observers towards boys with only verbal involvement, in comparison to co-operation with girls. Only very few studies investigated these relations for the science domain. T. A. Greenfield (1997) found that in kindergarten and primary school, girls receive less attention from the teachers during sciences classes, although they initiate as many teacher interactions as boys did. In contrast, Saçkes et al. (2011) studied the relation between children's gender and teachers' science practices and found that gender was not a statistically significant predictor of the availability or frequency of science learning opportunities in preschool. The study, however, assessed science learning opportunities based on teachers' reports of their practices on the group level and cannot draw conclusions about differential practices with regard to individual children. In summary, research suggests some gendered patterns in preschool teachers' practices in the literacy domain, but the results for science are few and inconsistent.

Modeling. Research on social learning suggests that children tend to imitate same-sex models more than opposite-sex ones due to perceived similarity to the model (Basow & Howe, 1980). Taking into account that over 90% of preschool teachers are female, it seems reasonable to assume that teachers own self-efficacy beliefs in science might be particularly relevant for girls. In fact, a recent study showed that at the primary school level, teachers' own anxiety about mathematics was related to girls', but not to boys', mathematics achievement (Beilock, Gunderson, Ramirez, & Levine, 2010). This relation was mediated by girls' endorsement of the commonly held stereotype that boys are better at math (Beilock et al., 2010). Indeed, a study by Martin and Ruble (2004) shows that children's rigidity in applying stereotypes peaks at ages 5 to 7. In line with the societally-prevalent stereotype that science is not for girls, preschool teachers typically report feeling unconfident in science and teaching science to children (D. B. Greenfield et al., 2009; Koballa & Crawley, 1985; Saçkes et al., 2012; Spektor-Levy et al., 2013). Teachers' own beliefs about science could therefore be communicated to the children through the activation of the children's own gender stereotypes. In addition, a recent study showed that girls are particularly susceptible to social influences with regard to their self-efficacy beliefs (Butz & Usher, 2015). Girls might thus be particularly vulnerable, as they are more susceptible to female teachers' own beliefs and are also the targets of the societally-prevalent stereotypes related to science. At the same time, girls might profit in particular from female preschool teachers who are confident in science, as they may counteract the societally-prevalent stereotypes and act as positive role models instead.

1.6. Research Objectives

The present paper aims to contribute to a better and more nuanced understanding how early science experiences in preschools may shape children's motivation in science. To this end, we examine the following research questions: (1) How are preschool teachers' self-efficacy beliefs in teaching science related to the frequency of their science activities, as one aspect of their science practices? (2) How do teachers' self-efficacy beliefs and their science activities relate to children's science motivation? (3) Are there gender differences in children's science motivation, and does the relation between preschool teachers' beliefs, children's motivation, teachers' science activities, and children's motivation differ by gender?

Based on the literature review we make the following predictions. Preschool teachers' self-efficacy for teaching science is positively related to the frequency of their science activities in the classroom (H1). Since regular science learning opportunities are considered to be important for the development of children's motivational beliefs in science, we assume that the frequency of teachers' science activities is positively related to children's science motivation (H2a). Based on social learning theory, we also assume that teachers' self-efficacy beliefs are positively related to children's own science motivation (H2b). With regard to teachers as role models, we believe that the self-efficacy beliefs of the (mostly female) teachers might be more important for girls' than for boys' motivation in science (H3).

2. Method

2.1. Procedure and Sample

The data was collected as part of the larger project [details removed for peer review], which examines the effects of early science education on both preschool teachers' and children's science competencies. In order to ensure a large variety of experiences with science among preschool teachers and children, roughly the same number of preschool centers with and without a focus on science education were included in the sample. Altogether 107 preschool centers from five federal states in Germany (Berlin, Hessen, North Rhine-Westphalia, Schleswig-Holstein and Thuringia) participated in the study. Preschool teachers were recruited through the center managers. To recruit children ages 5-6, parental consent documents were send out to parents of children in this age group. All teachers and children for whom we received informed consent were included in the sample.

Preschool teacher sample. N = 348 preschool teachers were included in the sample. Participants completed an online questionnaire on their beliefs about teaching science, their activities, as well as important background characteristics (gender, work experience, and highest educational degree). The vast majority of the participants were female (91%), on average participants had 13.5 years of work experience, and the majority had completed vocational training in early childhood education (71.0%; 6.2% had a Masters' degree or Diploma, 8.2% had a Bachelors' degree in a social-pedagogical subject; 12.0% had completed a vocational training in a social or social-pedagogical field; 2.1% had completed a vocational training in a different field, and 0.6% had not completed any vocational or educational training).

Children's sample. N = 277 children were included in the sample for our analyses. Information about children's age, gender, and the language children speak at home was obtained at the beginning of each child's interview. The sample mean age was 72 months (5.9 years, range: 4 to 7 years), 48% of the children were female, and 27% spoke another language other than German at home.

Matched sample of preschool teachers and children. Our research questions regarding the relation between teacher-level and child-level variables were answered using a matched dataset of preschool teachers and children. Allocation of preschool teachers to the children was based on teachers' ratings of how often they cared for each child in the sample. In 60.42% of the cases, the allocation of teachers to children was unambiguous, as there was only one preschool teacher with the highest caring time for an individual child. When there was a tie concerning the caring time per child among preschool teachers, we randomly selected one of the preschool teachers with the highest caring time to be included in the analyses. There were some children for which no data on their preschool teachers were available, as well as data on preschool teachers who did not take care of any child in our sample. These cases were removed from the analyses for research questions two and three. The final matched dataset consists of 234 children, nested in 88 preschool teachers, nested in 46 preschool centers (average cluster sizes: 2.7 children per preschool teacher and 5.1 preschool teachers per center). The children's sample statistics were similar to those of the full sample (mean age = 72 months; 49% female; 25% spoke another language other than German at home), however, a comparison of the children who were excluded from the matched sample with the children who were included in the matched sample revealed a small age difference (69 vs 72 months, respectively; see Appendix A, Table A1 for details). We argue that a difference of three months in age should not result in meaningful bias regarding our variables of interest. In fact, despite the age difference, children's science self-efficacy and enjoyment were nearly identical in both samples (see Table 1). Nevertheless, we control for children's age in all our analyses and therefore account for this small difference.

The 88 preschool teachers in the matched sample were similar to those in the full sample in their work experience (12.5 years on average) and education (66.5% vocational training in early childhood education; 7.6% Master's degree; 10.3% Bachelor's degree; 10.7% vocational training in a social or social-pedagogical field, and 4.9% in a different field; see Table A2 for more details). There were, however, slightly more male teachers in the matched sample than in the full sample (12% vs. 9%, respectively). In order to avoid bias, we control for teachers' gender, their work experience, and highest educational degree in all our analyses.

2.2. Measures

Teacher's self-efficacy for teaching science. The measure of preschool teachers' self-efficacy beliefs about teaching science was developed based on existing scales used in the P-TABS (Maier, Greenfield, & Bulotsky-Shearer, 2013) and in the SNaKE study (Lankes, Steffensky, Carstensen, Kuhn, & Nölke, 2012). Participants rated their confidence in teaching science to young children on a 4 point Likert scale. Response options range from disagree (1) to agree (4). The scale consisted of 7 items ($\alpha = 0.83$, example items: "I am confident that I can recognize early science learning opportunities"; "I am confident that I can explain science content in an age-appropriate way").

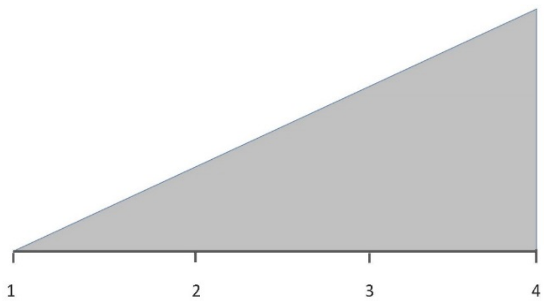
Teachers' science-related practices. We assessed one central aspect of teachers' practices, namely the frequency of their science-related activities using the following item: "Please recall the last three months: How often did you engage in exploring a science-related question together with the children in your classroom?". The item was administered with a closed response format ranging between *never* (0), *less than 1-3 times a month* (1), *1-3 times a month* (2), *once a week* (3), *several times a week* (4) and *daily* (5).

Caring time per child. Information about the allocation of preschool teachers to the children in our sample was obtained through the preschool teachers. Teachers were given a list of all the children in their preschool who participated in our study and were asked to indicate if they care for this child daily (4), several times a week (3), several times a month (2), less than several times a month (1), or never (0). On average, teachers cared for the children in the matched sample between daily and several times a week (N = 234; M = 3.73; SD = 0.60).

Children's science motivation. Children's science motivation was measured using the young children's science motivation scale (Y-SCM) (Oppermann et al., 2017). The Y-SCM is a questionnaire with standardized items and response options, which is carried out in one-to-one personal interviews. The scale consists of 28 items on children's self-efficacy (15 items) and enjoyment (13 items) in physical and life science. Each item is comprised of a descriptive statement of an everyday science learning situation and a subsequent question of how confident children would be in this situation or how much they would enjoy learning about this particular topic. The science topics covered in the P-SCM relate to the preschool science curricula in Germany as well as the research literature on science activities and materials that children typically encounter in preschool (D. B. Greenfield et al., 2009; Tu, 2006). The item development and the choice of response formats was based on a review of existing measures of motivational beliefs among children aged 5-6 years (e.g. Edens & Potter, 2013; Mantzicopoulos et al., 2008; Measelle, Ablow, Cowan, & Cowan, 1998). The items utilize a 4 point Likert scale response format combined with a graphical illustration in the form of a bar of increasing size (see figure 1). Scale reliability and factorial validity were established in a previous study (see Oppermann et al., 2017). Results from confirmatory factor analyses supported a two-factor structure (latent correlation between enjoyment and self-efficacy was r = .41), and reliability results for the self-efficacy (15 items, α = 0.87) and enjoyment (13 items, α = 0.86) subscales were good. Evidence of convergent and divergent validity stems from the positive relations of both scales with the preschools' science focus as well as non-significant relations to the children's receptive vocabulary skills (PPVT-III, Dunn & Dunn, 2004), numeracy skills (K-ABC, Melchers & Preuß, 2009), and general cognitive abilities (CFT1-R, Weiss & Osterland, 2012) (see Oppermann et al., 2017 for more information).

"Have you ever watched what happens to water in a pot while boiling noodles or potatoes? Imagine your preschool teacher asks you why steam rises over a pot with boiling water. Please show me how well you could answer that question:

Could you answer it very well [interviewer points to the largest area of the diagram] quite well [interviewer points to the second largest area of the diagram] not very well [interviewer points to the second smallest area of the diagram] or not at all [interviewer points to the smallest area of the diagram]?"



"Please show me how much you would enjoy learning more about why steam rises over boiling water. Would you enjoy that very much, quite a lot, not that much or very

Figure 1. Sample item and response format.

2.3. Statistical Analyses

Statistical models. To tackle our first research question concerning the relation between preschool teachers' science self-efficacy and their early science activities, we used multivariate regression analyses in Mplus (version 7.3) based on the full teacher-level dataset of N = 348. The data were clustered by preschool centers and standard errors adjustments were used to account for the multilevel structure of the data. As the percentage of missing data ranges between 1.1% and 8.3% and the data were missing completely at random (MCAR; test for MCAR; $\chi^2 = 4.94$, $df = 8$, $p = 0.76$), we used full information maximum likelihood (FIML) for estimation of missing values, which is considered the superior method under ignorable missing data conditions (Arbuckle, 1996; Enders & Bandalos, 2001). To enhance interpretation of the model coefficients, all variables were z-standardized before modeling.

The second research question regarding the relation between preschool teachers' efficacy, their science activities, and children's motivation, was investigated using two level path analysis with children at Level 1 and teachers at Level 2. We accounted for the non-independence of teachers within preschools by estimating the standard errors of the model parameters (type = twolevel complex in Mplus). All variables were z-standardized before modeling. Model fit was assessed with reference to RMSEA, CFI, and SRMR using the criteria suggested by Hu and Bentler (1999). The percentage of missing data for the matched teacher-child dataset ranges between 0% and 7.7% on the observed variables. As the data were missing completely at random (test for MCAR; $\chi^2 = 28.56$, $df = 27$, $p = 0.38$), we used full information maximum likelihood (FIML) for all analyses related to the second and third research questions.

