Long Term Persistence of Preschool Intervention on Children's Mathematical Development: Results From the German Model Project "Kindergarten of the Future in Bavaria"

Simone Lehrl
University of Bamberg

Katharina Kluczniok
University of Bamberg

Hans-Guenther Rossbach
Leibniz Institute for Educational Trajectories

Yvonne Anders
Freie Universität Berlin

Abstract

The present study examines how attending the German model project "Kindergarten of the Future in Bavaria" (KiDZ), which provided 138 children (aged 3 to 6) with traditional preschool stimulation combined with cognitive and domain-specific stimulation, is associated with children's competencies in mathematics over time to age 12 compared to a control group of 53 children.

Controlling for child and family background measures, attending KiDZ was positively associated with mathematical competencies at the age of 12 compared to the control group not attending. Those effects are mediated through grade and preschool quality. Furthermore, results showed that preschool quality was associated with higher competencies in mathematics at age 12, even when controlling for numerical skills at preschool and primary school age. The results suggest that preschool quality influences mathematical development over and above those effects detected previously in preschool. Thus, the academically oriented high-quality preschool intervention, KiDz, lays not only the foundation for a good start in school, but also for later development in secondary school

Keywords

Kindergarten of the Future in Bavaria (KiDZ), preschool, mathematical competence, primary school, mathematical development, Global Education Reform Movement, Germany, developmentally appropriate play activities

Introduction

Mathematical problem solving is an essential skill required to participate in society as it is linked to better social, health, and economic outcomes (OECD, 2016). Mathematical skills are acquired long before formal schooling starts for instance as children begin identifying numbers, shapes, and spatial relations (Krajewski, Nieding, & Schneider, 2008; Duncan et al., 2007; Geary, Hamson, & Hoard,

Corresponding Author:
Dr. Simone Lehrl, Otto-Friedrich-Universitaet Bamberg, Lehrstuhl für Elementar- und Familienpaedagogik, An der Weberei 5 (ERBA), Zi. 04.083, 96047 Bamberg
Email: simone.lehrl@uni-bamberg.de

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2000). In addition to the resources within the child, e.g., working memory or executive functioning (Geary, Hoard, Byrd-Graven, Nugent, & Numtee, 2007; Krajewski, Nieding, & Schneider, 2008), the learning environments that the child encounters play a crucial role in shaping children's mathematical competence development throughout the educational system (Bronfenbrenner & Morris, 2006; Lehrl, Kluczniok, & Rossbach, 2016). After the "PISA shock" of the 2000s wherein German students achieved only at the OECD average in all academic domains (Baumert et al., 2001), the quality of the German education system was questioned. In addition to primary and secondary school, preschool education[1] was also in the spotlight of public and scientific discussion. One result was change to the German preschool system (e.g., qualification of personnel, introduction of educational plans, strengthening the role of education in preschool versus care). These changes can be seen as a consequence of the Global Education Reform Movement. How these changes impacted practical work in preschools and child development in Germany cannot be finally estimated. There is, however, accumulating evidence that high-quality preschool education is one of the ways to raise children's academic outcomes, especially in mathematics (Anders et al., 2012; Barnett, 1998; Lehrl et al., 2016; Melhuish, Sylva, Sammons, Siraj-Blatchford, Taggart, & Phan, 2008; see for an overview Melhuish et al., 2015). Some of the limitations of these studies are that there is substantial variability across the studies regarding the target group (e.g., universal preschool vs. high-quality intervention for disadvantaged children), the persistence of preschool effects (effects within the preschool period vs. beyond), the type of activities researched (teacher-directed activities including instructional techniques versus child-directed activities including activities integrated in daily routines), and the type of quality measure (global quality indicators like responsive teaching vs. domain-specific quality indicators like instruction in mathematics).

Generally, there is evidence that preschool quality effects of universal preschool on mathematical outcomes are still present at the age of 11, 14, 15 and 18 (Sammons et al., 2008; Vandell, Belsky, Burchinal, Steinberg, & Vandergrift, 2010; Vandell, Burchinal, & Pierce, 2016); that attendance at high-quality interventions for disadvantaged children is effective for children's academic outcomes during the preschool phase and later for social and life-coping skills (see Barnett, 2011 for an overview); that effects of teacher-directed, instructional techniques on academic competencies seem to fade out after the preschool period (Anders, 2015); and that quality measures focusing on the domain-specific quality of instruction in preschool classrooms show higher effect sizes for mathematical development than measures focusing on global preschool quality (Anders et al., 2012; Lehrl et al., 2016; Sylva et al., 2006). To date, however, no study has examined how an intervention focusing on child-centered implicit learning through integrating academically oriented activities into daily routines that targets all children irrespective of disadvantage might influence academic development beyond the preschool years.

