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EDITORIAL

STEM in Early Childhood Education

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This special issue of the *European Journal of STEM Education* is dedicated to STEM in early childhood education. Early childhood education with respect to STEM already starts in the womb, when the not-yet-born baby accustoms itself to the material world surrounding it (Smith and Gasser, 2005). Certain sounds become familiar and newborns can already discriminate their mother tongue from other languages. After birth, the force of gravity imposes itself on the child, forcing it down. This is the start of a yearlong struggle to rise, which becomes the source of many metaphors we all use to make sense of our lives. When things do not go our way, we feel down and depressed. When we succeed, we lift our hearts and enjoy high spirits. Consequently, teaching children the meaning of 'up' and 'down' is much easier than teaching them 'left' and 'right', as any parent and Kindergarten teacher will know. 'Up' and 'down' are extremely meaningful and important to the child, whereas 'left' and 'right' are often quite arbitrary. Since we are subjected to gravity, we need flat feet and strong legs to cope with that force. We would notice it immediately when someone stands on its head and hands. But do you know which hand your colleague uses to pick up that cup of coffee?

Children perceive and act before they can speak or think consciously. Experiences in and with the material world are the starting point of cognitive development. STEM in early childhood education is not explaining children the laws of gravity; it is guiding them to and through experiences in which gravity plays a decisive role. Or any other concept that is important to children's lives. Children are not yet interested in correct reproductions of true statements about the world. They first of all want to know what the things in the world afford them to do (Gibson and Pick, 2000). Can you eat it? Is it safe? The motor system will children help to act, and the sensory system will help them to correlate objects and phenomena in the world to their experiences. STEM in early childhood education is about rich material environments that children can explore. It is also about helping them with conceptual development, by drawing their attention to salient features and by suggesting words for 'this' and 'that'. Conceptual development starts with experiences that impose themselves upon the child and crave for attention and interpretation. Some things make sounds, some things flow, some things can be put in other things. The development of verbal language skills and vocabulary cannot do without this process, and the development of scientific concepts cannot do without the metaphorical use of words like 'up', 'in' or 'current' (Lakoff and Johnson, 1980; Browne, 2003).

Words do not just come from personal, individual experience. They are suggested to the child from the social community in which it grows up. High quality interaction with adults, or older children, is as important for understanding the world and for healthy development as having the rich material experiences themselves. Learning about the material world is learning to play, is learning a language, is learning social skills, is learning to communicate (Van Oers, 2013; Vygotsky and Luria, 1994).

Learning about the material world of course is also learning about STEM. STEM is about questions that can be explored scientifically; or about technological problems that can be solved through engineering and design. These questions and problems will take on sophisticated, often mathematical expressions in adult and professional life. They will build on previous experiences and conceptualizations. But when you unwrap all these layers of conceptions and technology that uses other technology (Arthur, 2009), you will see that the laser pointer you use in your lectures is just your finger, but improved. Your cell phone is just your voice, but improved, so that it carries your voice over distance. Technology is an embodied answer to our embodied problems and that is why we have, or should have, an intuitive understanding of technology.

Alas, many people seem to become alienated from the material and technological world when they grow up (ASPIRES, 2013). In many countries, too few young people aspire for a career in science or engineering. Something goes wrong and schools seem to play a part in this. Instead of stimulating children to plunge headlong in the material world and start making sense of it, many teachers fear the openness and lack the pedagogical repertoire to guide children from experience to insight. Explorations quickly become messy and unpredictable, and children can ask questions that are difficult to answer. So instead of relying on the power of children's direct experiences of phenomena, too many teachers rely on mediators like textbooks and paper and pencil exercises or refrain from teaching STEM at all. It is okay when children play in the sandbox in their own time, but this is not 'real learning'. And yes, when they are sixteen, children may know that water is H_2O, that a whale is a mammal and jeans are made of cotton, but many will have lost contact with the processes that lead to this knowledge and to these products, and they do not know both the joy and the frustration that comes with investigating, designing, making, modeling, testing, improving and explaining.

So, it is vital to start teaching STEM at an early age and teach it well. Good teaching should be evidence based, or at least evidence informed. That is why research is important. And research on STEM in early childhood education can be quite divers, as is exemplified by the contributions to this special issue.

In the first contribution, *John, Sibuma, Wunnava, Dubosarsky and Anggoro* propose a problem-based curriculum for three- to five-year old children, with an explicit focus on engineering problems. They find that this affects engagement of the children but also the self-efficacy of the teachers.

Bers writes about ScratchJr, a tool with which children who cannot yet read or write can create programs. Certainly digital technology is of great relevance in the present and future life of young children, and it is important to give coding and computational thinking its proper place in educational settings.

Strawhacker and Bers focus on another big hype, the Maker Movement. They investigated a Kindergarten classroom that contributes to the children's technological development and found that Makerspace activities definitely have potential but that teachers' interaction with children matters too.

Engineering design problems are introduced in Kindergarten by *Tank, Rynearson and Moore* to investigate whether young children can engage in the stages of engineering design processes and learn to use engineering language.

Malone, Tiarani, Irving, Kajfez, Lin, Giasi and Edmiston bring engineering design challenges to Kindergarten, incorporated in drama, dance, visual arts and physical education. They investigated the effects on the understanding of what engineers do and of technology and found significant increases.

Ralph and Petrina focus on social learning with mobile devices, gathering data by using cameras worn by participants. They show that it is at least possible (if not guaranteed) to induce more prosocial sharing behaviors in children aged 3-4 when interacting with mobile devices.

Scientific reasoning is considered by many to be difficult. *Van der Graaf, Segers and Verhoeven* investigate the experimentation ability of Kindergarten children with learning problems.

Many children are anxious about mathematics. *Furner* investigates the mediating role of using children's books and children's literature in math lessons on developing mathematically confident young people, feeling that as children are less anxious, their performance may improve.

Stylianidou and co-workers, among them the late Anna Craft, reflect on the results of the 2011-2014 Creative Little Scientists project and provide recommendations to foster inquiry and creativity in early years STEM education.

Sumpter and Hedefalk analyze the strategies ('epistomological moves') teachers use to promote mathematical reasoning in preschool. They find that teachers most often instruct, confirm or conclude, but that they hardly use generative strategies that help children to produce arguments themselves and thus do not stimulate children to learn creative mathematical reasoning.

STEM learning does not only take place at schools or in day care settings. For young children, the family is the most important learning environment. *Sheehan, Hightower, Lauricella and Wartella* investigate whether parents' attitudes on STEM and their acquaintance with STEM careers predict their children's science and math skills, with interesting findings.

DeJarnette wants to add the A of Arts to STEM, because both develop curiosity and creativity. She investigates the effects of a professional development program on preschool teachers' self-efficacy and disposition to implement STEM.

Without the effort of the guest editors, Hannelie du Preez from Pretoria University in South Africa, Fani Stylianidou from Ellinogermaniki Agogi in Greece and Estelle Blanchet from Bordeaux University in France and

also coordinator of the Special Interest Group of the European Science Education Research Association (ESERA), creating this special issue would not have been possible. Without many reviewers devoting precious time to carefully providing feedback to the authors, we would not have reached this high quality. Thank you all!

So, enjoy reading and apply the insights to your own research and/or your educational practice!

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An Iterative Participatory Approach to Developing an Early Childhood Problem-based STEM Curriculum

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ABSTRACT

This paper describes an iterative participatory curriculum design approach to developing a problem-based STEM curriculum for preschool children. The curriculum aims to teach young children problem-solving using an adapted version of the engineering design process (EDP). Despite evidence showing that a rigorous, integrated STEM curriculum promotes cognitive development and curiosity, very little STEM or engineering instruction occurs in classrooms for three- to five-year-old children, and few studies include teachers in the curriculum design process. Research has shown that, when children experience an engineering curriculum, they show an increase in engagement, in the number of engineering behaviors displayed, and in persistence in completing activities. As well, when teachers are involved in designing curriculum, they are more likely to feel empowered and sustain implementation. Qualitative analysis of semi-structured interviews with 13 preschool teachers after the development process showed that teachers who participated in the process perceived increased knowledge and self-efficacy in teaching STEM in their classrooms. These reflections support using a participatory curriculum design approach for empowering teachers and enhancing self-efficacy in teaching STEM to young children. High teacher self-efficacy has been associated with positive classroom outcomes and teacher retention in the profession.

Keywords: curriculum development, engineering education, early childhood, STEM, teacher self-efficacy, iterative design

INTRODUCTION

This paper describes a collaboration between Science, Technology, Engineering, and Mathematics (STEM) educators, engineering experts, social and cognitive developmental psychologists, and a public preschool program in the northeastern United States to develop a problem-based STEM curriculum for preschool classrooms using a participatory design approach (Auerbach, 1992). The Seeds of STEM eight-unit curriculum guides preschool teachers and their students in the process of problem-solving by following the steps involved in the engineering design process (EDP): 1) identifying problems and defining criteria for successful solutions, 2) brainstorming solutions, 3) selecting testable solutions, 4) creating the solutions, 5) testing and improving the solutions, and 6) sharing the solutions with others. During each 3-week unit of the curriculum, the first half focuses on exploration of specific science concepts (e.g., habitats, buoyancy, forces), while the second half focuses on solving a problem that requires application of the science concepts (e.g., design a container to float cookies across a river). Preschoolers learn to solve environmental problems sequentially with guidance from the teacher. In this paper, we review current standards, highlight examples from existing preschool curricula, and describe the iterative design process used to develop the curriculum. We also share results from formative evaluation tools, including teacher feedback surveys and interviews about teachers' reflections on their ability to teach and integrate STEM and the problem-solving approach in their practice following their involvement in the development process.

Background

Stakeholders and experts in education and industry concur that it is essential to support the development of students' STEM literacy, or the ability to apply STEM concepts and skills (Bornfreund, 2011; Zollman, 2012) to address real-world problems. STEM literacy is considered crucial to students' future success (Fayer et al., 2017). However, a large portion of teachers and adolescent children in the United States are underprepared and become uninterested in STEM over time (Archer et al., 2010; NRC, 2011, 2014). National investment in developing a pipeline of individuals equipped with STEM competencies has been a priority for building knowledgeable, skilled, and innovative members of the workforce (Carnegie Corporation of New York, 2009).

Research on academic achievement shows a large disparity between low income and ethnic minority students in the United States (U.S.) and their White, middle-class counterparts. Children are first exposed to academic topics and skill-building activities during their pre-kindergarten years (Claessens et al., 2009; Federal Interagency Forum on Child and Family Statistics, 2013; Morgan et al., 2016). Since studies show that poor and ethnic minority children in the U.S. have already fallen behind before they enter public schools (Brooks-Gunn et al., 2007; Mickelson et al., 2013), a steady increase in early childhood education programs and enrollment has shown promising evidence in narrowing the performance gap (Haskins and Rouse, 2005; Howes et al., 2008).

Young children are naturally curious about their world (Engel, 2011; Piaget and Inhelder, 2000). Children actively participate in their environment, reason, define problems, manipulate, build and test prototypes, apply mathematical and scientific concepts, and share solutions with friends and family (Buchter et al., 2017). This results in the natural development of scientific inquiry and observation, measurement, prediction, inference, and communication skills (Platz, 2004) that increase with sophistication as children develop (Piaget and Inhelder, 2000).

The National Research Council (2012) defines engineering as an engagement in a systematic practice of design to achieve solutions to particular human problems (p. 11). Young children are natural engineers in the sense that they manipulate their worlds in an attempt to solve problems (Brophy et al., 2008; Cunningham, 2009). Yet, engineering is rarely included in the development of early childhood curricula (Bagiati and Evangelou, 2015). Debates about how early to introduce STEM concepts and the extent to which young children can understand the subject matter and develop the skills are commonplace (Tippett and Milford, 2016; Wood and Hedges, 2016). As a result, early childhood programs vary widely in their resources, quality, effectiveness, and time spent on instruction in the disciplines related to STEM, especially engineering (Cannon et al., 2017; Whitebook and Ryan, 2011).

Despite evidence showing that a rigorous, integrated STEM curriculum promotes cognitive development and curiosity (Fogarty, 2009; Klein and Knitzer, 2006; Zan and Geiken, 2010), very little STEM or engineering instruction occurs in classrooms for three to five year old children (Diamond, et al., 2013), and few studies actively include teachers in the curriculum design process (McFadden, 2015).