For our third research question we first tested for gender differences in children's motivation using analysis of variance (ANOVA). Evidence for measurement invariance of the child motivation scales (Y-CSM) to gender is provided in an earlier study by Oppermann et al. (2017). To test for differential effects of teachers' self-efficacy beliefs and their activities on boys' and girls' motivation, we applied a multiple group mixture model approach as described by Asparouhov and Muthen (2012). In this approach the grouping variable (gender) is entered as a manifest grouping variable using the "knownclass" option in Mplus. We calculated differences between the path coefficients by group and tested for significance using the "Model Test" option in Mplus. To identify the model, the teacher-level path (teachers' self-efficacy on their activities) was constrained equal across gender. As in the previous analyses, all variables were z-standardized and the nested structure of the data was accounted for by corresponding standard errors adjustments (type = twolevel complex mixture in Mplus).

3. Results

3.1. Descriptives

The descriptive statistics for our observed variables in the matched sample as well as the full teacher/children sample are displayed in Table 1. Teachers' ratings of their self-efficacy beliefs were above the theoretical mean of 2.5 in both samples, indicating that preschool teachers feel rather confident in their own ability to teach science to young children. On average, teachers reported engaging in science 1-3 times a month in both samples. Only 1.9% of preschool teachers engaged in science daily (Frequencies for the full sample: 16.6% engage in science several times a week, 16.9% once a week, 24.1% 1-3 times a month, 28.8% less than 1-3 times a month, and 11.6% never). Children's motivational beliefs in science were also above the theoretical average of 2.5 in both samples, indicating that children were confident in their own abilities in science and enjoy learning about science. Taken together, the means and standard deviations of the scales in the full vs. the matched sample are very similar, indicating that the matched sample represents the full sample of teachers and children well with regard to our variables of interest.

Table 1

Summary of descriptive statistics for the scales

	Full Sample					Matched Teacher-Child Sample				
	N	M	SD	Min	Max	N	M	SD	Min	Max
Teachers' self-efficacy	343	3.04	0.48	1.71	4.00	85	3.00	0.48	2.14	4.00
Teachers' activities	319	2.04	1.33	0.00	5.00	81	2.07	1.32	0.00	5.00
Children's self-efficacy	277	3.00	0.66	1.07	4.00	234	3.02	0.65	1.13	4.00
Children's enjoyment	277	3.55	0.54	1.46	4.00	234	3.57	0.53	1.54	4.00

Note. Full sample statistics relate to the full teacher and the full children's sample, respectively.

Table 2 displays the bivariate correlations between the scales based on the matched sample. Teachers' self-efficacy beliefs in science and their activities were positively related.

Teachers' self-efficacy beliefs were also related to children's self-efficacy beliefs, but not to their enjoyment. There was no significant relation between teachers' activities and children's self-efficacy or their enjoyment. Children's science self-efficacy and their enjoyment were positively related.

Table 2

Bivariate Correlations

	1	2	3
1 Teachers' self-efficacy for science teaching			
2 Frequency of teachers' science activities	.27**		
3 Children's science self-efficacy	.23**	.13	
4 Children's science enjoyment	.10	.03	.34**

Note. ** $p < 0.01$.

3.2. Relations between preschool teachers' science self-efficacy and the frequency of their science activities

Results for the regression analysis predicting the frequency of preschool teachers' science activities by their self-efficacy for teaching science are displayed in Table 3. Preschool teachers' self-efficacy for teaching science are positively related to the frequency of teachers' practices: The higher preschool teachers' self-efficacy for teaching science, the more often they engage in science activities together with the children in their classroom. There were no significant relations between any of the background variables (i.e., teachers' gender, work experience, and education) and teachers' science activities.

Table 3

Summary of regression results the frequency of teachers' science activities on their self-efficacy for teaching science

	Beta	*SE*	95% CI	*p*
Gender (0 = male)	.09	.07	[-.04, .22]	.19

Work experience	.05	.05	[-.05,.15]	.31
Highest educational degree	-.04	.06	[-.16, .08]	.53
Self-efficacy for science teaching	.31	.06	[.20, .42]	.00
R^2	.11	.04		.00

Note. N = 348.

3.3. Relation between preschool teachers' science self- efficacy, their activities, and children's motivation

The results for the path model predicting children's science self-efficacy beliefs and their enjoyment are displayed in Figure 2 (see Table B1 in the Appendix for the results including covariates). The overall model fit was satisfactory (χ^2 = 9.80, *df* = 9; RMSEA = 0.02; CFI = 0.99; SRMR = 0.04). Child-level results showed that children's science self-efficacy and enjoyment were positively correlated (*r* = .33, *p* < .001). Teacher-level results indicated a positive relation between teachers' self-efficacy for teaching science and the frequency of their science activities. The beta coefficient was similar to the regression results using the full teacher-level data (*ß* = .35, *p* < .001).

Teacher's science activities were not significantly related to children's science self-efficacy or their enjoyment. This null effect was similar for children's science self-efficacy and enjoyment (Δß = -.08, p = .47).

The indirect relation between preschool teachers' self-efficacy and children's self-efficacy, via teachers' science activities, was also not significantly different from zero (*ß* = .02, *p* = .65). Likewise, the indirect relation between preschool teachers' self-efficacy and children's enjoyment, via their activities, was not statistically significant (*ß*= .04, *p* = .21).

There was, however a positive direct relation between preschool teachers' and children's self-efficacy beliefs in science. The more confident teachers were in teaching science, the more confident children were in learning about science. There was no significant relation between teachers' self-efficacy beliefs and children's science enjoyment. Accordingly, teachers' science self-efficacy beliefs were more strongly related to children's self-efficacy beliefs than to children's enjoyment in science (Δß = .18, *p* = .03).

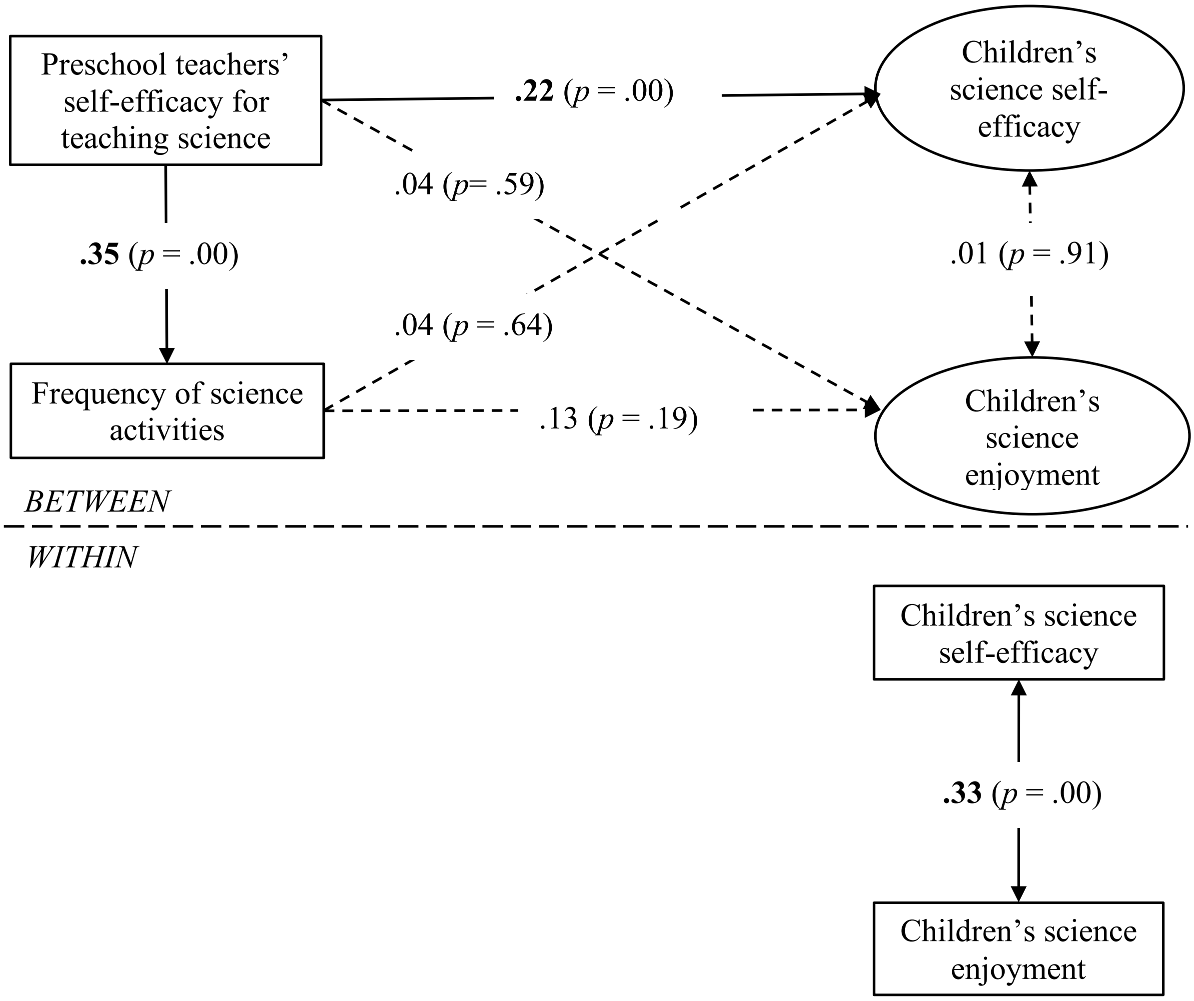


Figure 2. Results of the multilevel path model. Standardized coefficients are shown. The model included children's age, gender, and language spoken at home as covariates for the two motivation scales (on the within level) as well as teachers' gender, work experience, and highest educational degree as covariates for all dependent variables (on the between level). To ensure clarity of presentation, covariates and corresponding paths are not shown in Figure 1. Statistically not significant relations ($p > 0.05$) are indicated by a dashed line.

3.4. Gender differences

The ANOVA results for gender are displayed in Table 4. There was a significant difference in children's self-efficacy by gender: Girls were less confident in science than boys, but the effect size was small (Cohen, 1988). There was no significant gender difference in children's science enjoyment.

Table 4

Mean differences in children's motivation by gender

	Girls		Boys				
	M	SD	M	SD	F	*p*	Cohens' *d*
Science self-efficacy	2.89	0.69	3.11	0.62	7.45	.01	0.33
Science enjoyment	3.58	0.48	3.52	0.58	0.84	.36	0.11

Note. N = 277 children, 134 girls and 143 boys.

Figure 3 displays the results, including 95% confidence intervals, for the mixture multilevel model with children's gender as a grouping variable. Results for teachers' science activities revealed no significant relation to children's self-efficacy for either gender (Girls: $\beta = -.12$, $p = .32$; Boys: $\beta = .19$, $p = .08$), however, the difference between girls' and boys' path coefficient was significant. This indicates that the relation between teachers' science activities and children's self-efficacy beliefs was significantly stronger for boys than for girls ($\Delta\beta = .31$, $p = .02$). There was a similar pattern of results for children's enjoyment: Teachers' science activities were positively related to boys', but not to girls' science enjoyment (Girls: $\beta = -.06$, $p = .66$; Boys: $\beta = .26$, $p = .03$). The difference between girls' and boys' path coefficient was similar to that of children's self-efficacy, however, it was not statistically significant ($\Delta\beta = .31$, $p = .07$).

With regard to teachers' self-efficacy, we found a positive relation to girls' but not to boys' own self-efficacy beliefs in science: The path coefficient was larger for girls than in the whole sample, whereas for boys the coefficient was smaller and no longer significant (Girls: $\beta = .33$, $p = .00$; Boys: $\beta = .05$, $p = .63$). This relation was also significantly different for girls and boys ($\Delta\beta = -.29$, $p = .03$). The pattern of associations was similar for girls' and boys' enjoyment, however, none of the relations were significantly different from zero (Girls: $\beta = .14$, $p = .13$; Boys: $\beta = -.10$, $p = .23$). Nevertheless, the difference between girls' and boys' path coefficient was significant (Δß = -.24, *p* = .04), indicating that the relation between teachers' self-efficacy beliefs and children's enjoyment was significantly stronger for girls than for boys.

The indirect relation between preschool teachers' self-efficacy and children's self-efficacy, via teachers' science activities, was not significant for either gender (Girls: *ß* = -.04, *p* = .35; Boys: *ß* = .06, *p* = .15). Likewise, the indirect relation between preschool teachers' self-efficacy and children's enjoyment, via teachers' activities, was not significant for either gender (Girls: *ß* = -.02, *p* = .67; Boys: *ß* = .09, *p* = .08).