Hence, the present study investigates how participation in a high-quality German preschool model project (called "KiDZ – Kindergarten of the future in Bavaria") that aimed to promote children's mathematical skills in developmentally appropriate play activities during daily routines in preschool was associated with mathematical competencies in secondary school at age 12.

Specifically, the present study analyses whether (a) KiDZ attendance is positively associated with mathematical competencies at age 12 and (b) whether pathways from project attendance to adolescent mathematical competencies are mediated by preschool quality.

Different Approaches to Preschool Instruction

When comparing preschool effects, one challenge is to disentangle effects of preschool attendance, quality of the preschool stimulation, or attending a special program/intervention. Theorists assume that preschool attendance impacts children's development through the quality of interactions taking place in those settings (Bronfenbrenner & Morris, 2006). When studying effects of attending universal preschool or a special program on child outcomes, preschool quality might serve as a mediating variable.

Thus it must be asked, which components should an intervention contain to be of "high-quality", especially regarding mathematical development. In general, there are two different approaches to promoting children's mathematical competencies in preschool. First, there are specific trainings that are highly formalized, teacher-directed, and use a lot of instructional techniques such as work sheets. Such trainings are carried out in specific planned hours focusing on small groups of children (e.g., children in the final year of preschool; children at risk for later school failure). Some researchers showed positive effects of such early training programs for mathematical development during preschool through grade 1, indicating higher mathematical competencies for the intervention group compared to a control group without the specific training program (Krajewski, Nieding, & Schneider, 2008). Longer-term effects of such programs haven't been found yet.

Second, there are interventions that are informal, child-centered, and implement techniques that are integrated in the daily routines and normal course of preschool life and include all children. Traditionally, in Germany, this approach is an integral component of nearly all preschools. Hence, interventions following such a child-centered approach are particularly popular (Kluczniok, Rossbach, & Große, 2010) and have higher acceptance within preschools. Interventions focused on integrating academic content regarding mathematics and literacy into the daily activities of children via number game play resulted in short-term advantages compared to a control group (Ramani & Siegler, 2008; Ramani, Siegler, & Hitti, 2012; Hauser, Vogt, Stebler, & Rechsteiner, 2014; Hirsh-Pasek, Michnik Golinkoff, Berk, & Singer, 2008; Jörns, Schuchardt, Mähler, & Grube, 2013; Donie, Kammermeyer, & Roux, 2013). Moreover, such a play-based approach was significantly associated with higher gains in mathematical competencies when compared to a teacher-centred intervention (Hauser et al., 2014; Jörns et al., 2013; Donie et al., 2013). Several other programs, where playing number games was only one part of the whole program, also revealed substantial increases in mathematical competencies by using a wide range of numerical activities, including board games, simple arithmetic problems, monetary activities, number-related projects, number-related songs, and books and computer games that focus on numbers (Arnold, Fisher, Doctoroff, & Dobb, 2002; Griffin, 2000; 2004; Klein & Starkey, 2004; Starkey, Klein, & Wakeley, 2004).

Furthermore, studies on the effects of implementing "Developmentally Appropriate

Practice (DAP)" (Bredekamp & Copple, 1997) or the "Enriched Curriculum" (Walsh, McGuinness, Sproule, & Trew, 2010) that integrate such play-based, child-centered, and integrated activities to a comprehensive curriculum give important insights as to how such promotion approaches, which are also part of the model program KiDZ, are associated with child outcomes. Results of meta-analyses are sobering as they reveal low or no positive effects of implementing DAP or the Enriched Curriculum on academic outcomes (van Horn, Karlin, Ramey, Aldridge, & Snyder, 2005; McGuinnes, Sproule, Bojke, Trew, & Walsh, 2014). However, effects were found on different motivational and social-emotional domains revealing that children in DAP or the Enriched Curriculum benefit in terms of their learning effort and well-being (van Horn et al., 2005; Walsh et al., 2010). That there have been no effects found on academic outcomes might be partly explained by the implementation fidelity of the curriculum or the realized quality of the processes in classrooms. Thus, having a stronger focus on the processes within such programs and especially on the quality of those processes might be a valuable approach.