Characteristics of a High-Quality Early Education Curriculum

High quality early childhood programs are associated with long term positive outcomes (Reynolds et al., 2004). Such programs include rich materials that incite exploration (Moomaw and Davis, 2010), are developmentally appropriate (National Research Council, 2012), and culturally responsive (Gay, 2000). They encourage frequent and responsive interactions between child and teacher (Vygotsky, 1962) and increase child engagement (Howes et al., 2008). An effective way to foster young children's learning is by meeting their cognitive, emotional, and developmental needs through both direct instruction and play (Moomaw and Davis, 2010). Allowing children to take the lead in exploring phenomena and asking open-ended questions that provide opportunities for children to reflect, form theories, and explore also makes for higher quality programs (Aldemir and Kernami, 2017).

The National Association for the Education of Young Children (NAEYC, 2009) identified key criteria for a set of materials to be considered an effective curriculum: (1) Children must be active and engaged; (2) Goals must be clear and shared by all; (3) Curriculum must be evidence-based; (4) Content must be learned through investigation, exploration, and direct teaching; (5) The curriculum must build on prior learning and experience; (6) Professional standards validate the curriculum's content; and (7) The curriculum, if implemented as intended, must have beneficial effects.

Approaches to Curriculum Development

This paper describes the Seeds of STEM curriculum development process, based on expert defined learning outcomes and models (NRC, 2012). Clements' (2007) seminal work toward creating a curriculum research framework defined the elements needed to develop a 'research-based' curriculum. Recognizing the iterative nature of curriculum development, Clements argued for multiple testing before, during, and after the curriculum is developed. Accordingly, the Seeds of STEM curriculum was developed based on research-based outcomes, similar to Wiggins and McTighe's (2005) 'backwards design' approach, designed according to established learning models, tested in authentic settings, revised based on feedback from students and teachers, and its activities were evaluated multiple times to verify that the learning outcomes were met.

An iterative design approach helps to ensure that curriculum materials are effective and engaging (Couso, 2016; Diamond and Powell, 2011). Kinzie et al. (2009) developed a math curriculum for pre-Kindergarten which began with creative brainstorming, followed by development of early prototypes that were repeatedly revised, evaluated by teachers, and tried out in classrooms before they were deemed complete. For example, the developers conducted classroom observations in three pilot classrooms to evaluate the connections among activities throughout the year. They found that teachers tended to focus on completing activities rather than on encouraging students to think about them. As a result, they added language for teachers to use to prompt children to think and share their thoughts.

Similarly, a participatory curriculum design approach is one which cyclically involves stakeholders and end users in the design and decision making about the curriculum. Taylor (2003) grounds this approach on developing a partnership between different stakeholders in the curriculum and, in doing so, creating a sense of ownership of the product. By increasing stakeholder participation in the process, positive curricular impacts on learning and sustainability of implementation are thought to increase. This approach has been used in international and community education contexts to create curricular interventions to be maintained on a local level (Peters and Matarasso, 2005; Auerbach, 1992). Likewise, the participatory approach was used in the current project to help maintain preschool teachers motivation to remain involved and empower them to serve as co-developers.

Additional STEM curricula that have included teachers and their classrooms in the development process have shown to have promising outcomes. For example, *Building Blocks Foundations for Mathematical Thinking* is a mathematics computer-based curriculum for PK-2. It draws on the National Council of Teachers of Mathematics standards and National Association for the Education of Young children recommendations (Clements and Sarama, 2013b). *Tools of the Mind* is a research based, early childhood model that combines teacher professional development with a play-based curriculum that builds on quantitative and verbal skills for pre-kindergarten to kindergarten (Diamond et al., 2007). It aims to develop children's cognitive, social-emotional, and academic skills using Vygotskian theories and neuroscience research. *Engineering is Elementary (EiE)*, a curriculum developed by the Museum of Science in Boston, was expanded to include preschool children. The preschool version of the curriculum uses a three-step EDP: explore, create, and improve, adapted from the original five-step process of ask, imagine, plan, create, and improve. To introduce children to these terms, *EiE* teaches children new vocabulary and uses playful materials, songs, and activities to learn engineering. Using qualitative assessments, they observe how children respond to activities and ask teachers to provide feedback (Lachapelle et al., 2011). These examples show us that young children may not be able to spell engineering or read on their own at this age, but they can follow step processes, use technology, and work collaboratively to develop skills needed to think like an engineer (Davis et al., 2017).

THE CURRENT PROJECT

Project Goals

The research team set to develop an early childhood problem-based STEM curriculum for preschool children and teachers from diverse neighborhoods with low-income households. For these two populations, the following outcomes were established: First, by experiencing the curriculum children will improve their ability to appropriately use STEM vocabulary, to conduct each step of the engineering design process, as well as experience increase in overall STEM readiness. Second, teachers who teach the curriculum will improve their self-efficacy in teaching STEM to pre-K children and increase their knowledge of STEM and the engineering design process. To meet these goals, the study included the following phases: establishing a guiding framework for the curriculum, developing and testing the curriculum using an iterative participatory design, and pilot-testing the developed curriculum with a new population of children and teachers. The current paper focuses on the first two phases of the project.

Guiding Framework

To guide curriculum development, our team adapted the Dayton Regional STEM Center's Quality STEM framework (Pinnell et al., 2013) and defined eight principles for high-quality early childhood STEM experiences: developmental appropriateness, cultural responsiveness, applications of the EDP, integrity of academic content, quality of technology integration, connections to non-STEM disciplines, real world connections, and curriculum-embedded, performance-based assessment (Dubosarsky et al., 2018).

In regard to developmental appropriateness, we relied on the National Head Start Child Development and Early Learning Framework (2010), which specifies standards under the domains of social-emotional development, approaches to learning, logic and reasoning, mathematics knowledge and skills, and science knowledge and skills.

The integrity of academic content criterion in the guiding framework ensured that STEM became an integral part of the learning day, rather than an add-on to an existing curriculum. For that the team reviewed several sets of State and National US academic standards to define the learning outcomes of the curriculum. The reviewed standards included the Massachusetts Framework for Science, Technology, and Engineering for Pre-K (2014), the Common Core State Standards for kindergarten mathematics (2010), and the United States' Next Generation Science Standards (NGSS) for scientific and engineering literacy (NGSS Lead States, 2013).

The practices emphasized by the NGSS were adapted for preschool children and embedded into the curriculum's performance expectations. These practices included asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations, designing solutions, using evidence-based argumentation, and communicating information.

Establishing the Process of Iterative Development

The eight-unit Seeds of STEM curriculum was developed over an 18-month period through an iterative process of *design-testing-revision-testing* and followed the participatory curriculum design (PCD) approach (Taylor, 2003), where the end users of the curriculum (preschool teachers) were involved, and played a key role, in the development and testing of the curriculum. Since participatory curriculum design (PCD) method includes conducting stakeholder needs assessments, teachers completed an online survey at the start of the process gathering information about their background, perceived areas of needed professional development, their attitudes and knowledge about STEM education and engineering, as well as their perspective on multicultural awareness. Consistent with the PCD approach, the project team's role was to present design problems to the teachers, asking them to work together and discuss with one other to develop activities during face-to-face meetings. Teachers were provided with professional development to prepare for the process and continuously involved in the testing and evaluation of the different versions of the curriculum. Unlike some published versions of the PCD approach, the content to be taught was pre-determined by educational standards and frameworks in combination with expressed teacher needs, rather than by the community needs alone.

Teacher Recruitment

The team defined separate groups of teachers to participate in the curriculum creation and revision process: Developer teachers (DTG) and tester teachers (TTG2 and TTG3). To recruit teachers for all groups, the team partnered with a large urban Head Start program which managed 4 centers. A total of 621 children and their families were served by the Head Start program during testing cycles. Fifty-eight percent of families served were Hispanic; 21% were African-American; 20% were White/Caucasian, and 1% were Asian (Worcester Child Development Head Start Program Worcester Public Schools, 2017, p. 12).

All interested teachers completed a questionnaire during the recruitment session to measure their current STEM content knowledge, teaching practice, self-efficacy, and multicultural awareness. Developer teachers, referred to as the Developer Teacher Group (DTG) were charged with collaborating with the project's curriculum development team (CDT) to create the initial drafts of curriculum plans. To be considered for the DTG, the teacher had to meet these criteria: 1) having a Master's degree; 2) working in the urban Head Start center for more than one year; 3) mid to high scores on all Classroom Assessment Scoring System (CLASS) dimensions; 4) good reviews from the teacher's supervisor; and 5) teachers' interest in joining the development team. Recommendations for teachers who fit the criteria were solicited from the collaborating Head Start Center education director. Teachers for the Tester Teacher Groups (TTG2 and TTG3), were recruited from the same Head Start sites. Tester teachers had to be willing to implement activities and provide feedback on implementation days using an online feedback form. All teachers received stipends for time spent outside of the classroom to complete all development activities assigned to their group. In all, 6 preschool teachers from 6 classrooms formed the Developer Teacher Group (DTG), 20 teachers from 10 classrooms formed the second tester teacher group (TTG2), and 8 preschool teachers from 4 classrooms formed the third tester teacher group (TTG 3). On average, there were about 17 children in each classroom. All teachers were female, with the average age being 41.7 years old (standard deviation = 10.3 years old). Most (32 teachers; 91%) were of White/Caucasian descent, and three (3 teachers or 9%) belonged to minority groups. Five teachers held Master's degrees; two had Associate's degrees; 28 had bachelor's degrees. The following sections describe the elements in more detail that led to the development of the curriculum.

Table 1. Final iterative participatory development process for each unit in the curriculum. Key: CE = Content Experts; CDT = Curriculum Development Team; DTG = Developer Teacher Group; CDE = Child Development Expert; DE = Diversity Expert; AB = Advisory Board; TTG2 = Tester Teacher Group 2; TTG3 = Tester Teacher Group 3

Unit Plan		CE	CDT	DTG	CDE	DE	AB	TTG2	TTG3
Version 1	Development	x	x	x					
	Testing & Feedback			x	x	x	x		
Version 2	Revision		x						
	Testing & Feedback							x	
Version 3	Revision		x						
	Testing & Feedback								x
Version 4	Revision		x						
	Testing & Feedback			x			x		
Final Version	Last Revision		x	x					

Iterative Testing and Revision Process

The team of researchers and developer teachers went through several models of creating the first draft of each unit (Version 1), and through trial and error, found a collaboration model that yielded high-quality units. Prior to a face-to-face meeting, the project team shared with the DTG the expected learning outcomes for the unit to be developed, and the team worked collaboratively at the meeting to create the first unit draft based on the defined outcomes. At each meeting, lasting about four hours, the team researched books, videos, songs, and ideas for center activities, as well as small and large group activities. Then, the teachers implemented each one of the curriculum units in their classrooms on three separate occasions: by the DTG (Version 1), TTG2 (Version 2), and TTG3 (Version 3). Between each test, the unit underwent revisions based on comments provided by the teachers.

Feedback Survey

To obtain teacher feedback on unit activities and keep track of teacher implementation, the curriculum development team developed an online survey using Qualtrics. Teachers were asked to complete a survey following each day they implemented any curriculum activities in their classroom. Survey feedback informed curriculum revisions to be made and gauged the usability and feasibility of activity implementation. The survey consisted of closed- and open-ended items that elicited teacher feedback about the extent to which teachers believed lessons were successful overall and about modifications that teachers made to each activity outlined in the curriculum. These included changes in pedagogical strategies or in materials used, and providing a rationale for curriculum modifications, and general feasibility of use with classroom sub-populations (e.g., Dual Language Learners, children with special needs, 3-year-old children).

The feedback responses from each group of testing teachers were collected and summarized to create one final consolidated report for each activity of the unit. Additionally, a separate report was created to summarize teachers' feedback on the entire unit. The curriculum development team revised each unit following the feedback from each testing session.