In summary, the mixture model results indicate a distinct pattern: Teachers' self-efficacy beliefs were more positively related to girls' than to boys' science motivation, whereas teachers' science activities tended to be more positively related to boys' than to girls' science motivation.

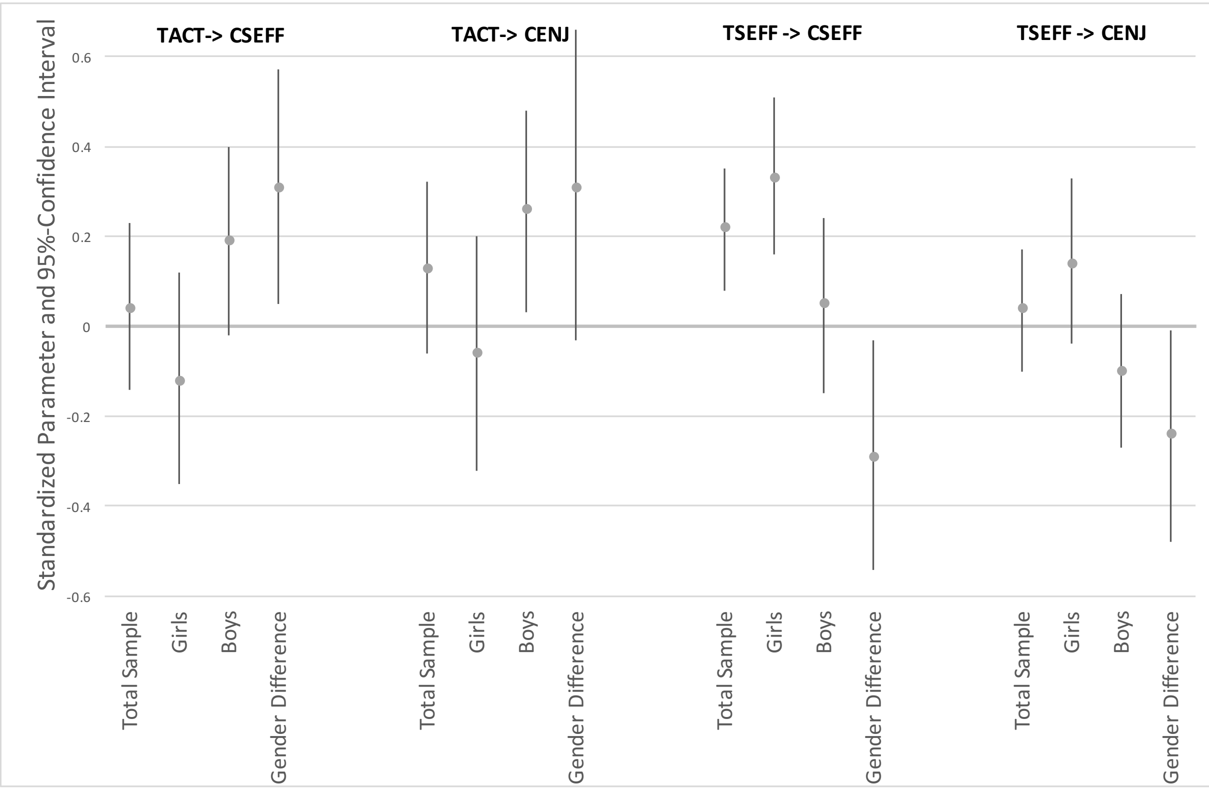


Figure 3. Results of the multilevel mixture model (N = 234 children nested in N = 88 preschool teachers.) TACT = Teachers' science activities; CSEFF = Children's science self-efficacy beliefs; CENJ = Children's science enjoyment; TSEFF = Teachers' self-efficacy beliefs. The model included children's age, gender, and language spoken at home as covariates for the two motivation scales (on the within level) as well as teachers' gender, work experience, and highest educational degree as covariates for all dependent variables (on the between level).

4. Discussion

The aim of the present study was to investigate the interplay of preschool teachers' self-efficacy beliefs in science, their practices, and boys' and girls' motivation to learn in science. Our key findings can be summarized as follows: (1) Preschool teachers' self-efficacy beliefs in science were positively rated to the frequency of their science activities. (2) Teachers' science self-efficacy beliefs were positively related to children's science self-efficacy beliefs in the entire sample. No significant relation was found for teachers' activities and children's motivation. Yet, these general relations were composed of gendered patterns: (3) Teachers' self-efficacy beliefs showed a stronger association with girls' than with boys' motivation whereas teachers' science activities showed a stronger association with boys' than with girls' science motivation. In the following, we discuss our key findings in light of the relevant research literature and give directions for further research.

4.1. Relations between preschool teachers' science self-efficacy and the frequency of their science activities

How are preschool teachers' self-efficacy beliefs in science related to their science activities? This question has not been empirically examined for the domain of science, yet. Previous studies in primary and secondary school (in domains other than science) identified teachers' self-efficacy beliefs as one of the most important predictors of teachers' behavior on the classroom (Goddard et al., 2000; Guo, Dynia, Pelatti, & Justice, 2014; Guo et al., 2010; Maier et al., 2013). Early science learning at the preschool level, however, differs from science education in primary and secondary school in that it is more informal and play-based, particularly in countries that follow a child-centered approach. Thus, teachers' confidence in their own ability to teach science might actually be more relevant than later in school, as it is entirely up to the preschool teachers to decide if and how many science learning situations they would like to offer in their day-to-day routines. In line with empirical findings and theoretical considerations, we expected a positive relation between preschool teachers' self-efficacy beliefs in science and the frequency of their early science activities. This hypothesis was empirically supported by our results: An increase of preschool teachers' self-efficacy beliefs of one standard deviation was associated with a higher rate of science-related activities in the preschool classroom by about one-third of a standard deviation. The size of this effect is similar to those found in the context of primary and secondary schools (see the meta-analysis by McBryde, 2013). Thus, teachers' confidence in their own ability to teach science seems to be highly relevant to their practices in all stages of science education.

4.2. Relations between preschool teachers' science self- efficacy, their activities, and children's motivation

Children's motivational beliefs are shaped by their experiences (Daniels & Meece, 2007; Wigfield et al., 1997). Thus, the development of children's motivational beliefs about science might largely depend on how often children get a chance to engage in science in preschool. In line with this assumption, previous studies have documented beneficial effects of an increase in science education at the preschool level for children's science motivation (Oppermann et al., 2017; Mantzicopoulos et al., 2008). Yet, little is known about how the frequency of individual teachers' science activities, within a heterogeneous sample of preschools, relates to the motivational beliefs of the children they engage with. Based on the research literature, we assumed that the frequency of teachers' science activities would be positively related to children's science motivation. Contrary to our hypothesis and previous findings, however, results revealed no significant relation between teachers' science activities and children's motivation in the total sample. This inconsistency with previous research may be explained by the distinct pattern of associations found for boys and girls (see below).

In addition to teachers' science practices, we were interested in how teachers might act as role models for the children in their classrooms. Social learning theory (Bandura, 1977b; Schunk & Zimmerman, 2007), as well as evidence from previous research indicates that modeling is an important process through which children can adapt their own motivational beliefs simply by observing self-efficacious models (Lirgg & Feltz, 1991; Stipek & Byler, 2001; Zimmerman & Ringle, 1981). These mechanisms, however, have not yet been investigated in the early childhood context and especially not as a function of children's gender. In line with the theoretical considerations as well as our hypothesis, results reveal a positive relation between preschool teachers' and children's science self-efficacy beliefs. In interpreting this finding, it is important to take into account the distinct pattern that we found for boys and girls.

4.3. Gender differences

Research on older children's science motivation documents a severe gender gap (DeWitt et al., 2011; Eccles et al., 1993; Saçkes et al., 2011). Yet, research on young children's motivational beliefs is limited, and results regarding gender differences are contradictory (Alexander et al., 2008; Andre et al., 1999; Leibham et al., 2013; Mantzicopoulos et al., 2008). Hence, one aim of this study was to test for gender differences in our sample of children aged 5-6 years. Results revealed that girls were less confident in science than boys ($d = .33$) whereas gender differences in children's science-related enjoyment were almost negligible ($d = .11$). Interestingly, the direction and size of this effect is consistent with findings later in primary and secondary school (DeWitt et al., 2011; Eccles et al., 1993; Saçkes et al., 2011). However, the fact that we did find a significant difference at the preschool level stands in contrast to some previous studies (Andre et al., 1999; Mantzicopoulos et al., 2008). This inconsistency might be explained by the fact that our sample was more heterogeneous and that we used a different measurement approach. For example, Mantzicopoulos et al. (2008) investigated gender differences using a different instrument with children who participated in a specific science program. Since children's motivational beliefs are grounded in their experiences and children in a pre-structured science program are likely to have similar science experiences, gender differences are less likely to emerge. Based on a more heterogeneous sample of children with different science experiences, our results indicate that gender differences in children's self-efficacy beliefs are already present at the preschool level in the science domain. It remains unclear, however, whether this gender difference is specific to science or whether it is part of a more general tendency of boys being more confident than girls. Although this question has not been addresses for children aged 5-6 years, research on older children, adolescents, and adults indicates that gender differences in motivation follow gender role stereotypes, i.e. boys being more confident in math and science, and girls being more confidence in language and arts (Eccles et al., 1993; Gentile et al., 2009; Meece, Glienke, & Burg, 2006; Pajares & Valiante, 2001). It seems reasonable to assume that the gender differences found in this study for younger children are also domain specific, i.e. specific to science, rather than indicative of a general tendency across domains. Nevertheless, further research is required to investigate the domain-specificity of gender differences in young children's motivation.

Based on the assumption that children's motivational beliefs are grounded in their experiences, gender differences in children's motivation might emerge due to differential experiences of boys and girls in the early science classroom. Although research for primary and secondary school documents that teachers treat girls and boys differently (Eccles & Blumenfeld, 1985; Fagot, 1977; Serbin et al., 1973), there is no research on gendered patterns in the relation between teachers' activities and children's science motivation at the preschool level. Thus, this study aimed to investigate whether the relation between teachers' activities and children's science motivation differs by gender. Our results support the notion of gendered patterns in teachers' practices: The relation between teachers' science activities and children's science self-efficacy was significantly stronger for boys than for girls. A similar pattern of results was found for children's enjoyment: Teachers' activities were positively related to boys', but not significantly related to girls' science enjoyment. The results point to a distinct pattern of associations between teachers' activities and children's motivation, which were stronger for boys than for girls. This might be because teachers interact more with the boys in their classroom during their science activities or because there is a qualitative difference in teachers' interactions. Both patterns of teachers' behavior have been documented for preschool

(Brandes et al., 2015; Kuger et al., 2011; Wolter et al., 2015) and primary school teachers' science practices (T. A. Greenfield, 1997). Alternatively, the results might be indicative of the fact that boys actively seek more science-related interactions with the teachers in their classroom and teachers simply react accordingly. However, it is important to note that Baram-Tsabari, Sethi, Bry, and Yarden (2006) found that girls asked more, not less, science-related questions than boys. Taken together, the present study provides evidence that gendered patterns in the relation between teachers' practices and children's motivation may well exist at the preschool level. To further our knowledge on the evolution of gender differences in children's motivational beliefs, longitudinal studies are required to identify the mechanisms underlying the statistical associations found in this study.

Teachers may not only influence girls' and boys' motivational beliefs in science through their practices, but also by acting as role models. Social learning theory suggests that children are more susceptible to models that are similar. Since roughly 90% of preschool teachers in our study were female, we assumed that teachers' self-efficacy beliefs in science might be more relevant for girls' than for boys' own motivational beliefs. Our findings support this assumption: The science self-efficacy beliefs of the mostly female teachers were significantly related to girls', but not to boys', self-efficacy beliefs in science. Similarly, the relation between teachers' self-efficacy beliefs and children's enjoyment was significantly stronger for girls than for boys. The results indicate that teachers communicate their own confidence in science to the girls they engage with. The importance of female teachers as role models for girls has been documented in a previous longitudinal study by Beilock et al. (2010) with regard teachers' math anxiety and girls' math achievement. This is the first study to reveal similar relations at the preschool level.

4.4. Limitations and directions for further research

There are a number of limitations to the present study that should be noted. First, although the sample was drawn from preschools all over northern Germany, participation in the study was voluntary, and thus the sample may suffer from selection bias. Moreover, it might not be representative of all preschools in Germany as preschools with a science focus might be overrepresented when compared to the German average.