The Preschool Quality and its Effects on Child Development

educational quality children experienced in their learning environments is considered to be of crucial importance to the development of their academic skills, but the definition and measurement of preschool quality that impacts child development is very challenging (for an overview of the quality debate see Pianta, Downer, & Hamre, 2016). A research-based approach is to conceptualize preschool quality as the variables that affect children's development (Pianta et al., 2005). In the centre of this approach is the child's well-being, specifically, their safety needs, health, intellectual stimulation, and social exchange (ECCE-Study Group, 1997). These needs can be met by providing responsive and warm interactions between teacher and child, developmentally appropriate stimulation towards the child, and a safe and stimulating spatial material surrounding (NICHD ECCRN, 2002; Pianta et al., 2005; Kluczniok & Rossbach, 2014). This quality model is based on the assumption that quality is measurable by standardized observational instruments (e.g., CLASS, ECERS) or questionnaires for parents and staff. In international longitudinal studies, standardized observational instruments are often used to analyze the impact of preschool quality on child outcomes. In the present study, we also follow this quality model and, consequently, measure preschool quality with standardized observations in preschool classes.

The few existing longitudinal studies show that higher preschool quality is associated with better academic (including mathematics) outcomes at age 8 (Lehrl et al.; 2016; Hill, Gormley, & Adelstein, 2015), age 11 (Sammons et al., 2008), age 12 (Lehrl et al., 2016), age 15/16 (Sylva et al., 2014; Vandell et al., 2010), and age 18 (Vandell et al., 2016). Lasting effects of high-quality preschool programs have been found in evaluation studies of high-quality early interventions for disadvantaged children in the US (Barnett, 1998; Camilli, Vargas, Ryan, & Barnett, 2010; Gilliam & Zigler, 2000; for an overview see Yoshikawa et al., 2013). For instance, the results of the Perry Preschool Program (Schweinhart, Montie, Xiang, Barnett, Belfield, & Nores, 2005) show long-lasting effects for the intervention group in various domains (e.g., higher high school graduation rates, better cognitive outcomes, lower special education for mental impairment). The

benefits of participating in the early intervention programs reach even into adulthood up to the age of 40 years (Schweinhart et al., 2005). Furthermore, evaluation studies of the Head Start Program suggest positive child outcomes in various domains including cognitive, health, and socio-emotional development. For example, the Head Start Impact Study (U.S. Department of Health and Human Services, Administration for Children and Families, 2010) showed positive effects on child outcomes in language and literacy during preschool but these benefits mostly dissipated by the end of grade 1 (so called "fading-out-effect"; for more information, see Barnett, 1998). For mathematical skills, a significant impact of Head Start could only be found at age 3. These findings are in line with a recent meta-analysis of 57 Head Start studies (Shager, Schindler, Magnuson, Duncan, Yoshikawa, & Hart, 2013) indicating that Head Start is effective in improving children's short-term cognitive and achievement outcomes (see also Puma, Bell, Cook, & Hyde, 2010; Puma et al., 2012). Duncan and Magnuson (2013, p.120) summarize after reviewing 84 programs that "most early childhood education studies that have tracked children beyond the end of the program treatment find that effects on test scores fade over time." Effects of interventions might fade out over time for several reasons: if non-participating children catch up (e.g., by receiving more investments), or if participating children forget the material they learned or the skills they developed (Hill et al., 2015; Jacob, Lefgren, & Sims, 2010). Fade out effects might be observed, as well, if measurements are not appropriate or implementation quality was not sufficient (PCERC-Preschool Curriculum Evaluation Research Consortium, 2008). Barnett (1998) questioned the fading out of early effects and saw methodological reasons for the misinterpretation of these studies (e.g., lower instructional quality in elementary schools for intervention children). He concluded that all the early model programs have long-lasting effects on school achievement and school career without the need for additional support during a student's school career.

Taken together, research evidence produces a mixed pattern of results. On the one hand, the studies investigating universal preschool and quality effects on academic outcomes suggest better outcomes for children attending high-quality preschools. On the other hand, the results of high-quality preschool programs suggest that effects of these interventions disappear in the long run. Thus, more empirical research is needed.

The German Preschool System

The following remarks are necessary to develop an understanding of the current German early childhood education context because the German preschool ('Kindergarten') is different from preschool concepts in many other countries (e.g., US, England, France). Generally, the OECD (2006) differentiates between two types of preschool systems: "Social pedagogy" (e.g., Germany, Norway, Sweden), and "readiness for school" (e.g., UK, France, and the US). German preschools apply the social pedagogy tradition which means that preschool phase is seen as a broad preparation for life and the foundational stage of lifelong learning. Countries adopting the readiness for school approach focus on cognitive development in the early years, and the acquisition of a range of knowledge, skills, and dispositions (OECD, 2006). German preschools – even if they are considered the elementary level of the general education system – do not belong to the public educational system (Rossbach, 2009). They are