Expert Review

Once a unit was developed and tested by the first group of teachers, it was also given to the project's experts that included engineers, early childhood teacher educators, early childhood researchers, a cognitive developmental psychologist, and a social psychologist with expertise in diversity and inclusion. Experts' feedback was incorporated into the second revision of each unit. For instance, during the development of a unit based on plants, the curriculum development team initially considered including the full life cycle of the plants (seed-plant-flower-fruit-seed). However, the advisory board suggested that since the full life cycle will not be observed during the timespan of the unit, the concept of a life cycle may be too abstract for some children. They recommended that the unit would only focus on what the children are readily able to see and touch. As a result, the unit was changed to focus on the plant parts (seeds, roots, stem, and leaves) and needs (sunlight, air, and water).

Professional Development

During the iterative curriculum development process, the project leaders conducted three professional development (PD) trainings with the participating developer and tester teachers to help them become familiar with the characteristics of high-quality STEM activities. These training sessions covered the following topics: 1) Engineering Design Process, 2) High Quality STEM education, and 3) Diversity and inclusion in STEM, specifically engineering. The topics of the training sessions were chosen based on teacher-reported needs assessed through a survey at the beginning of the study, and input from the curriculum development team as to the topics that will help teachers teach the curriculum with fidelity.

During the first training, the teachers learned about the engineering design process (EDP) and created a child-friendly visual of the "EDP wheel" to use in their classrooms (Dubosarsky et al., 2018). During the second training, teachers were introduced to the project-created framework for high-quality STEM experiences in early childhood and engaged in such activity. The third training covered issues related to diversity and inclusion in STEM education. The goal was to increase teachers' awareness and knowledge in pedagogy and reduce stereotyping based on race, nationality, gender, ability, socioeconomic status, language, and perceptions of engineering and engineers.

ITERATIVE DEVELOPMENT PROCESS IN DETAIL

Version 1: Developer Teacher Test

The six curriculum developer teachers were the first set of teachers to test the units in their classrooms. On average, there were about 17 children in each classroom. The teachers were provided with the unit plan (which they all participated in crafting), implementation instructions, materials (such as books and laminated images), and resource lists. The teachers were given full flexibility to add and/or modify activities and materials if deemed needed.

The most critical changes to each unit were made following Version 1 testing. For instance, initially the units were designed to be one-week long experiences that focus mostly on problem solving activities. However, during implementation of Unit 2, in which a character asked the children for help in getting a ring out of a block of ice, one of the developer teachers realized the need for background science experiences on properties of ice and water, and the processes of melting and freezing, prior to implementing the problem-solving activities in the classroom. The teacher then planned and taught some science activities, and in her feedback form she included additional pre-unit activities that covered the science concepts required for that unit. The teacher commented:

> I spanned this curriculum over two weeks so we could focus on the properties of water and how it can change specifically from water to ice and back again. The children were allowed to play with colored ice cubes and watch as they melted. We had daily conversations about what would make it melt faster and why. We also discussed how they would work as the children were drawing out their solutions. I think it worked out well that the children were engaged in this conversation throughout the unit so that when they came up with a solution that was based on prior knowledge and they were able to come up with great solutions.

As a result of this successful experience, the curriculum development team revised all units to become two part experiences, with the first half of each unit covering the science concepts related to the second half's problem-solving activities. Another suggestion was made to add images to the provided science vocabulary signs (such as water and the ice) for a more engaging and inclusive learning experience.

Initial units in this round called for using a character puppet named "Mr. Problemo" (modeled after a popular character on a U.S. children's television show) to introduce the problems to the children. However, during implementation of the unit the teachers suggested using a character that the children will be more excited about. Many of them had replaced Mr. Problemo with other story-book and television characters familiar to the children. One of the teachers commented:

> Instead of using a puppet and naming it Mr. Problemo we used a stuffed Pete the Cat since the children were already familiar with him and we had done a week of Pete the Cat books a few weeks prior. They seemed to respond very well and loved that he was back in our classroom.

In the later revision, the curriculum development team introduced a character called Problem Panda, who was introduced to the children in a laminated picture of real panda bear. The character presents a problem and asks for the help of the children in solving it in each unit.

Version 2: Tester Teacher Group 2

Twenty teachers (in 10 classrooms) participated in the testing of the revised units. As in Round 1 with the developer teachers (DTG), these tester teachers (TTG2) were also given full flexibility to add and/or modify the unit activities and materials.

The units were further revised based on the feedback obtained from the tester teachers. During this round, the teachers were asked to use the laminated Problem Panda as the main character in their activities. However, the teachers felt that using a more realistic looking object such as a stuffed animal or figurine would be more engaging for the students:

> Children were not interested [in the] laminated Problem Panda. We were able to get a reaction when another teacher pretended to be Problem Panda with another voice. The children enjoyed when Problem Panda introduced his four friends.

In the later revisions, the curriculum development team had introduced a stuffed toy to represent Problem Panda. Only moderate changes were made following the second testing, most of them focusing on adding books and other resources suggested by the teachers.

Version 3: Tester Teacher Group 3

The third group of 8 teachers (in 4 classrooms; TTG 3) was asked to test all 8 units in sequence. A new version of the feedback survey was created to be used by these teachers, asking teachers about the clarity of instructions and observed student outcomes. The teachers were instructed to follow the unit plans exactly as written and provide feedback. The reasoning for this request was that the team wanted to test the usability and feasibility of the curriculum as it was, as well as the clarity of instructions. New questions were added to the survey to obtain feedback on: 1) how well the unit and its activities met the learning objectives mentioned in the unit plan and, 2) ways in which the team can help teachers improve the teaching of this unit (e.g., teacher training, example videos).

The feedback from version 3 tester teachers was shared with the developer teachers and the advisory board to decide on further revisions to the curriculum. For instance, in a unit about the five senses, an activity calls for reading the book to introduce the concept of blindness to children. One teacher commented:

> My children listened to the story well and focused, but I do not think they understood the picture and blind connection. We decided to play a trust fall game where the children had to use their other senses while their eyes where closed to attempt to feel what it is like for a blind person.

In the revision, the curriculum development team included instructions to invite the children to try on blindfolds and conduct different tasks to experience what it feels like to lose their sense of sight for better understanding of the concepts.

Version 4: Research Team, Developer Teachers, and Advisory Board

One final curricular revision was done following the testing of the entire curriculum and based on the feedback regarding the clarity of instructions. Based on the Round 3 feedback, the developer teachers and the advisory board suggested changes including: adding icons and images to the unit plans to make them more engaging and accessible; determining a consistent structure for each engineering half of the unit; adding a script for teachers that would include specific open-ended questions; adding a unit overview; and adding a list of criteria to evaluate children's solutions.

IMPACT OF CURRICULUM DEVELOPMENT ON PARTICIPATING TEACHERS

At the conclusion of the development process, interviews were conducted with a sample of 13 Head Start preschool teachers who participated. All participating teachers were invited to be interviewed. Interviews were conducted with only those teachers who volunteered to participate. These interviews served in part as the project's formative evaluation from the perspective of the teachers, and were semi-structured in nature to better understand how teachers experienced the process and to allow issues and topics to arise that the team may not have considered previously. The interviews asked teachers to reflect on: 1) the changes to their teaching as a result of their participation; 2) what they perceived to be the essential or potential student outcomes of the curriculum; 3) any gaps they saw in the curriculum; and 4) any advice they had for other teachers who use the curriculum.

The interviews were conducted by the project evaluator. Four of the 9 interviews consisted of 2 teachers from a classroom, while the other five interviews had individual teachers participate. Two of the interviews were with developer teachers, while the other seven interviews were with tester teachers. All interviews took place at the teachers' respective schools and were video-recorded, with each interview lasting 15-20 minutes. Teachers received a copy of the interview questions before appearing on camera.

The interview data were qualitatively analyzed using an emergent thematic coding approach (Braun and Clarke, 2006). This approach allows for themes and patterns to arise based on the narratives shared by teachers in response to the interview questions. Each recorded interview was transcribed in full and de-identified. Transcripts were then reviewed to isolate teacher responses to each of the four main interview questions (changes in teaching; essential student outcomes; gaps in the curriculum; and advice to other teachers), which were then coded into categories based on the responses, until all types of responses were coded. The next section describes in more detail some of the major themes that arose from teachers' reflections.

In terms of how the curriculum development experience impacted their skills, knowledge, and teaching about STEM and engineering, teacher responses were coded into three main themes: increased knowledge of general teaching practices (5 instances), increased knowledge about the problem solving process (5 instances), and gains in general science or engineering knowledge (4 instances). Many teachers commented that their main takeaway was **learning to teach problem-solving using the engineering design process (EDP)**. For instance, one teacher stated: "I've never been taught the engineering design process… I have a lot of experience with science, with my Master's courses… but I've actually never taught the engineering design process or had my children retest and test things and improve…" Another commented: "...[Y]ou start to think of some of the topics you… [taught] before… [and] go further into it. How can we bring the engineering process into it? How can we get the children more involved?"

Other teachers stated the process **helped serve as a framework to discuss the science concepts (which some already were familiar with), to think about science in an action-oriented way**, rather than about 'something that sits on a table'. For example: "…[I]t gave us a procedure to follow to teach the curriculum instead of just putting everything out and say[ing], 'This week we are studying plants and seeds.' It actually gave us steps to follow and teach them."

Teachers also commented that they **learned to incorporate more hands-on activities**, which engaged the children: "It wasn't just pictures or the books, but it was also having that kind of hands-on activities and the children really enjoyed that." One also stated she learned the power of **open-ended questioning** to encourage further student thinking: "It has given me a great insight on how to ask questions to children, how to keep them thinking; it has really helped [me] grow over this last year using it."

More generally, teachers also stated that, in the process of preparing to teach the topics to the children, they **increased their own knowledge and vocabulary about the science topics covered as well as about the steps in the engineering problem-solving process**.

> "[I learned to use]… a lot of the vocabulary, you know, just relating back to the [problem-solving] process."
> "I definitely learned some things too. I definitely learned things about shadows and different topics of study."

Similarly, analysis of researcher notes from informal discussions with the developer and tester teachers during routine classroom visits found changes in teachers' expectations related to children's abilities. Several teachers reported being 'astonished' at the creative ideas children proposed to the problem. Teachers reported being skeptical at first, however adjusted their expectations once they saw children's ideas and solutions.

In terms of essential student outcomes, teacher responses were categorized into the following six themes: student knowledge of the problem solving process (7 instances), student engagement (4 instances), student use of vocabulary (4 instances), student attitude changes (3 instances), student career awareness (2 instances), and student collaboration (2 instances). In terms of gaps in the curriculum, teacher responses were categorized into four main issues: accessibility of materials to three-year-olds or dual language children (6 instances), lack of materials (3 instances), sequence of curriculum units (1 instance), and finding time to do the activities (1 instance). Finally, in terms of advice to other teachers, teacher responses were coded into two main categories: remember about the potential to reuse and adapt the curriculum after participation in the project (5 instances) and suggestions for teacher disposition/attitudes when starting to teach the curriculum (e.g., "have fun with it", "be patient", "try to hold your opinion"; 5 instances).

DISCUSSION

This paper detailed the development process of an early childhood problem-based STEM curriculum. The curriculum was developed to address the lack of high quality STEM curriculum for preschool classrooms. The partnership created between the curriculum development team and preschool teachers from the Worcester Head Start program reflects one of the tenets of using a participatory curriculum design approach. The diversity of expertise, a shared goal, and mutual respect that each member had for others on the team enabled the creation of innovative units. The iterative process of testing-feedback-revision-testing resulted in a high-quality curriculum that has been recently piloted in additional preschool classrooms to assess the potential impacts of the curriculum on teacher and student outcomes (Sibuma et al., 2018).

Our results suggest that the teachers who participated in the iterative development process increased their perceived self-efficacy in STEM pedagogy at the end of their involvement. Specifically, interview data suggested that the experience helped teachers expand their knowledge about science concepts, understand the engineering design process, and apply this process in guiding children to solve problems during the school day. According to

Bandura's social cognitive theory (1997), self-efficacy is the belief about one's own capability to perform a task. Research has shown that high teacher self-efficacy has been associated with more willingness to try new techniques, student motivation, and greater enthusiasm and commitment for the teaching profession (Henson, 2001; Rodríguez et al., 2014; Tschannen-Moran and Hoy, 2002). Teachers also reported a change in their teaching practice, such as how to ask children questions that promote critical thinking. A contributing factor to this change was the teachers' observation of their students' growth in their classroom. Teachers who reported being skeptical about teaching STEM and problem solving to young children realized that the children enjoyed solving problems, learned the vocabulary, and followed the process to solve problems in the class. Teacher attitudes towards STEM have been positively correlated with their STEM classroom practices (Thibaut, et al., 2018). Specifically, research has shown that participation in teacher professional development was positively associated with teacher efficacy (Ross and Bruce, 2007) and attitudes towards STEM teaching principles (Thibaut, et al., 2018).