Second, we cannot make inferences about causality due to use of cross-sectional data. Although we cannot exclude the possibility of bi-directional effects, previous research based on longitudinal data in primary and secondary school indicates that (a) preschool teachers' self-efficacy beliefs predict their practices (Guo, Connor, Yang, Roehrig, & Morrison, 2012; Künsting, Neuber, & Lipowsky, 2016), (b) teachers' practices predict children's motivation (Lerkkanen et al., 2012; Stipek et al., 1995), and (c) teachers' self-efficacy beliefs predict children's self-efficacy beliefs (Midgley et al., 1989; Stipek et al., 2001). Thus, we consider it more likely that the direction of the associations at the preschool level is consistent – not opposite – to the direction of associations at higher educational levels. Nevertheless, more research is required to test this assumption using a longitudinal sample.

A third limitation relates to our measure of teachers' science practices. The study was limited to one aspect of teachers' practices, namely the frequency of their science activities, which was measured based on a single item. Although the frequency of science activities is a rather homogenous construct, which may not require more than one item, future studies should nevertheless validate our measure using observational data. In addition, future research should broaden the scope to include other aspects of teachers' practices, such as the quality of teachers' science-related interactions with the children in their classroom. Quality in the early childhood context is often referred to as process quality (Anders, 2014; NICHD ECCRN, 2003) and describes the nature, rather than the frequency, of the interactions between preschool teachers and children. In addition to global aspects of process quality, such as a warm classroom climate, (Pianta et al., 2005), studies highlight the importance of domain-specific stimulation for children's learning and development (Anders, Grosse, Rossbach, Ebert, & Weinert, 2012; Kuger & Kluczniok, 2008), e.g. cognitively stimulating interactions or dialogues between teachers and children in science (Hopf, 2012). However, previous studies also show that high quality early science learning situations are very rare in preschool. For instance, König (2009) documented 60 hours of everyday practices in German preschools and found only one sequence could be characterized as high quality and it was not related to any educational areas, such as math or science. An experimental study by Hopf (2012) found that even in a setting, where teachers were asked to practice science together with a small group of children, only 23,1% of all interactions could be characterized as high quality. Thus, at this stage, it may be more relevant that children get a chance to engage in regular science activities together with their preschool teachers at all. Nevertheless, the quality of these learning activities remains relevant. Future research should account for both the quality as well as the quantity of teachers' science practices with regard to child outcomes.

Fourth, we assessed the frequency, i.e. quantity, of teachers' science activities on the teacher-level and cannot draw conclusions about teachers' interactions with each individual child. Yet the frequency of teachers' activities has been shown to be relevant to the boys in our sample and thus seems to capture an important aspect of teachers' practices. Future studies should look at the quantity of the individual interactions between preschool teachers and children more closely in order to get a more detailed understanding of how they affect children's science motivation.

4.5. Concluding remarks and implications for research and practice

The present study provides empirical evidence on the significance of preschool teachers' science self-efficacy beliefs for the frequency of their science practices. The more confident teachers were in teaching science to young children, the more often they engaged in science activities with the children in their classroom. Teachers' science activities, in turn, seemed to more strongly related boys' motivation, whereas teachers' own self-efficacy beliefs in science were more strongly related girls' motivation in science. Thus, taken together, the present study provides novel evidence on gendered patterns in the association between teachers' self-efficacy beliefs, their science activities, and children's science motivation. These results demonstrate that children's gender is highly relevant to their learning experiences in science. Based on these results, future studies should investigate these gendered patterns of associations linking teachers' self-efficacy, practices, and children's motivation in more detail using longitudinal data. This would provide a better understanding of how teachers' behavior might contribute to gender differences in children's early motivational beliefs about science.

With regard to the practical implications, our findings suggest that teachers should be more aware of their roles, not just as teachers in science, but also as role models for the children in their science classrooms. Moreover, strategies to promote teachers' self-efficacy beliefs in science might be fruitful. The pattern of results found in this study may indicate that girls and boys may both profit from more confident preschool teachers in science, but in different ways: Boys may benefit from confident teachers implementing more science activities, and girls from having confident teachers as role models. But how can teachers' science self-efficacy beliefs be improved? A recent study found that preschool teachers' self-efficacy beliefs in teaching science was positively related to their participation in professional training in science (Oppermann, Anders, & Lebski, 2016; Steffensky et al., 2017). This is in line with earlier findings by Lakshmanan, Heath, Perlmutter, and Elder (2011) who reported gains in secondary school science teachers' self-efficacy beliefs through professional development over the course of three years. Thus, preschool teachers' confidence seems to benefit from professional development in science. In turn, our results indicate that when teachers feel more confident in science, they seem to be more likely to regularly offer early science learning activities and embody confident role models for young children.

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Appendix A

Table A1

Comparison of children included and not included in the matched sample

	Included			Not Included				
	N	M/ %	SD	N	M/ %	SD	F	p
Age in months	232	72.28	5.51	43	69.21	7.08	10.24	.00
Gender (0 = male)	234	49%		43	47%		0.07	.79
Other language than German	234	25%		43	37%		2.87	.09
Science self-efficacy	234	3.02	0.65	43	2.89	0.73	1.35	.25
Science enjoyment	234	3.57	0.53	43	3.45	0.55	1.55	.22

Note. Included = Children, who were included in the analyses for our second and third research question. Not included = children, who were not included in the analyses for our second and third research question.

Table A2

Comparison of teachers included and not included in the matched sample

	Included			Not Included				
	N	M/ %	SD	N	M/ %	SD	F	p
Gender (0 = male)	85	85%		259	93%		5.49	.02
Work experience in years	85	12.37	11.45	256	13.91	11.62	1.12	.29
Highest educational degree	85	4.99	0.78	256	5.04	0.76	0.28	.60
Science self-efficacy	85	3.00	0.48	258	3.05	0.48	0.56	.46
Science activities	81	2.07	1.32	238	2.03	1.33	0.08	.78

Note. Included = Children, who were included in the analyses for our second and third research question. Not included = children, who were not included in the analyses for our second and third research question. Teachers' educational degree was coded as follows: 0 = no vocational education; 1 = vocational training in a different field; 2 = vocational training in a social or social-pedagogical field; 3 = vocational training in early childhood education; 4 = Bachelors' degree in a social-pedagogical subject; 5 = Masters' degree or Diploma in a social-pedagogical subject.

Appendix B

Table B1

Results of the multilevel path model

	Beta	*SE*	95% CI	*p*
Children's science self-efficacy on teachers'				
Gender (0 = male)	-.17	.20	[-.56, .22]	.40
Work experience	-.03	.06	[-.16, .10]	.66
Highest educational degree	-.05	.08	[-.20, .11]	.56
Science self-efficacy	.22	.07	[.08, .35]	.00
Science activities	.04	.09	[-.14, .23]	.64
Children's science enjoyment on teachers'				
Gender (0 = male)	.32	.24	[-.14, .79]	.17
Work experience	-.06	.06	[-.18, .07]	.36
Highest educational degree	.19	.07	[.05, .33]	.01
Science self-efficacy	.04	.07	[-.10, .17]	.59
Science activities	.13	.10	[-.06, .32]	.19

Note. N = 234.

Table B2

Results of the mixture multilevel model with children's gender as a grouping variable

	Girls				*Boys*			
	Beta	*SE*	95% CI	*p*	Beta	*SE*	95% CI	*p*
Children's science self-efficacy on teachers'								
Gender (0 = male)	-.22	.20	[-.62, .17]	.27	-.14	.18	[-.48, .21]	.44
Work experience	-.03	.08	[-.18, .12]	.73	.02	.09	[-.15, .19]	.81
Highest educational degree	-.18	.11	[-.39, .03]	.09	.12	.12	[-.12, .36]	.32
Science self-efficacy	.33	.09	[.16, .51]	.00	.05	.10	[-.15, .24]	.63
Science activities	-.12	.12	[-.35, .12]	.32	.19	.11	[-.02, .40]	.08
Children's science enjoyment on teachers'								
Gender (0 = male)	.11	.22	[-.31, .54]	.61	.17	.32	[-.46, .81]	.59
Work experience	.08	.08	[-.07, .24]	.30	-.10	.10	[-.30, .10]	.31
Highest educational degree	.04	.08	[-.11, .19]	.58	.32	.14	[.05, .60]	.02
Science self-efficacy	.14	.10	[-.04, .33]	.13	-.10	.09	[-.27, .07]	.23
Science activities	-.06	.13	[-.32, .20]	.66	.26	.11	[.03, .48]	.02

Note. N = 234.

STUDY 3

The influence of preschool teachers' content knowledge and mathematical ability beliefs on their sensitivity to mathematics in children's play

Oppermann, E., Anders, Y., & Hachfeld, A. (2016). The influence of preschool teachers' content knowledge and mathematical ability beliefs on their sensitivity to mathematics in children's play. *Teaching and Teacher Education*, 58, 174-184. http://dx.doi.org/10.1016/j.tate.2016.05.004

The study was conducted under the lead of Yvonne Anders and Hans-Günther Rossbach at the University of Bamberg, Department of Education, Chair of Early Childhood Education (Prof. Rossbach).

Abstract

In countries with a social pedagogic tradition for early childhood education, mathematical learning typically takes place in play-based situations. Preschool teachers' ability to recognize mathematical content in children's play is therefore an important prerequisite for educational quality. The present study examines how this ability relates to other aspects of preschool teachers' professional competencies. Findings from regression analysis indicate that mathematical content knowledge (CK) is associated with teachers' sensitivity to mathematical content. However, further analyses reveal that this association is mediated by preschool teachers' self-efficacy beliefs.

Keywords: preschool mathematics, pedagogical content knowledge, content knowledge, teacher beliefs, self-efficacy, self-concept

1. Introduction

Learning in mathematics starts long before children enter school. Young children are capable of acquiring basic competencies in mathematics (Cross, Woods, & Schweingruber, 2009; Ginsburg, Lee, & Boyd, 2008) and these early mathematical fundaments support later, more complex mathematical understanding in school (Clements, Sarama, & DiBiase, 2004; Cross et al., 2009; Duncan et al., 2007; Sylva et al., 2013). Consequently, early mathematical education has become an important objective of preschool programs in many western countries (OECD, 2011). The positive effects of preschool programs for later mathematical achievement in school are documented in recent longitudinal studies (Anders, Grosse, Rossbach, Ebert, & Weinert, 2012; National Institute for Child Health and Human Development Early Child Care Research Network [NICHD ECCRN], 2005; Sammons et al., 2009; Sylva et al., 2013). These studies have also shown that the success of these programs depends on the quality of the pedagogical interactions between preschool teachers and children: Higher quality leading to higher learning gains for the children (Anders, Rossbach, et al., 2012; Melhuish et al., 2008; Sammons et al., 2009; Sylva et al., 2013). However, offering high quality mathematical education is a challenging task for preschool teachers and requires a number of competencies (Cross et al., 2009). The specific competencies required depend on the preschool setting and these settings can vary between countries. Countries such as Australia, Canada, Germany, Korea, Sweden, Norway and Poland emphasize a child- centered approach in their curriculums (OECD, 2011). In these countries, early mathematical learning is typically play-based, embedded in life situations and building up on children's interests. Preschool teachers are therefore required to integrate early mathematical education in children's every day play activities (Ginsburg et al., 2008; McCray & Chen, 2012; McCray, 2008). Yet, in order to help young children engage in mathematics during play, preschool teachers need to be able to recognize the mathematical elements in children's play themselves (McCray & Chen, 2012). In a recent study, McCray and Chen (2012) showed that preschool teachers' ability to recognize mathematical content in children's play activities predicted the quality of early mathematical learning situations and children's learning gains. This ability is thus considered an important aspect of preschool teachers' professional competencies, more specifically, of their pedagogical content knowledge (PCK) (McCray, 2008). However, we currently know very little about which other aspects of preschool teachers' professional competencies are important for preschool teachers' ability to recognize mathematical content in children's play.

There is evidence that mathematical content knowledge (CK) is an important prerequisite for preschool teachers' PCK (Shulman, 1986; Siraj-Blatchford, Sylva, Muttock, Gilden, & Bell, 2002). Recognizing mathematical content in play-based situations requires mathematical CK. Moreover, preschool teachers can only implement early mathematical learning, if they have a conceptual understanding of the mathematical content they are required to teach (Cross et al., 2009).