part of the youth and social welfare department. Following the shock of the poor German results in the first PISA survey, some changes to the German preschool system were made. Beginning in 2004 official curricular guidelines were introduced in all 16 federal states of Germany, rather late compared to other countries (e.g., Sweden 1998, England 1999, 2000, and 2002, Norway 1996 and 2005; for an overview see OECD, 2006). These guidelines emphasise the promotion of cognitive and (pre)academic skills. This is a relatively new element of early childhood education policy in Germany and it challenges the German preschool tradition radically as the promotion of socio-emotional skills had been prioritized previously (Rossbach, 2009). Furthermore, a national agreement on the basic principles for early child care and education curricula (e.g., teacher role, view of the child) was adopted in 2004 and this became the framework for the federal state specific curriculum guidelines. The guidelines are not mandatory and there is no national inspection system to monitor the implementation of the guidelines as is common practice in other countries (e.g., the Early Years Foundation Stage in England; Melhuish, 2017). In most federal states the childcare providers are responsible for ensuring the quality of provision, and are free to choose how this is achieved. Traditional elements of charity and social care still dominate German childcare provision (Mischo, Wahl, Hendler, & Strohmer, 2012). In addition, in the last 10 years a great variety of supplemental programs focusing on domain-specific stimulation have been developed and implemented, especially in the domains of language/early literacy, mathematics, and science (including KiDZ, Komm mit ins Zahlenland [Let's visit numberland] (Friedrich, & Galgozy, 2008), Haus der kleinen Forscher [Little Scientists' House] (Anders & Ballaschk, 2014). There are, however, some concerns about academic stimulation in preschools as it is feared that such academic preschool education might result in disadvantages in other developmental domains (e.g., socio-emotional). These concerns are rooted in the tradition of German preschools focusing more on the stimulation of social than of cognitive skills. Until now, only a few of these educational programs have been subject to rigorous empirical evaluations.

Regarding the structure and financing of German preschools it can be said that most preschools are center-based, state subsidized, and community or welfare led organizations. So far, a small but a rising number of for-profit organizations are involved but most organizations remain non-profit or public. Parents pay a fee (in some federal states income-related) depending on the hours of the child's preschool attendance (about 5–20% of the overall cost). However, in some federal states the final preschool year immediately before transition to elementary school is free of charge. In general, German preschools are voluntary, but most preschoolers (91%) start at the age of three years (Autorengruppe Bildungsberichterstattung, 2016; OECD, 2015) before starting formal schooling at about age six. Usually, preschool classes are composed of several age cohorts. Thus, the age of children within one class often ranges between 3 and 6 years, or even between 1 and 6 years (Rossbach, 2009). Class size is about 25 children, with one or two caregivers per classroom (regulated by law in each federal state, and varying across states).

With regard to teacher training, the German preschool teacher education used to be highly standardized. It required assisting staff to complete two year's vocational training, and certified teachers to finish an additional three-year course. In order to implement

domain-specific stimulation in preschools and to raise the rate of academically trained preschool teachers, a number of applied universities have been offering more Bachelor degrees in early childhood education since 2008, as academically trained preschool teachers are quite common in other countries (for an overview of profiles of professionals in early childhood education and care see Oberhuemer, Schreyer, & Neuman, 2010). However, the percentage of preschool teachers with a college or university degree in German preschools is still low (2014: 5.3%, Bock-Famulla, Lange, & Strunz, 2015) compared to other countries.

The Model Project „Kindergarten der Zukunft in Bayern – KiDZ“

The KidZ project received public support because of the first results of PISA and PIRLS, which documented lower competence levels of school-aged children in Germany than expected or hoped; a higher value was set on systematic academic and domain-specific stimulation and preparation for school in preschools than in decades before. However, a deficit exists with regard to empirical evaluations of such educational programs and their effect on children's development. KiDZ was one of several intervention programs developed to focus on systematic academic and domain-specific stimulation. KiDZ provided children (aged 3–6) with traditional preschool stimulation (e.g., ideas of Froebel) referring to all developmental areas combined with more academic and domain-specific stimulation and school preparation (e.g., literacy center, science area, role play area). The main phase of KiDZ spanned from 2004 to 2009. In this time period, KiDZ was funded by the Bavarian State Ministry of Education, the Bavarian State Ministry of Labor and Social Welfare, Family Affairs, Women and Health, the Foundation *Stiftung Bildungspakt Bayern* and by the Bavarian industry association *vbw*. Afterward, there were follow-up studies analyzing mid- and long term effects of this model project funded by the Jacobs Foundation. KiDZ was conducted in three preschool centers with three preschool classes in each center. Each preschool worked with one primary school. The selected preschools were all located in the federal state of Bavaria and largely reflected Bavarian preschools with respect to the socioeconomic status and migration background of the families and children involved. Several features characterize KiDZ; however, the following are most important for this paper.