Limitations

As the interviews asked teachers to share their own perceived changes to their STEM knowledge and instructional behavior, observational analyses of classroom activity videos are being considered to verify changes to practice as expressed by the teachers. As is, we acknowledge that the data reported here are not empirical, but are based on individual reflections on the experience. In addition, although the team observed and heard similar feedback during the course of development, the interview data relied solely on teachers who self-selected to be interviewed and was not necessarily representative of the full range of experiences.

The positive outcomes of the curriculum development process, which includes the professional development of the teachers, went beyond the walls of the classroom. Several developer teachers have joined the curriculum development team in presenting the project at professional conferences and conducted professional development to a new group of teachers who implemented the curriculum. Teachers also expressed interest in sharing the importance of STEM with other preschool teachers.

Findings from the current project suggest that STEM curricula that are developed using an iterative participatory design approach may positively impact preschool teachers' self-efficacy and knowledge in teaching STEM and engineering topics. More research is needed in order to determine what and how specific parts of the collaboration in the participatory curriculum design process contributes to increased teacher self-efficacy and knowledge.

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Coding and Computational Thinking in Early Childhood: The Impact of ScratchJr in Europe

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ABSTRACT

In recent years, there has been an increased effort to introduce coding and computational thinking in early childhood education. In accordance with the international trend, programming has become an increasingly growing focus in European education. With over 9.5 million iOS downloads, ScratchJr is the most popular freely available introductory programming language for young children (ages 5-7). This paper provides an overview of ScratchJr, and the powerful ideas from computer science it is designed to teach. In addition, data analytics are presented to show trends of usage in Europe and and how it compares to the rest of the world. Data reveals that countries with robust computer science initiatives such as the UK and the Nordic countries have high usage of ScratchJr.

Keywords: early childhood, programming, computational thinking

INTRODUCTION

The idea of introducing computer programming in the classroom dates back from the late 60s'. At that time, Seymour Papert and colleagues at MIT developed the first programming language designed for children, LOGO. Using a simple textual language, children could type commands for a "turtle", so she could move around and draw geometrical shapes by dragging a pen (Papert, 1980). LOGO's popularity grew all over the world and new versions of LOGO were implemented in more than a dozen spoken languages on a variety of machines (The Logo Foundation, 2015).

However, although LOGO pioneered the growing trend of programming languages for children, Papert saw its greatest potential as an incubator of powerful ideas (Papert, 2000). That is, as a tool to engage children in new ways of thinking and "thinking about thinking" (Papert, 2005). Papert strongly believed in Constructionism, his philosophy of education that argued the power of programming languages became most salient when they provided opportunities for supporting the design and making of personally meaningful computationally-rich projects that invited children to think in new ways (Papert, 1980).

Programming provides an opportunity to engage in logical and abstract thinking, problem solving and the creative design process. In the last decade, new programming languages inspired by LOGO and Constructionism were developed. One of the most popular ones is Scratch (Resnick et. al, 2009), first released in 2007 and available for free, developed by Mitchel Resnick – Papert's disciple. Scratch was designed for children 8 years old and beyond, and provides an icon-based friendly interface, so children can create their own stories, animations and games. Furthermore, in the era of social media, once children create their projects with Scratch they can share them on-line with a community of peers that invites re-mixing. Today, over 29 million projects have been shared on the Scratch website (scratch.mit.edu) and the number keeps growing every day.

Scratch was designed following a "low floors, high ceilings, and wide walls" metaphor (Resnick, 2009). That is, it provides easy ways for novices to get started (low floor), ways for them to work on increasingly sophisticated projects over time (high ceiling) and multiple pathways for engagement for all children with diverse interests (wide walls). However, although the walls are wide, Scratch assumes children have a basic knowledge of reading and writing (programming blocks have words associated with their actions), as well as the ability to manage complexity and the almost infinite possibility of commands. When children are younger than 8 years old, they tend to not have the developmental maturity to use Scratch as they are faced with too many options and too many words.

ScratchJr was created to address this problem. It has even wider walls because it not only engages children with a variety of personal interests, but also with diverse developmental stages (Bers and Resnick, 2015). ScratchJr is a free digital coding playground that introduces powerful ideas of computer science into early childhood education (Bers, 2018b). Just like in the playground, children can choose different activities to do and use their imagination while making projects they care about. In addition, they develop abstract, sequential thinking and problem solving strategies while engaging in computational thinking.

This paper describes ScratchJr, and the decisions made in the early design stages to support young children to become programmers, presents examples of curricular innovations and materials developed for ScratchJr and provides overall analytics data regarding ScratchJr's use in the world, with a focus on Europe.

THE CONTEXT: POLICY CHANGES ABOUT COMPUTER SCIENCE EDUCATION

Along with the design of new programming languages for children, such as ScratchJr, research and policy changes all over the world brought a newfound focus to coding starting in early childhood (Sesame Workshop, 2009; Barron, et al. 2011; International Society for Technology in Education (ISTE), 2007; NAEYC and Fred Rogers Center for Early Learning and Children's Media, 2012; U.S. Department of Education, 2010; K-12 CS framework, https://k12cs.org/). Most of these changes were triggered by the need to educate the workforce of the future automated economy and by the realization that industry was in need of tech savvy workers. For example, the U.S. Bureau of Labor Statistics predicts that employment in information technology occupations will grow 12.5% from 2014 to 2024 (Fayer et al., 2017).

In the US, the "Computer Science for All" initiative was launched to bring programming into every single educational level (Smith, 2016). In Europe, as of the writing of this paper, 16 countries integrate coding in the curriculum at the national, regional, or local level, including: Austria, Bulgaria, the Czech Republic, Denmark, Estonia, France, Hungary, Ireland, Israel, Lithuania, Malta, Spain, Poland, Portugal, Slovakia, and the UK (Balanskat and Engelhardt, 2014; European Schoolnet, 2015; Livingstone, 2012; Bocconi et. al, 2016). Widespread resources are now available in Europe through the European Coding Initiative's resource website, or 'all you need is {C<3DE}', which is akin to the United States' Code.org site (see: allyouneediscode.eu and code.org).

Outside of Europe, countries such as Australia, Singapore, and Malaysia have also established policies and frameworks for introducing computer programming in K-12 education (Australian Curriculum and Assessment Authority, 2015; Digital News Asia, 2015; Malaysia Digital Economy Corporation, 2016; Siu and Mei, 2003). In Argentina, the Ministry of Education's training courses in computational thinking and programming reached more than 10,000 teachers during its first launch (Code.org, 2017) and similar experiences happened in Chile through the Kodea Foundation. Developing countries, such as Ghana, are also introducing coding through non-profit organizations like the Ghana Code Club (Nguyen, 2016).

According to the non-profit organization Code.org, which encourages schools all over the world to adopt programming curricula and promote broad participation in computer science, "The Hour of Code" initiative has surpassed 500 million students served, reaching one out of every 10 students on the planet. This is the largest education campaign in history (Code.org, 2017). However, historically, education campaigns have served a larger role than fulfilling the workforce's demands. They educate the future citizenry of a country. The use of literacy campaigns that mobilize people and resources on a large scale is a long-established practice. H. S. Bhola traces literacy campaigns back to the Protestant Reformation in Europe in the early 1500s (Bhola, 1997). Often, these literacy campaigns supported social, economic, cultural and political reform or transformation. In the 1970s, mass adult literacy campaigns were commonly initiated by governments following liberation wars with a revolutionary or decolonization agenda (Bhola, 1984).

As more people learn to code and computer programming departs the exclusive domain of computer science and becomes central to other professions and to new ways of thinking, coding takes on the civic dimension of literacy (Bers, 2018a). When developing ScratchJr, the goal was to design an introductory programming language not to prepare students for computer science degrees and careers (due to the shortage of programmers and software developers in the industry), but to provide them with the intellectual tools to serve a role in civic society. Coding is more than a technical skill; it is a way to achieve literacy in the 21st century, like reading and writing.

Figure 1. This image shows the programming app interface

Learning to code engages children in new ways of thinking that some researchers have called computational thinking (Wing, 2006; Barr and Stephenson, 2011; International Society for Technology Education and The Computer Science Teachers Association, 2011; Lee et al. 2011). This involves a range of analytical mental tools that are inherent to the field of computer science, including thinking recursively, applying abstraction when figuring out a complex task, and using heuristic reasoning to discover a solution. These mental tools are universally applicable (Wing, 2011). Therefore, they can be taught, not only through Computer Science courses, but in an integrated way with other curricular disciplines at school and from an early age.

Research shows that both from an economic and a developmental standpoint, educational interventions that begin in early childhood have lower costs and durable effects (Cunha and Heckman, 2007). While most nation-wide coding initiatives started targeting older children, there are recent endeavors focusing on early childhood. In Europe, countries such as the United Kingdom have adapted their curriculum to include coding, beginning in early childhood. In Asia, Singapore launched the nationwide PlayMaker initiative that brings robotics, amongst other coding technologies, into early childhood classrooms (Digital News Asia, 2015; Sullivan and Bers, 2017).

However, if the introduction of coding is going to start early, there is a need of technologies and pedagogical approaches that are developmentally appropriate and that take into consideration the cognitive maturity and abilities of young children (Bers, 2018b). ScratchJr was born out of that need.

SCRATCHJR: A DIGITAL PLAYGROUND FOR CODING

ScratchJr is freely available and can be downloaded for use on several platforms including iOS, Android, Amazon tablets, and Chromebooks which are rapidly growing in popularity (Leidl et al., 2017). As of February, 2018, there are over 9.5 million iOS downloads of ScratchJr with an average of 104,000 active users each week and over 20 million projects created. Volunteers from around the world have helped translate ScratchJr into 12 languages.

ScratchJr was developed out of a three-year research grant from the National Science Foundation (DRL-1118664), as a collaboration between the DevTech Research Group at Tufts University, the MIT Lifelong Kindergarten Group, and the Playful Invention Company, and is currently financially supported by the Scratch Foundation. It was released in 2014 and since then its user based has continuously grown (Bers and Resnick, 2015).

Used in classrooms and homes worldwide, ScratchJr enables children, who might or might not know how to read, to create interactive stories and games by snapping together graphical programming blocks. As shown in Figure 1, the ScratchJr interface allows children to use blocks that control motion, looks, sound, character communication, and more (Bers, 2018b).

ScratchJr has a palette of programming blocks, a user's library of projects, a main project editor, and tools for selecting and drawing characters and background graphics. Children drag blocks from the palette into the scripting area and then snap them together to create programs that are read and played from left to right. The programming blocks are organized into six categories represented by different colors: yellow Trigger blocks, blue Motion blocks, purple Looks blocks, green Sound blocks, orange Control flow blocks, and red End blocks. When put together as a jigsaw puzzle, these programming blocks allow children to control their character's actions on the screen. The programming blocks span concepts from simple sequencing of motions to more complex control structures.

ScratchJr's design features support problem solving by reducing unnecessary low-level cognitive burdens. These design decisions keep the challenge at an appropriate level and may help young children devote sufficient cognitive resources to the many high-level thinking processes involved in imagining and creating a program.

ScratchJr has a feature called "the grid" that overlays the animation stage (see Figure 2). It can be toggled on and off, and is most helpful when used during programming (as opposed to when presenting a project). The grid

Figure 2. This image shows the different ways to program motion using the grid

was designed to help children understand the units of measurement for each programming block for linear movement. The grid is similar to the upper right quadrant of the Cartesian coordinate system, with discrete rather than continuous units of measure. Its numbered axes prompt counting and provide a marker to track counting.

Several design decisions were made for seamless integration with literacy. The ability to create up to four independent "pages" and to integrate text and speech into a project allows children to create their own storybooks with a beginning, middle, and end.