In addition to mathematical CK, preschool teachers' beliefs are considered important as they guide and motivate daily pedagogical interactions (Fives & Buehl, 2012). According to the social cognitive theory, beliefs about ability in particular predict human motivation and action (Bandura, 1986). With regard to teaching, preschool teachers' math-related ability beliefs might influence their motivation and effort to initiate early mathematical learning situations. For instance, preschool teachers might only seize mathematics in play-based situations if they judge their mathematical ability to be sufficient for teaching early mathematics. In contrast, preschool teachers who consider their ability in mathematics to be low e regardless of their actual mathematical ability e might avoid mathematics and not recognize it in play-based situations. Therefore we assume that preschool teachers' mathematical ability beliefs play an important role for their sensitivity to mathematical content in play-based situations.

In this article, we explore how preschool teachers' mathematical content knowledge (CK) and their mathematical ability beliefs are interrelated and how they affect preschool teachers' sensitivity to mathematics in play-based situations, as one aspect of their pedagogical content knowledge (PCK). In the following, we outline the current state of research on preschool teachers' professional knowledge and ability beliefs. Finally, we introduce the theoretical framework for the study and formulate our research questions.

1.1. Preschool teachers' professional knowledge

Preschool teachers' professional knowledge is considered an important prerequisite for the quality of early childhood education (Lee, 2010; Siraj-Blatchford et al., 2002). Preschool teachers require an understanding of the concepts relevant to preschool education, of children's learning and development, and of effective pedagogy in order to initiate appropriate learning opportunities (McCray & Chen, 2012; Sylva et al., 2013). With regard to teaching early mathematics, two aspects of preschool teachers' professional knowledge are considered particularly important for the educational quality: Their mathematical content knowledge (CK) and their math-related pedagogical content knowledge (PCK) (Cross et al., 2009; Lee, 2010; McCray & Chen, 2012). The concepts of CK and PCK draw on Shulman's (1986, 1987) framework for schoolteachers' professional knowledge and were also adapted to the context of preschool education (Siraj-Blatchford et al., 2002).

In his framework Shulman (1987) defines CK as the necessary subject matter knowledge base for teaching, whereas PCK refers to the "blending of content and pedagogy" (p. 8) into an under- standing of how topics are best presented to learners. This suggests that mathematical CK is necessary for teaching mathematics, but mathematical CK alone does not guarantee high quality instruction. For instance, teachers require knowledge of basic mathematical concepts like addition and subtraction. However, mere mathematical CK of addition and subtraction does not guarantee that they can adequately explain these concepts to children. It is mathematical PCK of addition and subtraction that is required for effective mathematical instruction. Consequently, in the context of primary and secondary school education, mathematical PCK is considered a key prerequisite for high quality mathematical education (Ball, Lubienski, & Mewborn, 2001). Moreover, schoolteachers' mathematical PCK has been shown to be directly related to the instructional quality and students' learning gains (Baumert et al., 2010; Hill, Rowan, & Ball, 2005). For instance, results from the German COACTIV study revealed a substantial positive effect of teachers' PCK on instructional quality (Baumert et al., 2010). However, no direct effect on instructional quality was found for mathematical CK (Baumert et al., 2010). Similar results were obtained in a study by Hill et al. (2005) who showed that elementary teachers' PCK predicted students' learning gains during the first and third grade after controlling for key student and teacher level covariates.

Although these studies focus on elementary level school- teachers, it is conceivable that similar mechanisms exist for preschool teachers' professional knowledge. Nevertheless, when transferring the concepts of CK and PCK to early mathematical education, one needs to take into account the particular characteristics of preschool education. There are currently two different approaches in the literature that conceptualize aspects of PCK relevant to preschool teachers. Lee (2010) proposes a concept of mathematical PCK that is very similar to the original definition of PCK by Shulman (1987). According to Lee (2010) preschool teachers need to know "how to teach or transfer knowledge to the target children" in an understandable manner (p. 29). Whereas Lee's

(2010) concept might be suitable for preschool contexts, which apply a teacher-directed approach that focuses on direct instruction, this might be less the case for child-centered approaches, which emphasize play-based learning. Child-centered approaches are implemented in countries that inherited a social-pedagogy tradition (i.e. Australia, Canada, Germany, Korea, Sweden, Norway, Poland; see OECD, 2011). As this study is situated in Germany, we draw on McCray and Chen's (2012) concept of preschool teachers' mathematical PCK. According to McCray and Chen (2012), mathematical PCK represents preschool teachers' ability to help children "recognize, name, and experiment with the mathematics in their classroom environment" (McCray & Chen, 2012, p. 292). As early mathematical learning often takes place in children's play, teachers' ability to analyze children's play and recognize mathematical content suited for early mathematical education is an important aspect of their PCK (McCray, 2008). Based on this concept, McCray (2008) developed an interview that measures preschool teachers' ability to recognize mathematical content in a children's play scenario task. Using this instrument, McCray and Chen (2012) showed that preschool teachers' ability to recognize mathematics in children's play, as one aspect of their PCK, predicts process quality and children's learning gains.

In the international research literature, there is a consensus that CK is a necessary prerequisite for the development of PCK in primary and secondary teachers (Ball et al., 2001; Baumert et al., 2010; Kleickmann et al., 2013; Lim-Teo, Chua, Cheang, & Yeo, 2007; Shulman, 1987). Because PCK represents teachers' ability to integrate subject matter knowledge and pedagogical knowledge in a way that mathematics is coherent and engaging for the learners (Shulman, 1987), teachers require subject matter knowledge in mathematics (CK). This may also be true for the context of mathematical education in preschools: Preschool teachers require a conceptual understanding of mathematical content relevant to early mathematical education in order to recognize mathematics and promote mathematical learning opportunities (Cross et al., 2009). For instance, Jenßen, Dunekacke, and Blömeke (2015) found that preschool teachers' mathematical CK and PCK are highly related. Moreover, a recent study by Jenßen, Dunekacke, and Blömeke (2015) showed that preschool teacher's mathematical CK predicts their ability to recognize mathematically-relevant learning situations.

Unfortunately, preschool teachers' view of mathematical CK relevant to early mathematical learning is often too narrow (Mewborn, 2001). In many countries preschool teachers are not required to participate in special training for teaching preschool mathematics and thus their mathematical CK is limited to their own school education. However, mathematical content taught in school does not necessarily correspond to the mathematical con- tent that is appropriate for young children (Ginsburg et al., 2008; Sarama & DiBiase, 2004). In fact, Lee and Ginsburg (2007) note that preschool teachers need to expand their conception of mathematical content for young children to include all the major content areas. But which mathematical content areas are considered appropriate for preschool mathematics education? Mathematical content taught in preschools differs slightly between countries, but there is a consensus that the concepts of *numbers and operations*, *geometry and patterns*, *measurement* as well as *data and probability* are major areas of preschool mathematics (Clements, 2004; Ginsburg et al., 2008). Thus, preschool teachers require content knowledge (CK) of the mathematical areas mentioned above in order to meet their curricular goals. However, there is currently no sophisticated statement that indicates which level of mathematical CK is required of preschool teachers. Because mathematical CK is a necessary prerequisite for mathematical PCK, the level of preschool teachers' CK will affect the level of PCK and thus indirectly affect instructional quality. It is therefore important to investigate preschool teachers' CK with regard to the different mathematical areas as well as the level in each area.

Thus, according to the existing research literature, a sufficient level of mathematical CK is considered important for mathematical PCK, which in turn influences the quality of mathematical education. However, it is no guarantee that preschool teachers actually make use of their CK in pedagogical interactions. Whether or not they do use their CK to recognize mathematics in children's play activities and actively initiate mathematical learning also depends on the level of comfort with the mathematical concepts, more specifically, their math-related ability beliefs.

1.2. Math-related ability beliefs

Ability beliefs represent peoples' "broad beliefs about competence in a given domain" (Wigfield, 1994, p. 54). They function as a determinant of people's motivation and action and are often better predictors of human behavior than actual ability (Bandura, 1986; Pajares & Miller, 1994). With regard to teaching, domain specific ability beliefs have been shown to affect teachers' motivation and behavior in the classroom (Fives & Buehl, 2012; Guo, Piasta, Justice, & Kaderavek, 2010; Guskey, 1988; Midgley, Feldlaufer, & Eccles, 1989; Stipek, Givvin, Salmon, & MacGyvers, 2001). For instance, Stipek et al. (2001) found that elementary teachers who were less confident in their mathematical skills and their ability to teach mathematics had more traditional beliefs about instructional practices, such as teaching in a prescribed way, following procedures in textbooks and using teachers' manuals to correct student work. Moreover, teachers' self-confidence in their mathematical ability was significantly correlated with children's confidence as math learners.

Despite the importance of math-related ability beliefs, studies suggest that preschool teachers feel under-confident about mathematics and teaching mathematics to children (Copley, Clements, & Sarama, 2004). In fact, they prefer teaching literacy over mathematics (Copley & Padron, 1998). Yet, preschool teachers who feel unconfident about their mathematical ability might be less likely to look for or recognize mathematics in children's play.

Teachers’ mathematical ability beliefs might therefore be important for their ability to recognize mathematical content.

Two kinds of ability beliefs are especially relevant for teaching early mathematics: mathematical self-efficacy and mathematical self-concept. Self-efficacy refers to a person’s conviction in their ability to successfully perform on a specific task, whereas self- concept refers to a more general perception of one’s ability in a certain field (Bong & Clark, 1999; Ferla, Valcke, & Cai, 2009). In the literature, self-efficacy and self-concept are often not further distinguished as they are largely overlapping (Bong & Clark, 1999): Both constructs represent domain-specific ability beliefs. However, Bong and Skaalvik (2003) argue that there are important differences: Self-concept comprises of aggregated, heavily normative, past-oriented and rather stable judgments about ability, whereas self-efficacy beliefs tend to be goal-oriented and context specific as well as future-oriented and malleable. Applying this distinction to the context of early mathematical education, preschool teachers’ mathematical self-concept refers to their general perception of their own abilities in mathematics, whereas mathematical self- efficacy represents their conviction to perform well in a specific math-related task. These differences in mind, we expect that self- concept and self-efficacy also have a different impact on preschool teachers’ PCK. In the current study, we therefore consider both constructs.

Research on preschool teachers’ self-concept is scarce, especially regarding math-related beliefs. However, there is a qualitative study that focuses on schoolteachers’ mathematical self-concept: Based on interviews with primary and secondary teachers, Relich (1996) shows that teachers’ mathematical self-concept predicts their motivation to teach mathematics.

Although there is extensive research literature on school teacher general efficacy, only a few studies have investigated preschool teachers' math-related self-efficacy beliefs. Brown (2005) investigated preschool teachers' self-efficacy beliefs and found no significant correlation with their observed instructional practices. Findings on the interrelation of self-efficacy and mathematical CK are inconsistent: Results from a study conducted by Newton and colleagues indicate a positive moderate relation between preschool teachers' mathematical self-efficacy for teaching mathematics and their mathematical CK (Newton, Leonard, Evans, & Eastburn, 2012). In contrast, Swars and colleagues found no relation between pre-service elementary teachers' mathematical self-efficacy for teaching mathematics and their mathematical CK (Swars, Hart, Smith, Smith, & Tolar, 2007). Thus, more research is needed to investigate how preschool teachers' mathematical self-efficacy and mathematical CK are related and how these concepts affect preschool teachers' behavior.

Only a few studies compared academic self-concept and self-efficacy in the context of school education. To our knowledge, there is no study that investigated how the two beliefs translate into math-related instructional practices of preschool teachers. However, research based on student achievement data shows that students' academic self-concept is a better predictor of affective motivational variables, while academic self-efficacy is a better predictor of academic achievement (Ferla et al., 2009). Thus mathematical self-efficacy seems to be closer related to the actual performance than mathematical self-concept. It remains to be seen whether this distinct relation is also true for preschool teachers' mathematical self-concept and self-efficacy beliefs.

1.3. The present study: theoretical model and research questions

In this study we investigate the relation among (a) preschool teachers' professional knowledge, i.e. their mathematical CK and their sensitivity to mathematics in play-based situations, and (b) their math-related ability beliefs, i.e. their mathematical self- efficacy and self-concept.

The study aims to answer the following research questions:

1. How are preschool teachers' mathematical content knowledge and their sensitivity to mathematical content in play-based situations related?
2. How is mathematical content knowledge associated with mathematical self-efficacy and mathematical self-concept?
3. How are mathematical content knowledge, mathematical self- efficacy and self-concept related to preschool teachers' sensitivity to mathematical content in play-based situations?