First, KiDZ is a child-centered approach focusing on all children and all age groups in preschool (mixed age classes). KiDZ follows a broad understanding of the goals of preschool education for children. That means that preschool education aims to develop knowledge and understanding and this also includes metacognitive competencies. Children should also achieve a socio-emotional willingness to learn and their interests and motivations should be further developed. Second, the more traditional preschool processes (e.g. the ideas of Froebel) are enriched with (not replaced by) domain-specific stimulation. A special feature of KiDZ is that this comprehensive domain-specific stimulation of preschoolers' emergent skills in literacy, mathematics, and science is not primarily carried out in specific planned hours but is mainly integrated into the daily routines and normal course of preschool life. KiDZ tries to be balanced in its approach to the use of such situations and the use of specific teacher-led efforts to stimulate children in an effort to always integrate the learning into developmentally appropriate activities. For this purpose, many hands-on materials for teachers

were developed by experts in the field of early childhood education and implemented in special training for the KiDZ teachers in literacy, numeracy, and science to enhance their content knowledge in these domains (e.g., KiDZ-Handbuch [KiDZ-Handbook], Stiftung Bildungspakt Bayern, 2007). Third, special emphasis was put on the cooperation between preschool and elementary school. Unique to the KiDZ project is a system of team teaching where each classroom is staffed by two preschool teachers (as is the rule in Bavarian preschools) as well as an elementary school teacher. This integrated approach to teaching offers the opportunity for sharing concepts and materials and thus should ensure the high-quality of domain-specific stimulation in preschool and should facilitate smooth transitions for children as they later enter elementary school. Fourth, from the beginning of KiDZ, an empirical evaluation in a quasi-experimental longitudinal design was implemented in order to overcome the lack of research considering the effectiveness of preschool programs in Germany.

The Present Study

Against the background of the somewhat conflicting results of universal preschool studies and high-quality program evaluations, and the lack of research of long term effects of preschool programs and preschool quality, especially in Germany, the present study investigated whether (a) KiDZ attendance was positively associated with early adolescent mathematical competencies at age 12 and (b) whether pathways from project attendance to adolescent mathematical competencies were mediated through preschool process quality.

Method

Sample and Procedure

The evaluation of KiDZ was designed as a longitudinal quasi-experiment where treatment and controls were not randomly assigned. Children entered KiDZ classes or comparison groups at age three, on average, and they were expected to start elementary school three years later. The model project KiDZ started with classes in preschools that had (voluntarily) applied for participation (some degree of self-selection). Preschools of the comparison group had to be comparable with regard to several criteria (especially location and class composition) to the KiDZ preschools, and were preferred as a comparison group where a similar motivation and openness to reform could be assumed. Therefore, comparison groups were selected that had participated in the piloting of the Bavarian educational plan shortly before and have, thus, shown a high degree of engagement and motivation. Furthermore, these preschools had, at that time, experienced a lot of training. All preschools, preschool classes, and target children in the intervention group as well as in the comparison group were followed in a longitudinal design which was comprised of five measurement points in annual intervals representing the whole preschool period.

Two further measurement points evaluated KiDZ effects at the end of first and second grade, and yet another one measurement point in grade seven. At all measurement points children were tested and extensive data from parents and preschool teachers was collected. In addition, global and domain-specific preschool quality was observed every year by external experts. At the first measurement point, the intervention sample consisted of 138 children drawn from nine preschool classes in three centers. The comparison group consisted of 53 children

drawn from seven preschool classes in 2 centers. The proportion of children with migration background is almost twice as high in the comparison group (24% versus 13%). The overall attrition from the first measurement point (191 children) to the seventh measurement point (83 children) amounted to 56.5%. The attrition rates in the intervention group totaled 62.3% (a loss of 86 children) and 41.5% (a loss of 22 children) in the comparison group. When comparing drop-out and participating children, no differences among the predictor variables emerged (t-test, *p*-level .10). The drop-out was mainly due to families having changed residence without notifying the research group or not being able to make time for data collection. At first glance this attrition rate seems quite high, but it is important to keep in mind that the study was running for more than 10 years in different settings (preschool, primary school, secondary school). Similar dropout rates are reported by other longitudinal studies like the BiKS-3-10 study (drop-out rate from preschool to grade 4: 48.9%, Homuth et al., 2014) or the ECLS-K study (dropout rate from kindergarten to grade eight: 52.0%, Tourangeau, Nord, & Sorongon, 2009).