The design and development process of ScratchJr started by observing how young children used Scratch (www.scratch.mit.edu), designed for older children 8 and up, and noting their difficulties (Flannery et al., 2013). For example, we noted that children were getting lost with so many possibilities for programing commands. Thus, we simplified the programming blocks options and offered a more limited programming palette. We also noticed that movement happened too fast and children had a difficult time understanding the relationship between the programming blocks and their resulting actions. We decided to slow down processes, so every block would take time before the triggering of the action.

We worked with hundreds of teachers and children through informal afterschool sessions, educator workshops, experimental classroom interventions, and at-home play sessions. Additionally, we conducted online surveys and face-to-face focus groups to obtain feedback. These provided valuable insights for our design team.

SCRATCHJR'S DESIGN PRINCIPLES

I. Inspired by Bers framework that describes how new technologies for children can become "playgrounds" that encourage open-ended exploration, creativity, imagination and social interactions, as well as skill building, mastering and problem solving (Bers, 2018b), ScratchJr was designed as a digital playground for coding. At the playground, children are exposed to diverse activities to choose from. They can go to the sand box, the swing, the slide, or just run around. They can play with sticks, ride their bikes, or create fantasy worlds. Similarly, while using ScratchJr, children can engage in all kinds of activities beyond coding. They can create and modify characters in the paint editor, record their own voices and sounds, and even insert photos of themselves using the paint editor's camera option. And, of course, they can incorporate those media rich materials into their projects to personalize them. Furthermore, what is unique about a coding playground such as ScratchJr, in contrast to a multimedia creation tool, is that children encounter powerful ideas from computer science when programming their games, animations or stories.

ScratchJr was designed to support children in engaging with seven powerful ideas of computer science that are developmentally appropriate for young children (Bers, 2018b): algorithms, modularity, control structures, representation, hardware/software, design process, and debugging (see **Table 1**). These ideas are aligned with educational computer science frameworks utilized in schools, such as the K-12 Computer Science Framework, the CSTA K-12 Computer Science Standards, and the ISTE Standards for Computer Science Educators.

Table 1. Powerful Ideas from Computer Science and Connections to ScratchJr

Powerful Idea	Definition	Early Childhood Connections	ScratchJr Application
Algorithm	A series of ordered instructional steps taken in a sequence to solve a problem or achieve an end goal.	Understanding abstraction and sequencing.	When children put together the colorful ScratchJr programming blocks in a logical order and create a sequence of actions (a script) for the chosen characters.
Modularity	The breaking down of tasks or procedures into simpler, manageable units that can be combined or re-used to create a more complex process.	Understanding that a complex task needs to be broken down into smaller tasks.	In ScratchJr, a common practice of modularity is to copy a portion of a script (coding sequence) from one character to another. For example, if a child wants to make a ScratchJr dance party featuring several characters, she can create a chunk of code for a dance move and copy it to multiple characters.
Control Structures	Control structures determine the order (or sequence) in which instructions are followed or executed within an algorithm or program. For example, repeat functions, loops, conditionals, events, and nested structures, are all control structures.	Understanding control structures requires an understanding of patterns and the concept of making decisions based on certain conditions as well as cause and effect.	In ScratchJr, children explore the concept of control structures by utilizing control flow blocks that allow them to create loops and repetitions as well as set different variables such as speed.
Representation	Programming languages represent information through the use of a symbol system. At the same time, computers store and manipulate data and values in a variety of ways. In order to be made available, this data is represented in different ways.	Understanding that concepts can be represented using symbols, and that programming languages are formal constructed symbol systems designed to communicate instructions (an algorithm) to a machine.	ScratchJr uses different forms of representations. Colorful blocks represent different types of commands. For example, blue blocks represent motion.
Hardware/Software	Computing systems need hardware and software to operate. The software provides instructions to the hardware, which might or might not be visible. Hardware and software work together as a system to accomplish tasks, such as receiving, processing, and sending information.	Understanding systems and their components, as well as the complex interplay between "instructions" (code) and "objects that receive those instructions".	ScratchJr is the software, the programming language that runs on different hardware devices.
Design process	This iterative process involves several steps: ask, imagine, plan, create, test, improve, and share. The process is open-ended, in that a problem may have many possible solutions.	Understanding that creating a final product to be shared with others involves several steps and continuing revising of the work.	In ScratchJr the design process starts when a child asks a question that gives birth to an idea and ends with creating a final project that can be shared with others. The design process makes computational thinking visible: coding becomes a tool of expression.
Debugging	Fixing problems through systematic analysis and evaluation, while developing troubleshooting strategies.	Learning how to debug is an important skill that is similar to "checking your work in math" or "editing" in literacy. It teaches the powerful lesson that things do not just happen to work on the first try, and that many iterations are usually necessary to get it right.	When using ScratchJr to create a personally meaningful program children naturally engage in debugging by fixing what doesn't work and problem solving.

TEACHING WITH SCRATCHJR

Although ScratchJr is a developmentally appropriate programing language that can be learned without knowing how to read or write, Papert warns against a "technocentric perspective" in which the technology is placed at the center of the teaching and learning process. (Papert, 1987). Therefore, in addition to designing the programming language itself, the ScratchJr team developed teaching materials to support the use of ScratchJr both at home and at school. On the ScratchJr website (scratchjr.org) one can find freely available curriculum units designed for K-2 with a focus on learning ScratchJr by making connections with other content areas such as literacy, narrative genres, and ludic experiences. In addition, ScratchJr Coding Cards (Bers and Sullivan, 2018) have recently been released. This set of cards involves three different kind of activities: off-the-screen games to help children understand the powerful ideas from computer science through unplugged experiences; on-screen activities to learn about the ScratchJr interface; and ScratchJr challenges to build skills on the different aspects of the programming language.

Figure 3. This image shows the Lunar New Year collaborative project

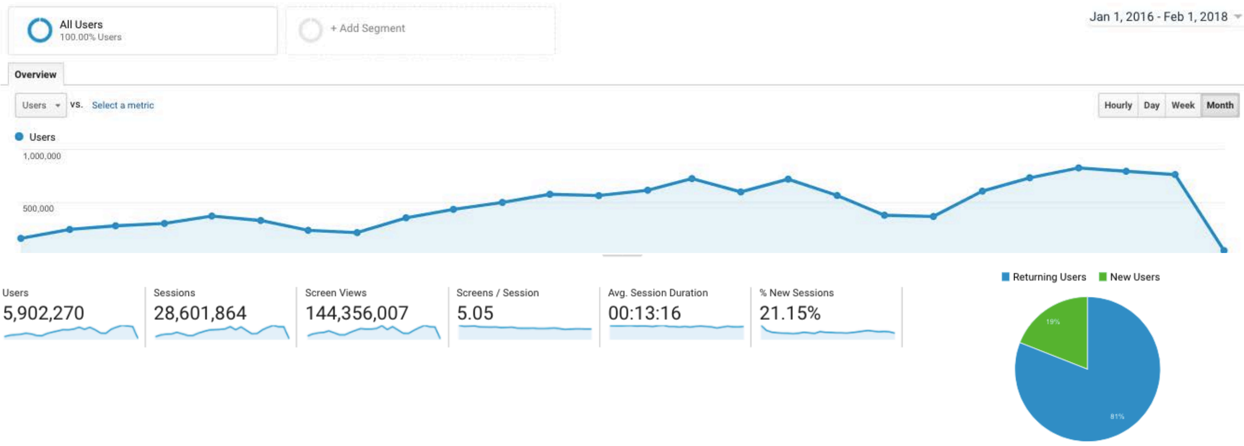


Figure 4. This image shows the Google Analytics overview

Most of the teaching resources developed by the ScratchJr team are focused on helping children engage in computational thinking by making their own personally meaningful projects. Thus, they are designed for one child with one tablet. However, this approach doesn't truly provide a "playground" experience for children. In the playground, children tend to play together. To address this issue, the DevTech research group developed the "Collaborative ScratchJr Projects Guide" to support teachers in the making of multi-tablet collaborative projects, with images and movements that can span across multiple screens and thus involve multiple children. Collaborative ScratchJr projects can have an overall theme, storyline, or learning goal and allow children to interact with the app and with each other in new, creative ways.

In **Figure 3** there is an example project that the DevTech Research Group created. The project features the Lunar New Year, a holiday that is celebrated in many Asian nations to welcome the arrival of spring. Using nine coordinated tablets, this ScratchJr project displays different parts of the festival: the blooming peach and pear flowers, the traditional Dragon Dance, and the lighting of red lanterns and firecrackers. To make this project, programmers had to work together not only through coding, but also by imagining and planning. In the ScratchJr website it is possible to find other examples of collaborative projects.

USING SCRATCHJR: ANALYTICS

Since ScratchJr's launch in 2014 the app has been downloaded over 9.5 million times and is currently being used in every country in the world (except North Korea and Western Sahara). Since January 2016, the ScratchJr team started to collect Google Analytics data to examine usage patterns. Google analytics is a free tool that allows small-to-medium organizations to collect data on user behavior by installing a "cookie" on devices that download ScratchJr. Researchers can gain access to ScratchJr user activity as it happens in real-time on the app, as well as audience demographics, acquisition, and behavior (Leidl et al., 2017).

An overview of the type of data acquired through Google Analytics can be seen in **Figure 4**. Weekly usage in **Figure 5** shows a tall peak occurring during Computer Science Education Week each year in December. Thus, this educational initiative is widely successful in promoting coding in schools. Furthermore, there tends to be a sharp decline in usage from the end of December to January, likely indicating that while students are home for winter vacation they are not using ScratchJr frequently. There is also a dip in usage during the summer months. The data indicate that ScratchJr is used mainly in school settings.

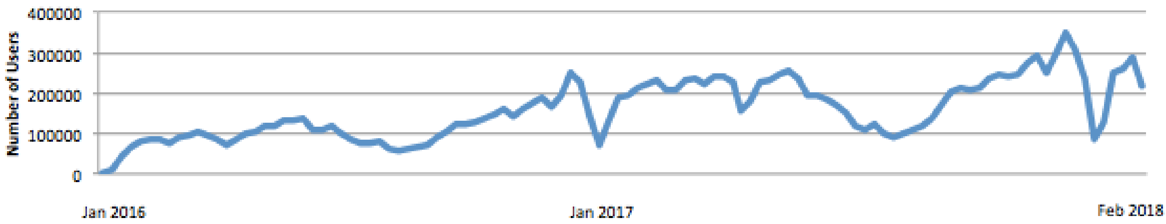


Figure 5. This line-graph shows weekly ScratchJr usage

During the two-year period from January 2016 to February 2018, over 20 million new projects were created and over 26 million existing projects were edited and revised, showing that ScratchJr users are actively working on improving and testing their programs. Of these projects, over 7 million have been created in Europe (35%) and over 9 million have been edited and revised in Europe (45%).

Furthermore, over 600,000 projects have been shared with others via email or Apple AirDrop®. Of these projects, 225,000 have been shared in Europe (38%). In this relatively short amount of time, over 406 million programming blocks have been used, the five most common blocks being "Forward," "Start on Green Flag", "Up", "Back", and "Say" and the three least common blocks being "Stop", "Start on Touch" and "Start on Message". These results from Google Analytics are consistent with previous research on coding and cognitive development (Flannery and Bers, 2013; Portelance et al., 2015). Many of the most popular blocks for children to use are the blue motion blocks, which are simple commands for children to start programming their characters. However, the least common blocks include starting a program (besides on green flag) and sending messages, which are cognitively more challenging concepts for children to grasp as they require a higher level of sequencing abilities.

The frequency of block usage in Europe reflects how ScratchJr is used internationally. The consistency among users of various continents is likely due to the fact that children tend to code in a similar manner regardless of their location, and ScratchJr's freely available curriculum shares many similarities.

Additionally, ScratchJr maintains a rate of 249,000 returning users each month, while still attaining a consistent rate of 255,000 new users each month. In Europe there is a rate of 50,000 returning users each month with 83,000 new users per month. Data usage in Europe reflects the international trend of having more new users each month than returning users thus showing that ScratchJr is a consistently growing app.