Based on the literature review we developed a theoretical model (see figure 1).

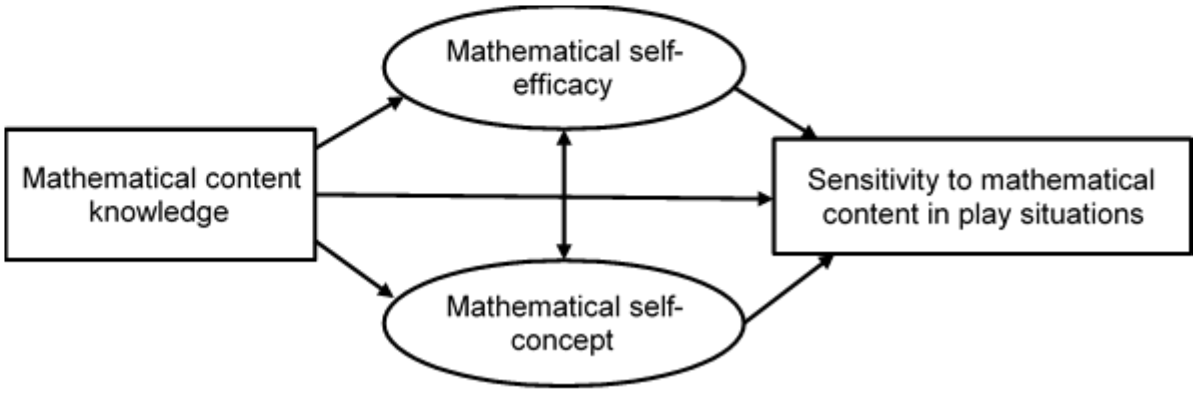

Figure 1. Theoretical model.

The model is based on the following assumptions: First, we assume that mathematical CK predicts preschool teachers' sensitivity to mathematical content (H1), because pre- school teachers need mathematical CK in order to recognize mathematical content in play-based situations. Secondly, we assume that preschool teachers' judgment about their mathematical ability, i.e. their ability beliefs, will be predicted by their actual mathematical ability, i.e. their mathematical CK (H2). Lastly, we assume that preschool teachers' mathematical CK as well as their math-related ability beliefs predict their sensitivity to mathematical content (H3).

2. Methods

2.1. Procedure and sample

The data was collected as part of a larger study conducted by H.-G. Rossbach and Y. Anders at the University of Bamberg, Germany. The study investigated preschool teachers' math-related competencies as well as their acceptance of early mathematical education in preschool. To our knowledge, this was one of the first studies to assess preschool teachers' mathematical competencies in Germany[1] and thus it was of exploratory nature in some aspects. Overall, the participants completed several questionnaires and assessments mainly with reference to mathematics. For mathematical CK, we used 4 items, each of which represent a different area of mathematical CK. Preschool teachers' sensitivity to mathematical content in play-based situations was measured by asking teachers to analyze a written description of a play scenario. Mathematical self-concept and self-efficacy beliefs were obtained through questionnaires. Results from the tests and questionnaires regarding other aspects of preschool teachers' mathematical competencies and their acceptance of preschool mathematics are not central to this paper and have been published elsewhere (Anders & Rossbach, 2015).

For the study, 221 preschool teachers were recruited from 29 randomly sampled early childhood centers in two federal states of Germany (42.2% in Bavaria and 54.8% in Berlin). The vast majority of the participants were female (91.4%), the mean age was 40 years, ranging between 18 and 63 years (see Anders and Rossbach (2015) for more information regarding the sample). Testing took place in the preschool centers under instruction and supervision of trained research staff. The preschool teachers voluntarily participated in the study, and reports of the

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[1] The German project KomMa (see Dunekacke et al., 2013) started around the same time.

individual results were given as incentives.

2.2. Measures

Teachers' ability to recognize mathematical content in children's play, as one aspect of their mathematical PCK. Preschool teachers' ability to recognize mathematical content in children's play was assessed using a play-based scenario task. The scenario and the questions were borrowed from McCray's PCK interview (2008), which was adapted from an elementary-level version previously invented by Ball (1990). Instead of personal interviews, we used half-standardized questionnaires. Participants were asked to identify parts of the scenario that - according to their understanding - contain aspects of preschool mathematics. The scenario reads as follows:

"Britta and Jacob are playing together with dolls. They want to put their five babies to bed. Since there are no doll beds, they construct them one out of three shoeboxes. Jacob says "But there aren't enough cribs." Britta responds, "These babies are younger" picking out the three babies with no hair and setting them near the shoeboxes. She picks up the two babies with thick hair, says "These babies don't need to nap anymore," and sets them aside. Jacob says, "OK, but this baby needs the most room" and puts the biggest bald baby in the biggest shoebox. Britta watches him and then puts the medium-sized bald baby in the medium-sized shoebox and the smallest bald baby in the smallest shoebox. Jacob says, "Now go to sleep, babies."

The scenario covers a wide range of mathematical concepts, representing the key areas of mathematics recommended for early childhood education: *numbers*, *operations*, *geometry and patterns* as well as *data and measurement* (Clements, 2004; Ginsburg et al., 2008; McCray, 2008). For instance, recognizing that there are not enough cribs requires one-to-one correspondence, which is a key part of number sense. Using shoeboxes instead of cribs due to their similar shape requires geometrical thinking. Moreover, assigning three different-sized dolls to three different-sized shoeboxes re- quires classification (data) and measurement in order to determine which doll needs the most room and which box offers it (McCray & Chen, 2012; McCray, 2008). A more detailed illustration of the alignment of the scenario task with the key areas of mathematics can be found in Table A1 in Appendix A. Participants were asked to *name* as many mathematical elements as they could identify. Furthermore, they were prompted to *describe* the nature of the mathematical content and to *categorize* it according to McCray's (2008) taxonomy (numbers and operations, shapes and spatial sense (geometry), patterns (algebra), classification (data), and measurement). The coding scheme was inspired by, but not identical to McCray's (2008). Answers were coded as follows: 1 point was given for each correctly identified part of the scene, 1-3 additional points for each correct description of the nature of the mathematical content and 1 point for each correct categorization. All together eight mathematical parts could be identified in the scenario. Each part contained between one and three different aspects of mathematical content that could each be assigned to one category. The theoretical maximum score equals 32 points. Coding of participants' responses was carried out by an experienced researcher. The encoding strictly followed the coding scheme and was supervised by a senior researcher. In addition, 20% of the cases were coded by a second coder. Neither coder is an author of this paper and both coders were oblivious to the hypotheses of the study. We calculated a two-way random intra-class correlation coefficient (ICC) as an estimator of inter-rater agreement for continuous data. The ICC equals 0.829 which is generally considered sufficient for research purposes (Cicchetti, 1994; Hays & Reviki, 2005).

Mathematical content knowledge. Participants solved four math problems, each problem representing one content area of mathematics required for early child- hood education (*numbers*, *operations*, *geometry and patterns* as well as *data and measurement*). As these mathematical content areas are also represented in the play scenario task, the CK items were aligned with our measure of teacher's sensitivity to mathematical content in terms of the underlying mathematical areas. For instance, identifying the outline of a prism requires geometrical thinking, which is also required for comparing the shapes of shoeboxes and cribs in the scenario task. Similarly, solving an equation for x taps into algebra. In the scenario task very basic algebra is required for setting the right number of dolls aside (subtraction). For a more detailed overview of the alignment among the measures see Table A1 in Appendix A. The items were adapted from the TIMSS 2003 mathematics test. The level of difficulty was chosen with reference to the secondary school curricular standards and equals the level of year 7 mathematics courses. By choosing this level of mathematical CK we did not aim to make any normative statement regarding the level of mathematical CK that preschool teachers should possess. Correct answers were coded 1, missing or incorrect answers with 0.

Items

a) "*A TV costs 250 Euros. How much would the TV cost with a 30% discount?*"

b) "*Please solve for x. 3x + 5 = 17.*"

c) "*The following table summarizes the amount of time that Mick needs to walk his dog over 5 days. On average, what is the duration of his walks?*"

d) "*The picture below shows a triangular prism. Which of the following diagrams shows the outline of the prism?*"

Mathematical self-concept. The measure of preschool teachers' mathematical self-concept draws on well-established scales (Baumert et al., 2008; Marsh, 1990; Ramm et al., 2006). Participants rated their perception of their general ability in mathematics on a 4-point Likert-scale. The scale consisted of 4 items (a 0.91, example item: "Mathematics is one of my strengths.")

Mathematical self-efficacy. The measure of preschool teachers' mathematical self-efficacy beliefs draws on existing scales used in the PISA (2003) and in the COACTIV study (Baumert et al., 2008; Ramm et al., 2006), but was adapted in content to represent the mathematical content areas required for early childhood education: *Numbers*, *operations*, *geometry and patterns*, *data and measurement* (Clements, 2004; Ginsburg et al., 2008). Participants rated their confidence to solve specific math tasks on a 4-point Likert-scale. The scale consisted of five items ($\alpha = 0.75$, example item: "How confident do you feel about your ability to solve the following math problem? Calculating the price of a TV with 30% discount"). Two of the five items were directly aligned with two of the CK items because they used the same mathematical task and tap into the same key area of mathematics underlying the task. The other three items use different mathematical tasks, but still tap into the same key mathematical areas as the CK items (see Table A1 Appendix A). For instance, the item "*How confident do you feel about your ability to solve the following math problem? Calculating the travel time to get from A to B based on a train schedule*" captures preschool teachers' self-efficacy beliefs in the area of data and measurement. In terms of the mathematical area, this item is aligned with the following CK item, which also taps in to the area of data and measurement: "*The following table summarizes the amount of time that Mick needs to walk his dog over 5 days*. *On average*, *what is the duration of his walks?*"

2.3. Statistical analyses

We tested our first hypothesis, i.e. that preschool teachers' mathematical content knowledge (CK) predicts their sensitivity to mathematical content in play-based situations, by regression analysis in R (version 3.0.2). Hypothesis 2, i.e. mathematical CK predicts mathematical ability beliefs, and 3, i.e. mathematical CK and ability beliefs predict preschool teachers' sensitivity to mathematical content, were tested by structural equation modeling (SEM) using the package "lavaan" in R. This allowed us to estimate latent coefficients for the constructs of mathematical self-efficacy and mathematical self-concept. To enhance interpretation of the model coefficients, all variables were z-standardized before modeling. Model Fit was assessed with reference to RMSEA, CFI and SRMR using the criteria suggested by Hu and Bentler (1999). Percentages of missing data on individual variables range between 1.8% and 5.4%. Missing data patterns were analyzed and Little's (1998) MCAR tests indicated that the data was missing completely at random (MCAR; $\chi^2 = 108.34$, $df = 119$, $p > 0.05$).

There is a consensus that under ignorable missing data conditions (MCAR and MAR) full information maximum likelihood (FIML) is the superior method for structural equation modeling (Arbuckle, 1996; Enders & Bandalos, 2001). Therefore, we used FIML estimation, which is implemented in the R package "lavaan".

3. Results

3.1. Descriptive statistics

Table 1 displays the descriptive statistics for all scales. The results indicate considerable variance between the ratings of preschool teachers on all scales. Comparing the means of the two scales assessing preschool teachers' ability beliefs, the findings indicate that mathematical self-efficacy and mathematical self- concept seem to measure different constructs. Whereas preschool teachers' ratings of their mathematical self-efficacy (M = 3.10) were above the theoretical mean of 2.5, ratings of their mathematical self-concept (M = 1.80) fell below the theoretical mean of 2.5. Thus, preschool teachers seem to be much more confident about their mathematical ability to solve specific math tasks than about their general mathematical ability. The test scores for mathematical content knowledge suggest that, on average, preschool teachers could solve two to three of the four math problems (M = 2.67). However, there was considerably high variance (SD = 1.14). Results for the scenario-based task assessing preschool teachers' sensitivity for mathematical content in play-based situations revealed that none of the preschool teachers in our sample reached the theoretical maximum of 32 points. On average, preschool teachers named, identified, and categorized eight to nine mathematical elements in the scenario (M = 8.53); the maximum empirical score was 17 points.