Age 12 Outcome: Mathematical competencies

Mathematical competence was assessed by the DEMAT6+ (Goetz, Lingel, & Schneider, 2013) which is a curricular valid standardized test including three subtests in the domains of arithmetic, geometry, and written math problems. The test consists of 32 questions. The test was administered individually. The dependent measure was the number of correct responses (Max = 32; Min = 3; M = 14.6; SD = 6.7). We used raw scores in the further analyses.

Treatment Variable

A variable was built representing the participation in KiDZ (model group) or not (control group). The sample consists of 72.3% participants in the model project KiDZ.

Quality of the Preschool

Preschool quality measures were based on observational ratings conducted in the first, second, and third preschool year when children were three, four, and five years old. Quality was assessed during a four-hour visit of the preschool in the morning by trained observers using a German version of the ECERS-E (Rossbach & Tietze, 2007; Sylva, Siraj-Blatchford, & Taggart, 2003). The ECERS-E includes four subscales, the quality of learning environments for verbal literacy, mathematics, science literacy, and caring for diversity and individual learning needs. Since the present study focuses on the domain-specific and general effects of domain-specific quality with a special focus on children's mathematical skills, the subscale *mathematics* was used in the present analyses. The subscale includes four items which refer to activities and resources supposed to foster children's mathematical skills like counting, comparing, measuring, etc. The scores range from one to seven with one indicating inadequate quality, three minimal quality, five good quality and seven excellent quality of preschool. Correlations across the measurement points were low to moderate, indicating change over time, presumably due to the potential changes in classroom composition (e.g., vacant places become available to the next group of three year olds after the summer break) during and between the preschool years, which is quite common in German preschools (Kuger et al., 2015). For the present analyses we averaged the three measurements of the quality indicator to create one scale representing

preschool quality in the mathematical domain throughout the whole preschool phase (M = 3.7, SD = 1.0).

Numerical Skills During Early and Middle-Childhood

Children's numerical skills at the *end of preschool* are considered by using the standard scores on the subscale *arithmetics* of the German version of the Kaufman Assessment Battery for Children (K-ABC; Melchers & Preuss, 2003) (M = 18.2, SD = 3.6). The scale measures children's skills in counting, identifying numbers, knowledge of shapes, and understanding of early mathematical concepts like addition or subtraction.

To measure mathematical competencies in adding and subtracting in elementary school, a standardized test of arithmetic skills (Heidelberger Rechentest (HRT), Heidelberger Calculation Test, Haffner, Baro, Parzer, & Resch, 2005) was given. For the present study, the number of correct responses combined for the three subtests focusing on number fact knowledge and simple mental arithmetic have been considered (M = 18.0; SD = 5.0; see Lehrl et al., 2016 for further information).

Child and Family Background Variables

Comprehensive data on child and family background variables were collected by standardized questionnaires and interviews developed by the research team for the purpose of the evaluation, which were administered to parents. Based on the literature (Hartas, 2011) and after careful preliminary analyses, for the current study we selected the following set of variables as controls for possible selection bias. Descriptive statistics are depicted in Table 1. Gender, age in months, type of school (secondary school vs. other school types), grade (five-eight and maternal education (certificate for college or university entrance vs. no certificate) were used as child and family background predictors with potential influence on children's competence development.

In addition, the experiences in the learning environments at home and at elementary school were accounted for. The early home learning environment (HLE) is comprised of a composite score created by averaging the parent reported frequency of six education related parent–child activities in the home and out of home in accordance to Melhuish et al. (2008). Activities include reading to the child, letter games, number games, language games, drawing/building, and visiting the library. Frequency could be rated on a 6-point-scale ranging from 0 = never to 5 = daily (Cronbach's Alpha = .67). Instructional quality in mathematics in 1st grade of primary school was rated during observations of two or three lessons (45 min each) on one day in the morning whenever mathematics was taught in Grade 1. The scores range from one to seven with one and two indicating low quality, three–five medium quality, and six and seven high quality. The scale includes items such as "positive culture of handling mistakes", "transparency of lesson's goal", "quality of the tasks/problems", "freedom of thinking/communication", and "illustrative material to create mental images" and was shown to be predictive for arithmetic development during primary school (Lehrl et al., 2016).