According to Google Analytics the geographical areas with the most ScratchJr usage is the "Americas" (consisting of North America, South America, Central America, and the Caribbean) with 43% of the total usage. Europe is the next continent with the most usage with 34%, followed by Asia (12%), Oceania (consisting of Australia, New Zealand, and Polynesia) (9%), and Africa (1%).

In Europe the countries with the most ScratchJr usage are the United Kingdom (40% of European usage), Sweden (10%), France (10%), Spain (7%), Italy (5%), Finland (5%), the Netherlands (4%), Poland (3%), Germany (2%), and Denmark (2%). It is important to note, however, that Google Analytics only takes into account the total number of users for each country and that the percentages are not proportional to the population of the countries.

Figure 6 provides visual data for the percentage of ScratchJr usage by each country's population. Taking population into account, the top countries using ScratchJr are Sweden (2% of the population), Finland (2%), the United Kingdom (1%), and Denmark (1%). This should come as no surprise as the UK and Nordic countries have robust initiatives to integrate coding into the curriculum.

According to EU Code Week the "British government wants to ensure that all pupils can understand and apply the fundamental principles and concepts of computer science." Furthermore, coding in the UK is seen as a means of creative thinking, not just filling an industry gap. In primary schools 5-7 year olds learn what algorithms are and how they are executed on digital devices, as well as about creating and debugging programs as well as using logical reasoning to predict the outcome of a script (EU Code Week 2014). In Denmark and Sweden the concepts of Computational Thinking are taught to children including abstraction and debugging as well as digital citizenship. In Finland algorithmic thinking plays a role, however it is introduced mainly in mathematics. Furthermore, Professional Development Programs in Finland and Sweden introduce primary school educators to ScratchJr (Bocconi et al., 2018).

Figure 7 shows the total ScratchJr usage in each country in Europe. Compared to the rest of the world, countries in Europe have very high ScratchJr usage. In **Figure 8** the top ten countries using ScratchJr across the world are shown. The United Kingdom is the second country in terms of usage (18% of international ScratchJr users). Other top countries include Sweden (5%), France (4%), and Spain (3%).

ScratchJr usage in Europe based on day of the week and month reflects international trends. In **Figure 9** the ScratchJr usage in Europe based on day of the week is shown. The most popular days of the week are Friday and Thursday, with the least popular being Saturday and Sunday. **Figure 10** visualizes the ScratchJr usage in Europe

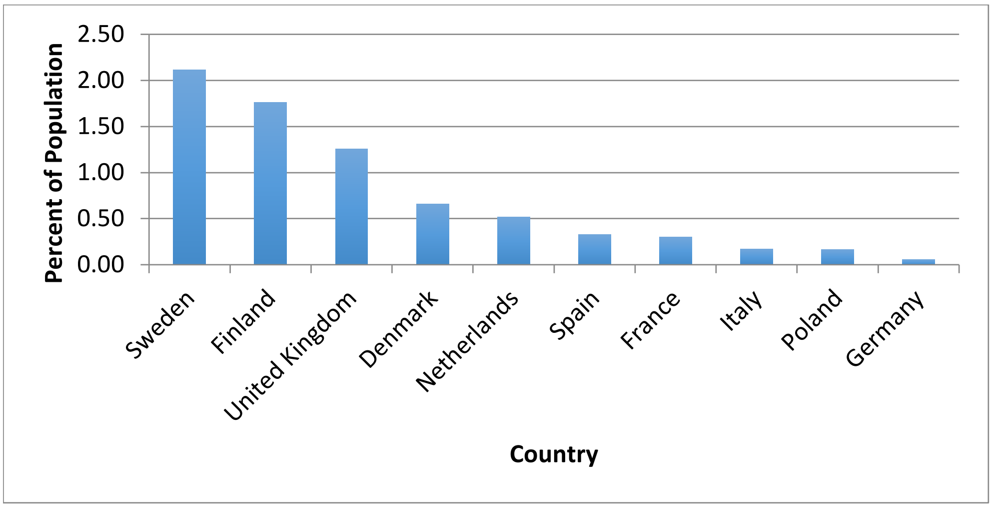


Figure 6. This chart shows the percentage of the population using ScratchJr

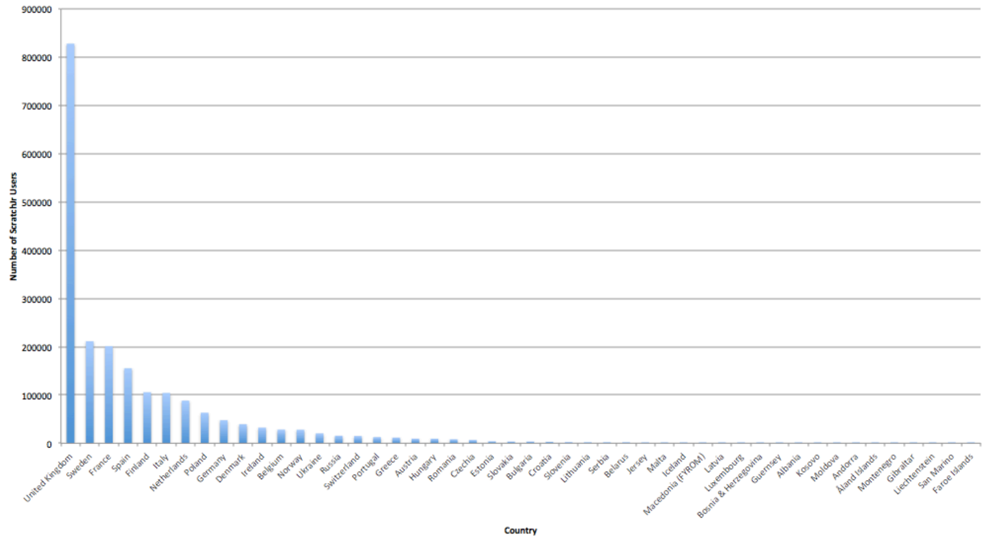


Figure 7. ScratchJr users for each country in Europe

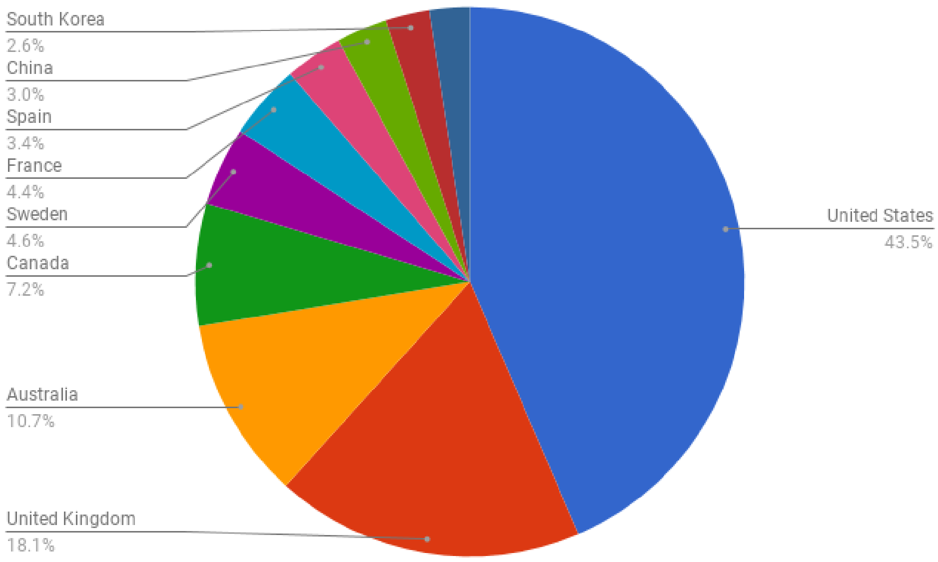


Figure 8. The top 10 countries in the world using ScratchJr

by month of the year. The most active months are November and December while the least active are July and August, vacation time. The increase in December is most likely due to Computer Science Education week initiatives.

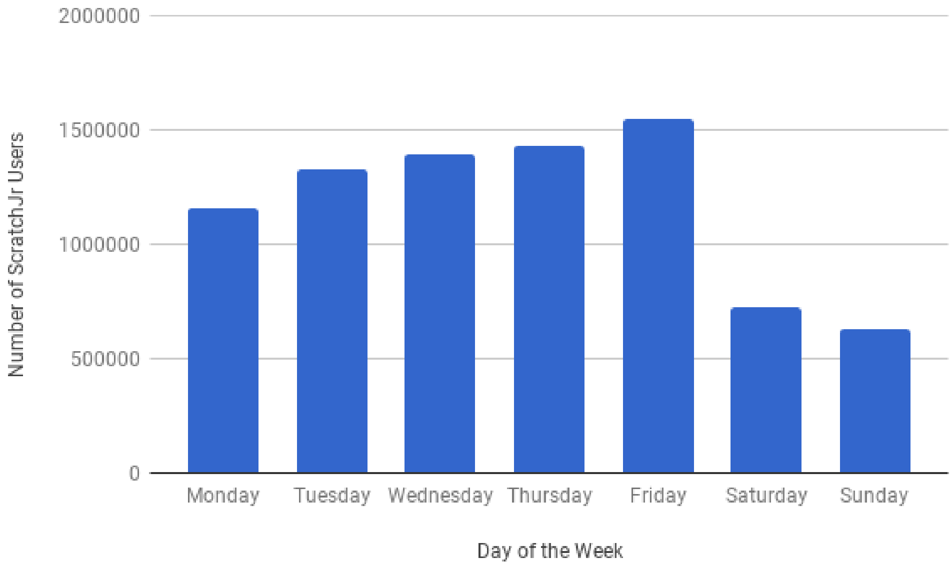


Figure 9. Shows the number of ScratchJr users in Europe by day of the week

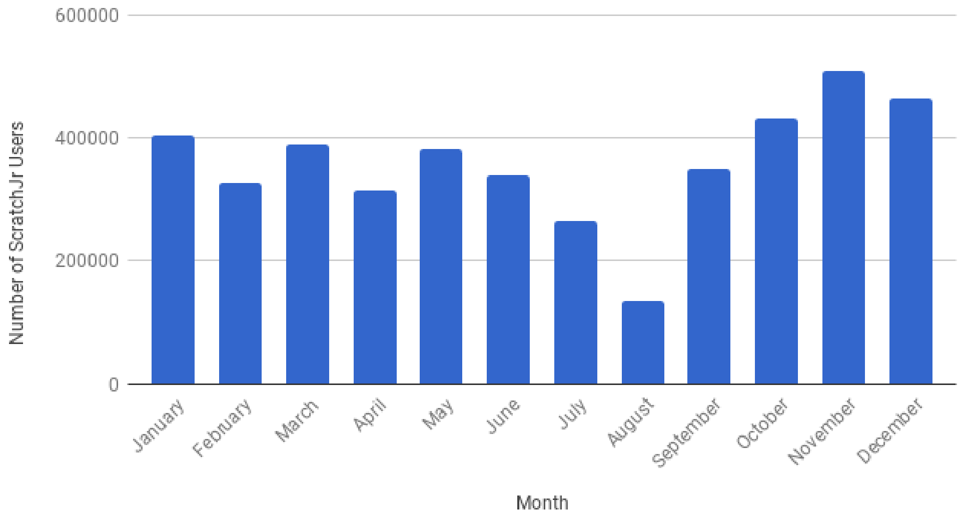
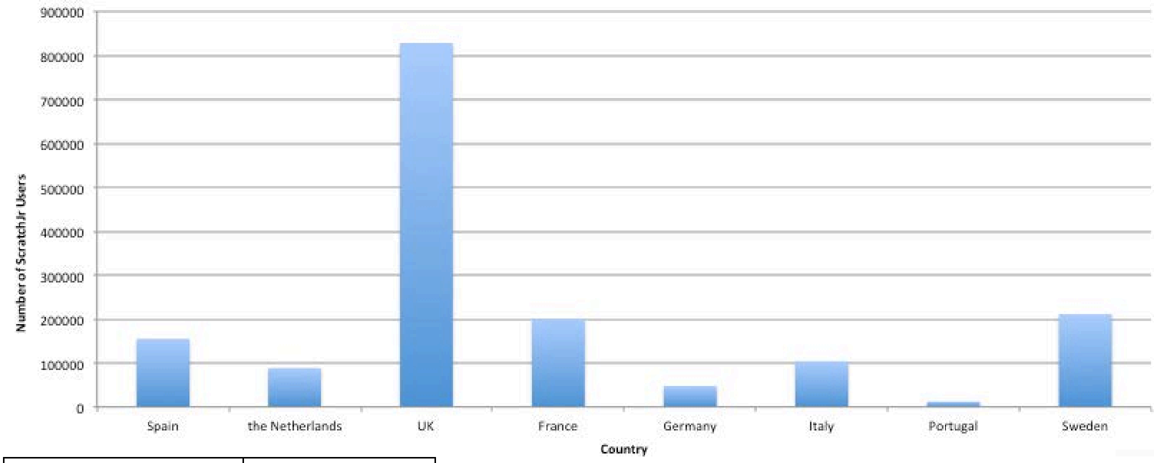