Table 1

Descriptives

	Mean	SD	Min	Max
Mathematical self-efficacy	3.10	0.67	1	4
Mathematical self-concept	1.80	0.77	1	4
Mathematical content knowledge	2.67	1.14	0	4
CK Item 1: *"A TV costs 250 Euros. How much would it cost with a 30% discount?"*	0.62	0.49	0	1
CK Item 2: *"Please solve for x. 3x + 5 = 17."*	0.70	0.46	0	1
CK Item 3: *"The following table summarizes the amount of time that Mick needs to walk his dog over 5 days. On average, what is the duration of his walks?"*	0.64	0.48	0	1

CK Item 4: *"The picture below shows a triangular prism. Which of the following diagrams shows the outline of the prism?"*	0.72	0.45	0	1
Sensitivity to mathematical content in play-based situations	8.53	3.86	0	17

Table 2 shows the bivariate correlations between the scales. Correlations between all scales were positive and statistically significant ($p < 0.01$). Mathematical content knowledge was moderately correlated with mathematical self-efficacy ($r = 0.38$) and mathematical self-concept ($r = 0.27$). Mathematical self-efficacy and mathematical self-concept were moderately correlated ($r = 0.41$). Sensitivity for mathematical content in play situations showed the strongest association with mathematical self-efficacy ($r = 0.34$), followed by mathematical content knowledge ($r = 0.29$). Mathematical self-concept was only weakly correlated with sensitivity for mathematical content in play situations ($r = 0.16$).

Table 2

Bivariate Correlations

		1	2	3
1	Mathematical self-efficacy			
2	Mathematical self-concept	.41***		
3	Mathematical content knowledge	.38***	.27***	
4	Sensitivity to mathematical content in play situations	.34***	.16*	.29***

Note. * p < 0.05, ** p < 0.01, *** p < 0.001

3.2. Results for our research questions

Relations between preschool teachers' mathematical CK and their sensitivity to mathematical content. We answered our first research question using linear regression of preschool teachers' sensitivity to mathematical content in play-based situations on their mathematical content knowledge (CK). The results are displayed in Table 3. In line with our first hypothesis, mathematical content knowledge was positively associated with preschool teachers' sensitivity to mathematical content in play-based situations (β = 0.29, $p < 0.001$). The higher preschool teachers' mathematical CK, the better they recognized mathematical content in the children's play scenario. Teachers' mathematical CK explains 9% of the variance of their sensitivity to mathematics in children's play. Taking into account that preschool teachers' ability to recognize mathematics in children's play depends on several factors, such as their experience with early mathematical learning situations and their pedagogical knowledge, we consider the relations between the variables as meaningful despite the relatively low amount of explained variance.

Table 3

Mathematical CK as a predictor of sensitivity to mathematical content in play-based situations

	B
Mathematical content knowledge	0.29***
R^2	0.09

Note. *** p <0.001

Relations among preschool teacher's mathematical CK and their ability beliefs. The second and third research questions were answered using structural equation modeling (SEM). The covariance matrix for the SEM analysis is displayed in Table B1 in Appendix B. The standardized results for the latent SEM model are displayed in Fig. 2. According to the criteria suggested by Hu and Bentler (1999) the overall model fit was satisfactory ($\chi^2 = 72.15$, $df = 40$; RMSEA = 0.06; CFI = 0.97; SRMR = 0.04). All factor loadings were significant at $p < 0.001$. In addition, the amount of variance explained by the latent factors indicates that the latent factors sufficiently captured the empirical data (25.1% - 50.3% and 69.3% - 76.8% for mathematical self-efficacy and mathematical self- concept, respectively).

In line with our second hypothesis, mathematical content knowledge (CK) predicted both types of ability beliefs, with higher mathematical CK leading to higher math-related ability beliefs. However, this relation was stronger for mathematical self-efficacy ($\beta = 0.43$, $p < 0.001$) than for mathematical self-concept ($\beta = 0.28$, $p < 0.001$), which underlines the differences between the constructs. Mathematical CK seemed to be more closely related to mathematical self-efficacy than to mathematical self-concept. Moreover, controlling for the influence of mathematical CK, mathematical self-efficacy and mathematical self-concept were only moderately correlated, thus indicating that they represent different facets of preschool teachers' ability beliefs ($r = 0.43$, $p < .001$).

Relations between teacher's mathematical CK, their ability beliefs and their sensitivity to mathematical content. With regard to our third hypothesis, preschool teachers' sensitivity to mathematical content in play-based situations was predicted by their mathematical self-efficacy ($\beta = 0.34$, $p < 0.001$), but not by their mathematical self-concept ($\beta = 0.04$, $p > 0.05$). Thus, preschool teachers with higher mathematical self-efficacy are more sensitive to mathematical content in play-based situations and thus more likely to recognize mathematics. In contrast, preschool teachers' mathematical self-concept had no direct effect on their sensitivity to mathematical content in play-based situations. Moreover, the SEM results showed that mathematical self-efficacy fully mediates the effect of mathematical CK on preschool teachers' sensitivity to mathematical content in play-based situations. Whereas mathematical CK significantly predicted sensitivity to mathematical content in play-based situations in the linear regression model, mathematical CK loses its influence in the mediation model ($\beta = 0.14$, $p > 0.05$). The SEM results thus contradict our third hypothesis that both ability beliefs as well as preschool teachers' mathematical CK predict their sensitivity to mathematical content. Instead, only mathematical self-efficacy had a substantial influence on preschool teachers' sensitivity in the mediation model.

Based on our findings that mathematical self-efficacy functions as an intermediary factor between CK and PCK, is it important to test whether mathematical self-efficacy indeed acts as a mediator rather than a moderator variable. To test for moderation, we conducted separate SEM-analyses using the original structural model with preschool teacher's self-efficacy beliefs as a latent interaction term: Just like in the original model, CK predicts both, self-efficacy and self-concept, and all three variables predict preschool teacher's sensitivity to mathematics in children's play. The only difference between the moderator model and the original model is the additional interaction term between teacher's mathematical CK and their self-efficacy beliefs.

The moderation model provided an acceptable fit to the data (χ^2 = 164.50, *df* = 99; RMSEA = 0.06; CFI = 0.95; SRMR = 0.08), although slightly worse than the original mediation model. Overall, the relations between the variables in the model remained similar to the original model: Preschool teacher's mathematical CK predicted both, preschool teachers' self-efficacy beliefs (β = 0.47 p < 0.001) as well as their self-concept in mathematics (β = 0.29 p < 0.001). The main effect of teacher's self-efficacy beliefs on their sensitivity to mathematics remained moderate and significant (β = 0.31 p < 0.001), whereas mathematical self-concept had no significant effect on teachers' sensitivity (β = -0.03, p > 0.05). Moreover, the main effect of CK on teacher's sensitivity remained small and non-significant (β = 0.14, p > 0.05). The additional interaction between teachers' mathematical CK and their self-efficacy beliefs had no significant effect on teachers' sensitivity to mathematics (β = 0.01, p > 0.10). Thus, we conclude that preschool teachers' self-efficacy functions as a mediating variable.

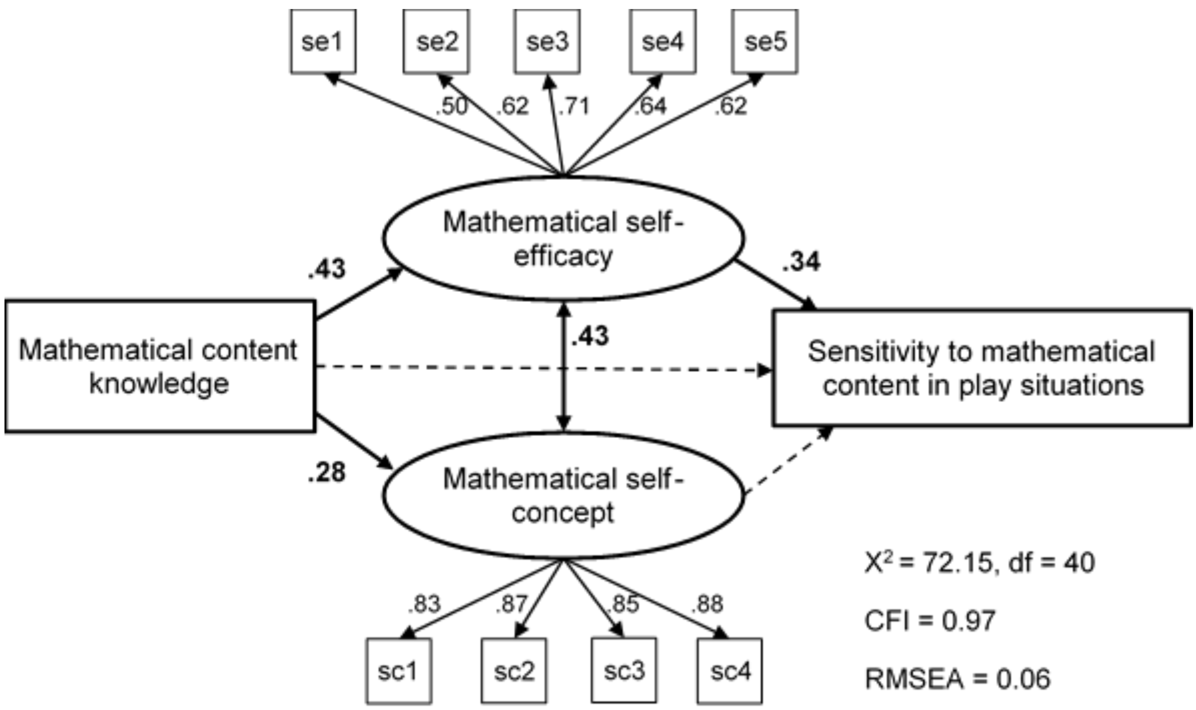

Figure 2. SEM Results. Solid lines represent significant coefficients (p < 0.001), dashed lines represent non-significant coefficients.

4. Discussion

The present study investigated preschool teachers' mathematical content knowledge (CK), self-efficacy beliefs and self-concept with regard to their influence on teachers' sensitivity to mathematical content in play-based situations. Confirming our first hypothesis, preschool teachers' mathematical CK was positively related with their sensitivity to mathematical content in the regression analysis: The higher preschool teachers' mathematical CK, the better they were at recognizing mathematics in the children's play scenario. The results are consistent with previous findings by Dunekacke et al. (2015) and support the assumption that mathematical CK is a prerequisite for preschool teachers' ability to recognize mathematical content in play-based situations, as one aspect of their mathematical PCK. However, the relation between mathematical CK and teachers' sensitivity was only moderate and the amount of variance explained by mathematical CK was rather low. This contrasts previous findings by Jenßen et al. (2015), who showed that preschool teachers' mathematical CK and PCK were highly correlated (r = 0.67). These differences might be due to the fact that our results are based on manifest instead of latent relations and that we focus on only one aspect of preschool teachers' PCK, namely their sensitivity to mathematics in children's play.

When mathematical ability beliefs were taken into account, the direct relation between preschool teachers' mathematical CK and their sensitivity did not show to be significant. Instead, an indirect relation via preschool teachers' mathematical self-efficacy beliefs remained. This may indicate that preschool teachers' self-efficacy beliefs serve as a filter through which math knowledge and experiences are interpreted. Preschool teachers' judgment about their mathematical knowledge are in turn related to their consciousness of teachable moments in children's play. Thus, self-efficacy beliefs play a vital role for teachers' ability to recognize mathematical content in children's play situations.

Even though mathematical self-efficacy seems to be an important factor for preschool teachers' sensitivity to mathematics in play-based situations, mathematical CK is not negligible: Basic mathematical content knowledge is considered necessary for the development of mathematical PCK (Ball et al., 2001; Baumert et al., 2010; Cross et al., 2009; Shulman, 1987). Moreover, CK was related to math-related ability beliefs and thus indirectly affected preschool teachers' sensitivity. Preschool teachers who scored better on the mathematics assessment also judged their ability in mathematics significantly higher. This relation was stronger for mathematical self-efficacy than for mathematical self-concept. Overall, mathematical self-efficacy seemed to be more closely related to actual ability, such as mathematical CK and the ability to recognize mathematical content in play-based situations, than mathematical self-concept. This can be explained by the different theoretical conceptualization of the two constructs: Self-efficacy beliefs are considered to be task-specific and entirely cognitive whereas self-concept is defined as a general and more affective judgment of ability (Bong & Skaalvik, 2003; Ferla et al., 2009). Thus self-efficacy beliefs are naturally closer related to performance, including preschool teacher's ability to recognize mathematical content, than is self-concept.

4.1. Limitations and directions for further research

One limitation of the study relates to the nature and size of the sample. First of all, the data is comprised of a German sample that is limited to two federal states and thus might not be representative of all preschool teachers in Germany.