Statistical Analyses

To examine whether preschool quality is associated with early adolescent outcomes in mathematic skills at 12 years of age, pathway models were run using MPlus version 6.1 (Muthén & Muthén, 2008-2013) testing for direct effects. If direct effects are found, we

examine in addition, whether child outcomes at pre- and primary school mediate these associations by testing indirect effects. The analyses account for missing data through full-information maximum likelihood (FIML; Arbuckle, 1996) based on the data for all 191 children originally recruited for the study. Descriptive characteristics can be seen in Table 1.

Table 1.
Descriptive characteristics of the sample

	%	M	SD
Mathematical skills at age 12 (DEMAT 6+)		14.64	6.74
Preschool quality (ECERS-E math; 1-7)		3.69	0.95
Treatment (1=model group, 0=control group)	72.3% model group		
Mathematical skills at end of preschool (K-ABC Arithmetic)		18.24	3.64
Mathematical skills at primary school (HRT; Math fluency)		18.03	4.97
Age (in months)		143.31	5.13
Early HLE (1-7)		3.06	0.80
Grade (5-8)		5.94	0.57
Instructional quality of elementary school (mathematics) (1-7)		3.96	1.07
Type of school	72.3% secondary school		
Mother's educational level	36.2% university degree		
Gender	50.3% male		

Results

Pathway Models Predicting Mathematical Competencies in Secondary School (age 12) From KiDZ Participation

The first model contains the pathway model in which age 12 outcomes in mathematical competencies were predicted from KiDZ participation while controlling for family and child background variables as well as the home and primary school learning environments. Table 2 shows the standardized path coefficients for this model (model 1).

Results indicate that KiDZ participation is significantly associated with mathematical competencies (b = .22, p < .05) at age 12 suggesting that children in the KiDZ group show better mathematical outcomes at age 12.

Regression Models Predicting Mathematical Competencies in Secondary School (age 12) From Pre-school Quality

The second set of analyses contains pathway models in which age 12 outcomes in mathematical competencies were predicted from preschool quality in three separate models, while controlling for family and child background variables as well as the home and primary school learning environments. Table 2 shows the standardized coefficients of those models (model 2-4).

Results indicate that preschool quality is significantly associated with mathematical competencies (model 2: b = .42, p < .05) even when controlling for mathematical competencies in preschool (model 3: b = .37, p < .05) and primary school (model 4: b = .24, p < .10) at age 12 suggesting that higher preschool quality is associated with better mathematical outcomes at age 12.

As treatment effects diminish when controlling for preschool quality, indirect effects of project participation via preschool quality was tested via pathway modeling and showed significant effects (b = .20, p < .05).

Table 2.

Associations between program attendance, preschool quality, and mathematical competencies at age 12.

	Model 1	Model 2	Model 3	Model 4
	b	b	b	b
Mathematical skills at preschool age			.19+	.10
Mathematical skills at primary school				.34*
Grade			.34*	.25*
Treatment (1=model/0=control)	.22*		-.20+	-.20+
Preschool quality (ECERS-E math)		.42*	.37*	.24+
R^2	.41	.50	.63	.67

Note. b = standardized regression coefficient; effects controlled for child's gender, age, maternal education, early years HLE, type of school attended, instructional quality of the primary school; *p < .05; + p < .10

Discussion

The present 10-year follow up study on the effects of an academically oriented preschool intervention on academic development addressed two major questions:

(a) Is attendance positively associated with early adolescent mathematical competencies at age 12?

(b) Are pathways from attendance to adolescent mathematical competencies mediated through preschool process quality?

Participating in KiDZ and Mathematical Competencies at Age 12

A relatively consistent finding across decades of childcare research is that preschool quality is related to children's academic outcomes (see Melhuish et al., 2015 for an overview). The present study extends this huge body of research by showing positive longer term associations between preschool quality and mathematical competencies measured approximately seven years after the children had left their preschools. KiDZ participation was indirectly associated with adolescents' mathematical functioning via preschool quality indicating that a highly academically oriented preschool intervention is able to increase preschool quality which in turn predicts child outcomes in the long run.

Previous long-term studies have focused on high-quality interventions aimed at children at risk because of poverty or low birth weight. The current findings suggest that the quality of preschool experiences can have long lasting effects in a socio-economically diverse sample. Results also reveal that children profit from high preschool quality over and above the effects detected earlier on preschool numerical skills (Kluczniok, Anders, Sechtig, & Rossbach, 2016) or primary school numerical skills. By providing children with high-quality domain-specific stimulation and beyond, KiDZ shows lasting effects on academics that are crucial for children's further success. The high quality experiences in the KiDZ preschools appear to boost children's mathematic development, persisting to secondary school. Possible mechanisms behind this association might be that children in high-quality preschools "learned to learn," for example, through better approaches to learning like motivation, enjoyment of learning, and learning effort. Thus, KiDZ seems to provide children with high-quality domain-specific stimulation that lays not only the foundation for a good start in school but also for later development in secondary school.