Figure 10. Shows the number of ScratchJr Users in Europe by month

Google Analytics tracks language by recording a user's language setting from their browser using ISO codes. Percentages reflect the proportion of devices registered with a particular language with all registered languages. The most popular registered languages in Europe are:

1. English-Great Britain (32%)
2. Swedish-Sweden (8%)
3. French-France (7%)
4. Spanish-Spain (4%)
5. English-US (4%)
6. Finnish-Finland (4%)
7. Italian-Italy (3%)
8. Dutch-Netherlands (3%)
9. Polish-Poland (2%)
10. German-Germany (1%)

The ScratchJr team places a priority on trying to support language localization. Therefore, ScratchJr volunteers from around the globe use Transifex, a web-based translation platform, to translate the ScratchJr app and website. Volunteers can request to localize in a certain language and are added to that team's page. They can then translate strings, a sequence of text, for the app and website. For the website, volunteers have the option of translating "live", thus seeing how their translations look on the ScratchJr webpage. After the strings are translated certain volunteers who have been promoted to reviewers look over the translations to ensure their accuracy. Currently



Language	Country
Catalan and Spanish	Spain
Dutch	the Netherlands
English	UK
French	France
German	Germany
Italian	Italy
Portugese	Portugal
Swedish	Sweden

Figure 11. The number of ScratchJr users in European countries with languages included in ScratchJr app

ScratchJr is translated into Catalan, Chinese, Dutch, French, English, German, Italian, Japanese, Portugese, Spanish, Swedish, and Thai. Eighteen additional languages are currently being translated to be included in future updates. One caveat to language translation is that only languages that are written left-to-right can be included. Right-to-left languages such as Hebrew and Arabic cannot be translated for ScratchJr because of how the app was initially configured. In addition to the ScratchJr app and website, the Official ScratchJr Book, written by Dr. Marina Umaschi Bers and Dr. Mitchel Resnick (Bers and Resnick, 2015), has been translated into Dutch, Swedish, Korean, Chinese, French, Turkish, Polish, Chinese, and Spanish.

Of the twelve languages that the ScratchJr app supports, ten are the primary language spoken by countries in Europe. **Figure 11** shows the ScratchJr usage in these ten countries (Spain includes both Spanish and Catalan). The relationship between translated language and ScratchJr usage is two-fold. Many of the languages that are included in the latest ScratchJr update are from countries which showed high ScratchJr usage before the translated version of the app was introduced. Having a high demand for translation encourages volunteers to translate ScratchJr into their language of origin.

CONCLUSIONS

In accordance with the international growing trend, the teaching of coding is becoming an increasingly important focus in European education. This paper describes ScratchJr, the most popular programming language for early childhood, and presents an overview of how it is being used in Europe. The paper shows that European usage trends are in alignment with the rest of the world in terms of coding patterns and daily and monthly usage. For example, students in Europe are more likely to use ScratchJr during the school week than the weekend, showing that the app is used heavily in educational settings. Furthermore, countries with stronger policies regarding the teaching of computer science, such as the UK and the Nordic countries, show higher usage.

Additionally, of the twelve languages that the ScratchJr app supports, ten are the primary languages spoken in European countries. Future work will focus on expansive localization and translation initiatives, informed by the analytics data.

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Promoting Positive Technological Development in a Kindergarten Makerspace: A Qualitative Case Study

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ABSTRACT

As education communities grow more interested in STEM (science, technology, engineering, and mathematics), schools have integrated more technology and engineering opportunities into their curricula. Makerspaces for all ages have emerged as a way to support STEM learning through creativity, community building, and hands-on learning. However, little research has evaluated the learning that happens in these spaces, especially in young children. One framework that has been used successfully as an evaluative tool in informal and technology-rich learning spaces is Positive Technological Development (PTD). PTD is an educational framework that describes positive behaviors children exhibit while engaging in digital learning experiences. In this exploratory case study, researchers observed children in a makerspace to determine whether the environment (the space and teachers) contributed to children's Positive Technological Development. N = 20 children and teachers from a Kindergarten classroom were observed over 6 hours as they engaged in makerspace activities. The children's activity, teacher's facilitation, and the physical space were evaluated for alignment with the PTD framework. Results reveal that children showed high overall PTD engagement, and that teachers and the space supported children's learning in complementary aspects of PTD. Recommendations for practitioners hoping to design and implement a young children's makerspace are discussed.

Keywords: learning environments, makerspaces, positive technological development, early childhood STEM

INTRODUCTION

In the US and abroad, formal and informal learning spaces are becoming progressively more technology-rich and oriented toward STEM (science, technology, engineering, and mathematics) learning and 21st century skills development (Bellanca, 2010; Breiner et al., 2012; Burke, 2014; Chang et al., 2015; National Research Council, 2013). As digitally-enriched learning approaches become more prevalent in education, schools are investing more money into dedicated STEM learning spaces and classrooms (Wang et al., 2016). It is urgent to understand the learning benefits of these novel learning spaces and materials. New advances in educational research have identified computational thinking practices, 21st century skills, and technological literacy as content-specific learning outcomes that students are developing in these new learning environments (Bers, 2018; Bellanca, 2010; Bybee, 2000; Dakers, 2006). However, in addition to STEM content knowledge, research emphasizes the importance of developing character skills associated with this pedagogical shift towards technology integration, including collaborative problem-solving, design and inquiry cycles, and STEM identity development (Bers, 2012; Minner et al., 2012; Sullivan, 2016). Digital citizenship learning frameworks such as Ribble's Nine Elements of Digital Citizenship focus on teaching children to collaborate, communicate, and learn safely through technology, and to responsibly deal with ethical technology issues such as cyber bullying and protecting private information (Hollandsworth et al., 2011; Ribble, 2015). Traditional intervention methods struggle to capture the richness and complexity of the in-situ, learner-driven, collaborative learning experiences that characterize informal STEM pedagogies (Allen and Fraser, 2007; National Research Council, 2009).

Particularly in informal learning settings, such as home, after-school, and makerspace environments, the benefits of STEM engagement are often intangible and difficult to measure (Allen and Fraser, 2007; Cox, 2013; National Research Council, 2009). Consequently, despite the importance of social and emotional experiences in informal STEM education, there is limited empirical research about the impact of technology-rich learning environments on children's psychosocial development. This is especially concerning in early childhood (ages 4-8 years) where interdisciplinary and experiential STEM activities are pivotal to children's socioemotional growth, as children are already forming identities and potentially harmful stereotypes about STEM disciplines (Kuhn et al., 1978; Metz, 2007; Signorella et al., 1993; Steele, 1997; Sullivan, 2016). This paper seeks to address this gap in the literature, by investigating the positive character outcomes of Kindergarten children (aged 5-7 years) as they engaged in technology-enriched learning activities within an early childhood makerspace. The study uses the lens of Positive Technological Development (PTD), a pedagogical framework that describes developmentally appropriate experiences that young children can have when using technology (Bers, 2012).

In the following sections, we will summarize relevant research on STEM education in early childhood and the PTD framework. Following this, we describe the current study which examined one Kindergarten classroom of $n = 17$ students and $n = 3$ teachers during their visits to an early childhood makerspace. Specifically, this study asks the following research questions: 1) *How did Kindergarten children in a makerspace engage in the different kinds of behaviors described by Bers' (2012) PTD framework*, and 2) *Which elements of the learning environment specifically supported children's PTD.* Researchers measured the frequency of children's positive behaviors and interactions (such as collaboration and creativity) by using an evaluative tool rooted in the PTD framework. Results from these evaluations and ethnographic observations were analyzed to determine the PTD alignment of the children, teachers, and the physical space. Limitations of the current study and recommendations for future work will be discussed. The paper will conclude with a reflection about the impact of this work for the field of informal STEM education in the early childhood years.

LITERATURE REVIEW

In this section, we first summarize relevant research on informal STEM learning for supporting cognitive and psychosocial development in young children and discuss theoretical underpinnings for pursuing this work. We then describe the PTD framework for designing positive experiences with technology in early childhood to support children's interpersonal and intrapersonal development. Finally, we describe promising findings from research on PTD in a variety of learning settings and connect findings to the current research question on children's PTD in makerspaces.

The Role of Technology in Young Children's Psychosocial Development

Advancing STEM education, particularly the emergent sub-domain of technology, has grown into an international topic (Becker and Park, 2011; Bybee, 2010; Marginson et al., 2013). Education researchers argue persuasively that technological fluency and digital literacy are critical for children's 21st century readiness (Bellanca, 2010; Clements and Samara, 2003; Yelland, 2005). However, some worry that rapid innovation is outpacing our ability to understand the risks of these new technologies, and that children's technological fluency will come at the cost of their psychosocial development (the development of social patterns and individual thoughts and behaviors) (Alliance for Childhood, 2000; Armstrong and Casement, 2000; Turkle, 2016). In a survey of 3,377 US parents, participants reported that they are concerned with their children's technology use and that they actively seek ways to help children use digital media to support psychosocial development, particularly in areas of integrity and communication (Common Sense Media, 2017, p. 7).

Although these are valid concerns, empirical research shows that young children do engage in rich social experiences through digital media. This modern debate about the safety of computer technology echoes similar debates about television, radio, and films earlier in the 20th century. As Wartella and Jennings (2000) point out, each wave of controversy and research surrounding new technology eventually found that technological experiences are not created equal, and children can gain social and cognitive advantages from quality interactive technologies. Research has shown that young children can make social, emotional, and cognitive developmental gains by engaging with certain computer technologies (Bers, 2012; Clements and Samara, 2003; Scardamalia and Bereiter, 1993; Sullivan and Bers, 2016; Yelland, 2005). Many studies involving screen-based technologies have shown the potential to enhance 4- and 5-year-old children's self-reflection, science inquiry, creativity, peer-to-peer socialization, and verbal conversation (Clements and Sarama, 2003; Flether-Flinn and Gravatt, 1995; Yelland, 2005). Bers suggests that the best way to foster these kinds of healthy experiences with technologies is to consider the context and purpose of technology exposure and connect to other domains and activities that are healthy for children (Bers, 2012). For example, screen-free coding tools like the KIBO robotics kit can engage children in physical coding activities that foster gross-motor coordination, and open-ended tools like the ScratchJr programming environment can present coding as an expressive medium to promote story-telling and artistic development (Bers, 2018; Pea and Kurland, 1984; Resnick, 2006; Wyeth, 2008).