Second, although the sample was randomly drawn, participation in the study was optional and thus the sample might suffer from selection bias. However, this would only affect the generalizability of the central tendencies in the measures of professional knowledge and ability beliefs, but not the generalizability of the found associations between the constructs. Moreover, the descriptive statistics show that there is considerable variance on all variables, indicating that preschool teachers with higher as well as lower levels of mathematical knowledge and ability beliefs are represented in the sample. In fact, the maximal empirical score on the play scenario tasks suggests that there is room for improvement.

Third, preschool teachers' ability to recognize mathematical content in children's play is just one aspect of their mathematical PCK. Moreover, we are measuring teachers' ability to recognize mathematical elements in a children's play scenario task rather than their actual behavior in the early childhood classroom. However, McCray and Chen's (2012) findings indicate that teachers' ability to recognize mathematical content in the play scenario task predicts the quality of teachers' mathematics instruction in the classroom as well as children's learning gains.

A further limitation of the study relates to the measure of preschool teachers' mathematical self-efficacy beliefs. Preschool teachers' mathematical self-efficacy was assessed regarding their confidence to solve specific math tasks, rather than their confidence to teach mathematics to young children, which might be more relevant to their instructional practices. However, recent studies show that mathematical self-efficacy, which refers to the level of comfort with mathematical content, predicts self-efficacy for teaching mathematics (Bates, Latham, & Kim, 2011; Bitto & Butler, 2010; Kahle, 2008). Nevertheless, it is important to note that our operationalization of teachers' self-efficacy beliefs might have affected the associations between the variables. Future investigations are therefore needed to examine different measures of teachers' self-efficacy beliefs separately and compare their effects on preschool teachers' sensitivity to mathematics in play- based situations as well as on the relation between teachers' CK and their sensitivity. However, despite this limitation, the found associations between self-efficacy and self-concept as well as between CK and self-efficacy are in line with the research literature (Bong & Clark, 1999; Bong & Skaalvik, 2003; Newton et al., 2012).

Finally, we would like to draw attention to the limitations of our measure of teachers' mathematical CK. At the time of the study no validated test for preschool teachers' mathematical CK had been published and we therefore drew on established standardized performance test items for 7th grade mathematics. Choosing 7th grade level mathematics for our CK items was a pragmatic choice rather than a normative statement about the level of mathematical CK that preschool teachers should possess. In fact, there is still no general consensus regarding the level of mathematical CK required by preschool teachers. The research literature on secondary school teachers' mathematical CK, however, states that teachers require mathematical CK at least one level higher than the level they are assigned to teach (Baumert et al., 2010; National Mathematics Advisory Panel, 2008). In line with this conceptualization, Wittmann and Levin (2016) mention elementary school mathematics as a minimum level of mathematical CK for teaching in preschool. Yet, so far it has not been investigated whether elementary level mathematical CK is indeed sufficient. The positive relation between preschool teachers' mathematical CK and their sensitivity to mathematics in children's play in our study, however, indicates that a higher level of mathematical CK is generally beneficial for teachers' sensitivity to mathematical content. Similar results have also been obtained by Dunekacke et al. (2015): The higher teachers' mathematical CK, the better they were at recognizing mathematical learning situations and planning appropriate actions. Moreover, the mean distribution of responses to the CK items in our study shows that the level of mathematical CK was adequate for our sample of preschool teachers. Nevertheless, it is important to note that the measure of mathematical CK was limited to four items and thus can only capture very rough differences in teachers' competency levels. Future studies should therefore investigate the level and complexity of mathematical CK required of preschool teachers, using a more sophisticated test.

Another issue relates to the content coverage of our CK items: Although the items were specifically chosen to represent the major areas of mathematics, they can only cover a fraction of mathematical CK relevant to early childhood education. The variable should therefore be interpreted as a broad indicator rather than an exact assessment of mathematical CK. Moreover, the CK items were aligned with the scenario task in terms of the broad underlying mathematical areas, but not in terms of the context. More specifically, because the CK items were borrowed from a 7th grade mathematics test, the context did not relate to the early childhood classroom but was rather abstract (e.g. solving an equation for x, calculating the outline of a prism). This might have contributed to the fact that preschool teachers' mathematical CK explained only 9% of the variance in teachers' sensitivity to mathematics in children's play. In future studies a more context-specific and validated measure of preschool teachers' mathematical CK, such as the instrument recently published by Blömeke et al. (2015), should be used for further investigation.

5. Conclusion and practical implications

To our knowledge, this is the first study in Germany to present empirical evidence for the role of mathematical self-efficacy beliefs in the relation between mathematical CK and preschool teachers' sensitivity to mathematics in play-based situations. The results underline the importance of preschool teachers' mathematical self-efficacy for preschool teachers' ability to recognize mathematical content. As this facet of pedagogical content knowledge (PCK) has been shown to influence teachers' pedagogical practice and children's learning gains (McCray & Chen, 2012), the results underline the significance of perceived confidence in mathematics for the quality of early mathematical education.

This link entails important practical implications: Promoting preschool teachers' content knowledge in mathematics alone might not improve their ability to recognize mathematics. In addition, professional development should improve teachers' confidence in their own mathematical ability in order to enhance their sensitivity to mathematical content in play-based situations. But can preschool teachers' self-efficacy beliefs be changed? Self-efficacy beliefs are in fact considered to be easier to change than self-concept, which is regarded as a rather stable and more general perception of ability (Bong & Skaalvik, 2003). So how can professional development programs elevate preschool teachers' mathematical self-efficacy beliefs? According to Bandura (1997), different factors can enhance self-efficacy beliefs: performance, e.g. mathematical knowledge; feedback; vicarious experiences, e.g. witnessing other preschool teachers' succeeding in a mathematical teaching task and psychological responses, e.g. reducing mathematical anxiety. Thus improving preschool teachers' mathematical CK is an important step, however, professional development pro- grams should also address preschool teachers' awareness of their knowledge. Findings from a study with 63 preschool teachers showed that vicarious experiences, such as watching videos of successful mathematics instruction, increased their confidence in their own ability to teach mathematics (Rosenfeld, 2012). Similarly, mentoring and math instructional methods classes have been shown to enhance preschool teachers' mathematical self-efficacy (Ciyer, Nagasawa, Swadener, & Patet, 2010). Consequently, professional development programs should make use of a wide range of methods, such as training in teaching mathematics, peer teaching and constructive feedback, in order to enhance preschool teachers' self-efficacy beliefs and thereby to facilitate their ability to recognize mathematics in children's play. And as a matter of fact, it is crucial that preschool teachers recognize mathematics more often in order to promote early mathematical learning. Research shows that mathematical education often only plays a minor role in preschool teachers' daily routines (Cross et al., 2009). Although there is empirical evidence that young children are willing and capable to learn mathematics (Ginsburg et al., 2008), most of their potential might not be realized (Cross et al., 2009). The lack of opportunities for young children to learn mathematics might partly be due to the fact that many preschool teachers do not recognize these opportunities. This poses a problem particularly for preschool teachers who follow a child-centered approach, as opposed to a teacher-directed approach, because they have to actively initiate early mathematical education in children's day-to-day activities. The more open the framework of mathematical education, the more initiative is required of preschool teachers and the more important it is that they recognize mathematical content in order to be able to initiate mathematical learning.

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Appendix A

Table A 1
Alignment of the three measures and the key mathematical areas

	Numbers & Operations	Geometry	Patterns (Algebra*)*	Data (Classification) & Measurement
Preschool level mathematics	*Counting, knowing numbers, comparing quantities*	*Identify & describe shapes/ Analyze, compare, create and compose shapes*	*Basis algebraic thinking: Understanding addition & subtraction as putting together/ taking from*	*Describe and compare measurable attributes. Classify objects and count the number of objects in each category*
Sample mathematical elements in the scenario task	Jacob says "but there aren't enough cribs."	Since there are no doll beds they construct them one out of three shoeboxes.	She picks up the two babies with thick hair, says "these babies don't need to nap anymore," and sets them aside.	Jacob says, "OK, but this baby needs the most room" and puts the biggest bald baby in the biggest shoebox. Britta […] puts the medium-sized bald baby in the medium-sized shoebox and the smallest bald baby in the smallest shoebox
7th grade mathematics	*Analyze proportional relationships and solve real-world math problems*	*Construct, describe geometrical figures, solve problems involving angle, surface area, volume*	*Solve problems using numerical and algebraic expressions and equations*	*Select appropriate statistical methods to analyze data: Use and interpret measures of center and spread*
CK items	A TV costs 250 Euros. How much would the TV cost with a 30% discount*?*	"The picture below shows a triangular prism. Which of the following diagrams shows the outline of the prism?"	Please solve for x. 3x + 5 = 17."	The following table summarizes the amount of time that Mick needs to walk his dog over 5 days. On average, what is the duration of his walks?"
Self-efficacy items	How confident do you feel about your ability to solve the following math problem? Calculating the price of a TV with 30% discount"	How confident do you feel about your ability to solve the following math problem? Understanding diagrams in newspapers. How confident do you feel about your ability to solve the following math problem? Calculating how many square meters of tiles are needed to tile the floor.	How confident do you feel about your ability to solve the following math problem? Solving an equation like 3x + 5 = 17."	How confident do you feel about your ability to solve the following math problem? Calculating the travel time to get from A to B based on a train schedule.

Note. The descriptions of the mathematical standards have been shortened to fit the table and are merely exemplary.

Appendix B

Table B 1

Sample covariance matrix for the SEM analysis

	CK	Se1	Se2	Se3	Se4	Se5	Sc1	Sc2	Sc3	Sc4	Sensitivity
CK	.99										
Se1	.24	1.00									
Se2	.19	.29	1.00								
Se3	.35	.42	.34	1.00							
Se4	.30	.27	.48	.45	.99						
Se5	.22	.31	.47	.45	.33	.99					
Sc1	.23	.22	.27	.34	.33	.20	1.00				
Sc2	.22	.22	.25	.28	.31	.19	.68	1.00			
Sc3	.26	.20	.24	.31	.30	.23	.74	.76	1.00		
Sc4	.24	.19	.26	.33	.32	.20	.75	.80	.70	1.00	
Sensitivity	.27	.12	.28	.29	.18	.27	.19	.17	.17	.09	.99

Note. Variables were z-standardized before the analysis. Se1– Se5 = Self-efficacy items one to five. Sc1 – Sc4 = self-concept items one to four.

ERKLÄRUNG

Hiermit versichere ich, die vorliegende Arbeit mit dem Titel „The role of motivation in early mathematics and science education“ selbstständig angefertigt zu haben. Sämtliche Hilfsmittel, die ich verwendet habe, sind angegeben. Die Arbeit ist in keinem früheren Promotionsverfahren angenommen oder abgelehnt worden.

Berlin, Dezember 2017 ____________________________

EIGENANTEIL UND VERÖFFENTLICHUNGEN

Die folgende Tabelle veranschaulicht den Eigenanteil an den veröffentlichten oder zur Veröffentlichung eingereichten wissenschaftlichen Schriften innerhalb meiner Dissertationsschrift.

Autoren	Titel	Status	Eigenanteil
Oppermann, E., Brunner, M., Eccles, J. S., & Anders, Y.	Uncovering young children's motivational beliefs about learning science	Veröffentlicht in *Journal of Research in Science Teaching*, 24(2), 195-217	Aufarbeitung der Literatur und des theoretischen Hintergrunds; Federführung bei der Konzeption; Entwicklung und Pilotierung der Y-SCM Skala; Mitarbeit bei der Datenerhebung; Statistische Analysen; Federführung bei der Verfassung des Manuskriptes
Oppermann, E., Brunner, M., & Anders, Y.	The interplay between preschool teachers' science self-efficacy beliefs, their teaching practices, and girls' and boys' early science motivation	Eingereicht	Aufarbeitung der Literatur und des theoretischen Hintergrunds; Federführung bei der Konzeption; Mitarbeit bei der Datenerhebung; Statistische Analysen; Federführung bei der Verfassung des Manuskriptes
Oppermann, E., Anders, Y., & Hachfeld, A.	The influence of preschool teachers' content knowledge and mathematical ability beliefs on their sensitivity to mathematics in children's play.	Veröffentlicht in *Teaching and Teacher Education*, 58, 174-184.	Aufarbeitung der Literatur und des theoretischen Hintergrunds; Federführung bei der Konzeption; Statistische Analysen; Federführung bei der Verfassung des Manuskriptes

Berlin, Dezember 2017

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