The present study reveals evidence for the lasting effects of preschool quality on children's mathematics development through age 12. These results of KiDZ have to be seen against a broader perspective of other findings (not reported here) that show that KiDZ does not have negative effects on children's emotional development e.g., joy of learning and well-being (Kluczniok et al. 2016). Thus, in response to the concern that children's socio-emotional skills may be neglected at the expense of their cognitive skills when they attend academically oriented preschool programs, the KiDZ findings demonstrate that such trade-offs need not occur. Taken together this study provided important insight with regard to the mastering of transitions in school careers and the findings make a strong case for enhancing preschools' process quality.

What can we learn from preschool projects like KiDZ? The KiDZ results contribute to the ongoing debate on how to enhance and manage preschool quality in early childhood education and care in Germany. The findings of long-term effects on children's development have great importance to the argument for investments in early childhood education and care. In particular, the domain-

specific stimulation integrated into appropriate play activities in preschool seems to be a successful approach to enhancing preschool quality and child development. The KiDZ program differs from academic and standardized learning via specific training programs because the program is for all children and all age groups in preschool, independent of children's skills, and is not primarily carried out in specific planned hours. Moreover, KiDZ adopts a comprehensive domain-specific stimulation of preschoolers' emergent skills in literacy, mathematics, and science that is mainly integrated into the daily routines and normal course of preschool life. In addition, KiDZ tries to ensure a balance between such situations and teacher-centered efforts to stimulate children in a developmentally appropriate way. Thus, the combination of traditional preschool education, referring to all developmental areas, enriched with domain-specific stimulation of the children appears to be beneficial for child development.

In the context of the German debate, the lack of negative effects of early academic stimulation on children's emotional development is also a key message for the political debate on further directions of early childhood education and care. Compared to other curricula and programs in Germany, KiDZ is more oriented towards stimulating cognitive competencies and advancing children's knowledge and understanding in several domains. This, however, can only be done if, at the same time, children's socio-emotional willingness to learn, interests and motivation, and value orientations are considered. Concerns that such a play-based academic preschool education might result in disadvantages in other developmental domains (e.g., socio-emotional) are therefore unfounded (Kluczniok et al., 2016).

To conclude, KiDZ represents a successful way of promoting preschool quality and also highlights successful directions of professional development for preschool teachers who have been broadly qualified with content knowledge in different domains (e.g., literacy, numeracy, science) during the KiDZ project.

Limitations and Avenues for Further Research

Although the present study has a number of important findings, there are also some limitations. First, the sample was a small, regional sample in Bavaria, although there was enough power to detect findings. A second concern is the attrition rate over time. In the KiDZ group the attrition rate totaled 62.3% and 41.5% in the control group. The drop out was mainly due to families having changed residence without notifying the research group or not being able to make time for data collection. At first glance this attrition rate seems quite high, but it is important to keep in mind that the study was still running after more than 10 years in varied settings (preschool, primary school, secondary school). Similar dropout rates are reported by other longitudinal studies like the German BiKS-3-10 study and the ECLS-K study from the US.

The next steps of our research involve further analyses of the lasting effects of KiDZ related to other developmental domains, e.g., socio-emotional developmental aspects like coping with life, and joy of learning. By doing so, the importance of KiDZ can be extended to other important developmental domains.

Notes

1. In this article, we use "preschool" as a term for institutional child care for ages 3 and above, prior to school entry. In contrast to other countries (e.g., the US kindergarten), the German "Kindergarten" is an institutional setting for all children from age 3 up to the start of elementary school which usually begins the age of 6

(for more details see chapter “The German preschool system)”.

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About The Author(s)

Dr. Simone Lehrl, is a researcher at the University of Bamberg. Her research interests are the conditions and impact of the quality of early years learning environments.

Dr. Katharina Kluczniok, is a researcher at the University of Bamberg. Her research focuses on the concept and the impact of early years learning environments.

Prof. Dr. Hans-Guenther Rossbach, is a professor at the University of Bamberg. His research focus is on longitudinal studies in early childhood education and especially the impact of preschool quality on children's development**.**

Prof. Dr. Yvonne Anders, is a professor at the Free University of Berlin. Her research focus is on quality in early years learning environments, and conditions and impacts of professional development of early years practitioners.