Recently, work on educational technology has focused on informal learning environments as promising spaces for supporting learners' personal and social growth through novel STEM experiences (Honey and Kanter, 2013; Bers, Strawhacker, and Vizner, 2018; Syvertsen and Pigozzi, 2010). For example, makerspaces, often located in schools and libraries, are collaborative workspaces with a variety of novel and traditional building tools (e.g. 3D printers, laser cutters, woodworking equipment), that allow learners to work on personally meaningful projects within a community of peers and mentors (Honey and Kanter, 2013). Developmentally appropriate environments, collaborative technology arrangements, and support resources (e.g. staff people, reference materials) are all design elements of a learning space that can maximize children's positive interactions with novel digital tools (Antle and Wise, 2013; Bers, 2012; Bers et al., 2018; Syvertsen and Pigozzi, 2010). Makerspaces have been identified as community spaces that can support apprentice-mentor relationships, promote democratization of knowledge, and foster community engagement (Blikstein and Worsley, 2014; Kafai, Peppler, and Chapman, 2009; Rajala 2016; Sheridan et al., 2014). This is because makerspaces are designed to allow a variety of experimental and learner-driven approaches to design-oriented tasks with novel tools, so they welcome a diversity of learning styles while also supporting conventional engineering and technologist practices (Kafai et al., 2009; Syvertsen and Pigozzi, 2010). This distributed expertise across all members of the group (rather than just one educator) can also address challenges of unconfident teachers who are uncertain about how to teach new technologies and skills (Bers et al., 2013; Litts, 2015). Learning theorists in the Vygotskian tradition would call makerspaces sites of sociocultural learning, since they foster a community of individuals with shared interests, whose relationships evolve over time as they each pursue diverse expertise (Cole, 1996; Lave and Wenger, 1991; Lemke, 2001; Leontiev, 1978; Vygotsky, 1963). In other words, makerspaces can support interpersonal and intrapersonal development, providing children opportunities to cultivate a strong personal identity through building, maintaining, and leading their community. In this study, we investigate the affordances of a makerspace for supporting children's psychosocial development and measure their developmental outcomes through the lens of the PTD framework, described in the next section.

Positive Technological Development (PTD)

Positive Technological Development is a framework to evaluate the learning that happens in informal learning environments, when children engage in digital experiences (Bers, 2012). PTD is rooted in Seymour Papert's pioneering work on Constructionism, a theoretical approach concerned with the unique meta-cognitive learning opportunities afforded by computer programming (Papert, 1980). Papert argued that when children code, they create digital "microworlds," or virtual spaces where they have programmed all the rules and behaviors in that world. When creating (and testing, and breaking) these programmatic rules, children can learn about how the real world works, and also about their own thinking processes (Papert, 1980). PTD also draws on research from the field of Positive Youth Development, which focuses on how to foster positive and pro-social developmental outcomes in children and young adults (Lerner et al., 2003). The purpose of the PTD framework is to apply development science to inform our understanding of how children can "use technology to make positive contributions to the development of self and of society" (Bers et al., 2009, pg. 22). In practice, PTD serves as a flexible, interventionist framework for educators to design and evaluate curriculum in a variety of early childhood settings to support children's positive engagement with digital experiences and for designers of technologies to develop positive technical affordances. In the current study, PTD was used to guide the design of the makerspace where the study took place (Bers et al., 2018) as well as the observational data collection measures. The six behaviors of the PTD framework, or the "6 Cs" are the main constructs of interest (Bers, 2012). In the next section, each of these six aspects of PTD is described in detail.

PTD is evidenced by six positive behaviors that children exhibit when engaging in developmentally appropriate digital explorations (Bers, 2012). These include three intrapersonal skills of content creation, creativity, and choices of conduct, and three interpersonal skills of communication, collaboration, and community building (see **Figure 1**) (Bers et al., 2009). PTD behaviors are evidence that children are developing positive character assets and can be supported by technology-rich classroom activities.

Intrapersonal skills in PTD are related to a child's self-regulation and personal growth (Bers, 2012). By engaging deeply with expressive technologies and media, children can engage in rich personal exploration. Content creation is a child's ability to fluently use tools and materials to create new artifacts or meaningfully alter existing ones. This

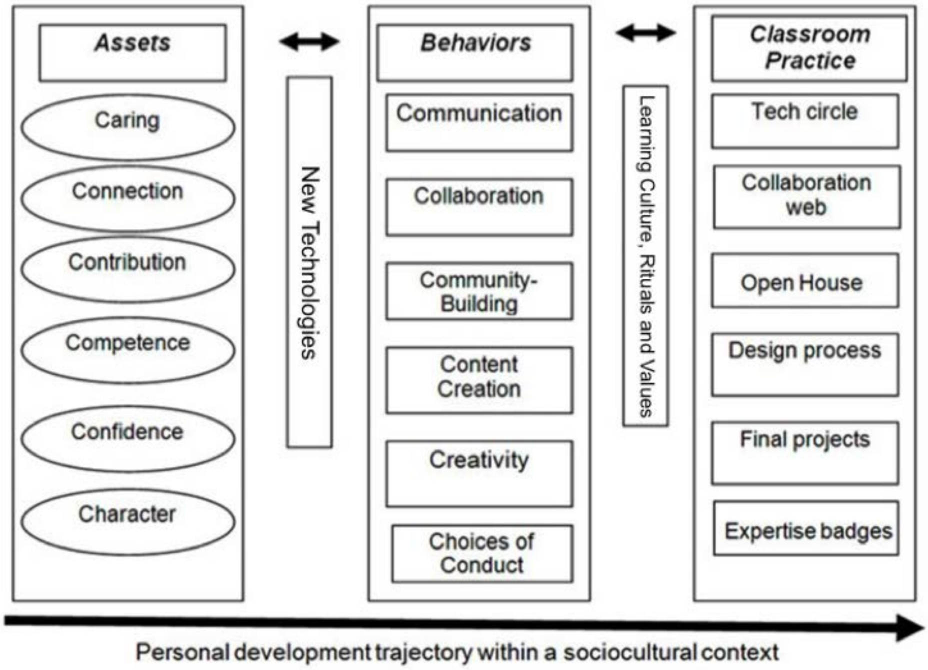

Figure 1. The Positive Technological Development Framework. The PTD behaviors (center column) are rooted in character assets of Positive Youth Development (left) and can be supported by positive classroom practices with technologies (right) (reproduced with author permission from Bers, 2012)

skill is related closely to a child's sense of competence, or their ability to persevere towards their goals by engaging in a design process (Bers, 2012). Creativity refers to a child's flexibility, imagination, and interpretive skill. Creativity is evident when a child has confidence in her own ideas and believes that her perspective is worth expressing through her created work (Pugnali et al., 2017). Choices of conduct relate to a child's personal sense of morality, typically exhibited through their decision making. This skill is correlated with the development of character (Bers et al., 2009). Children who demonstrate strong and consistent choices of conduct often cultivate technological expertise and digital literacy through their dedication and hard work (Kazakoff, 2014).

The interpersonal skills relate to children's ability to cultivate relationships and emotional connection with others. PTD advocates for a technological landscape with diverse communication media (e.g. text, voice, image) specifically to help children forge positive connections with others. Communication refers to children's ability to share ideas and interpret the work of others and is connected to a child's sense of caring about people other than themselves. Collaboration extends shared ideas into shared action, through organized systems of coordinated design. The ability to collaborate is a key developmental milestone for young children and signifies their developing sense of mutual connection with others (Bers, 2012; Vygotsky, 1973). Finally, community building represents an integration of the other assets supported by PTD, as children can channel their personal and social skills to form caring networks of collaborators in both digital and physical spaces. Community building through technology might involve using technology to design a tool to help others, or creating and participating in a virtual community. Community building in PTD represents the child's ability to use design skills to contribute meaningfully towards the good of the community.

All of these skills combine to form children's holistic psychosocial development. The PTD framework is useful for effecting positive outcomes through technology (Bers, 2012). In the next section, we summarize research findings on the effectiveness of PTD as an interventionist framework.

Prior Research with PTD

Because it is an interventionist approach, the PTD framework has been applied to designing and evaluating curricula, environments, and technologies for children. The ScratchJr programming app (Flannery et al., 2013), the KIBO robotic kit (Sullivan et al., 2015), the ZORA Virtual World for medical communities (Bers and Cantrell, 2012), and several early childhood makerspaces (Bers et al., 2018) have all been designed with PTD constructs and recommendations in mind. It is important to consider the design of learning spaces, as spaces can impact children's learning in same way that teachers can (Bers et al., 2018; Brooks, 2011; Strong-Wilson and Ellis, 2007). Additionally, teachers face challenges of preparedness and lack of confidence when introducing new technologies (Banas, 2010; Bers et al., 2013; Mumtaz, 2000). Researchers have found that teachers can be wary of integrating new technologies into their practice and are sometimes not confident to try hands-on learning experiences with the tools themselves (Bers et al., 2013). In this study, we explore how a makerspace can support children's PTD engagement, even in ways that a teacher may not be able to.

Design elements of PTD-aligned tools and spaces include leveraging children's intuitive understanding and developing knowledge about the world, creating child-directed experiences, allowing children to learn about technology as they use it, and ensuring that the environment and context of the holistic education experience align with the goals of introducing the technology (Bers, 2012; Strawhacker et al., 2015). Tools should be responsive, with clear indicators of where to touch, and should offer creative opportunities to children to build digital artifacts of their own design (Bers, 2012). Environments should offer technologies at a child's eye-level, with room to play and space to work, and flexibility to let children shape the space to their own needs (Bers, Strawhacker, and Vizner, 2018). Tools designed with these features in mind show consistently high engagement and enthusiasm from child users (Bers and Cantrell, 2012; Bers et al., 2018; Flannery et al., 2013; Sullivan et al., 2015).

PTD is also used to evaluate learners' psychosocial outcomes. In an early study of PTD engagement in 186 adolescent youth, Bers et al. (2009) found high correlations between their PTD behaviors and students' fully developed character assets, confirming the relationship between PTD and psychosocial development. Bers et al. (2009) also recommended including ethnographic descriptions of children's behaviors, to contextualize general measures of PTD engagement. In another study researchers at a 1-week intensive summer technology workshop for young children investigated children's PTD engagement while one group used ScratchJr and another used the KIBO robot (Pugnali et al., 2017). Children demonstrated high overall engagement with PTD constructs, although ethnographic observations revealed qualitative differences in how children engaged in PTD (Pugnali et al., 2017). For example, both groups engaged in communication, but children working with the physical robotic kit were able to use visual cues (e.g. looking around the room) to get inspiration from friends or alert a teacher to off-task behavior, while children using the tablet-based ScratchJr were less likely to view each other's projects, and more likely to verbally communicate with friends for ideas or ask teachers for help.

Researchers have also explored PTD engagement in school settings. In five English-speaking schools in Singapore, 98 preschool children were assessed on their PTD engagement during a structured 7-week robotic intervention (Sullivan and Bers, 2017). Observational checklists called "PTD Checklists" were used to categorize children's behavior along 5-point Likert-style scales to determine how often they demonstrated PTD behaviors. On average, children showed high engagement in all areas of PTD except for community building and choices of conduct. The authors hypothesized that the high engagement with other aspects of PTD was related to the focus of the robotics curriculum on building and programming robotic technologies.

Purpose of the Present Study

In the current study, we depart from previous work on PTD by observing children in informal, open-ended play sessions in a makerspace rather than during structured curricular activities. The makerspace setting and technological tools available to children were all designed or selected to align with the PTD framework. The purpose of this study is to learn the affordances of the space and learning community for supporting PTD engagement. In order to capture children's PTD outcomes, we applied ethnographic methods for observing PTD (Bers et al., 2009; Sullivan et al., 2017), combined with a modified version of the PTD Checklists used by Sullivan and Bers (2017). This study addresses the following research questions:

1) How can Kindergarten children in a makerspace engage with the different aspects of Bers' (2012) PTD framework?
2) Which elements of the learning environment specifically supported children's PTD?

Question one pertains to group dynamics, and so children's behaviors were categorized with PTD checklists at the aggregate level. The average amount of PTD behaviors across all children comprised the PTD engagement of the group being observed. We hypothesized that children would engage equitably in all aspects of PTD, because the space was designed with all PTD aspects in mind. In order to address question two, the PTD checklist was modified to apply to teachers and the physical space, to capture the holistic learning environment. we hypothesized that the space would support all aspects of PTD because it was designed to align with the PTD framework, while educators might have different strengths across the aspects because people have diverse experiences that might not necessarily align with a learning framework like PTD. Further, we hypothesized that teachers would show lower engagement in aspects of creativity and content creation. This hypothesis is consistent with prior findings from teacher professional development research, which shows that teachers can be unconfident with novel technologies and hesitant to try new tools themselves (Ber et al., 2013).

METHOD

Participants

N = 20 participants (*n* = 3 teachers, *n* =17 children) from the Eliot-Pearson Children's School (EPCS) engaged in open-ended learning activities in the Early Childhood Makerspace at Eliot-Pearson. EPCS is a private, tuition-based school in Medford, MA that offers needs-based aid to eligible families according to Massachusetts state guidelines. It is also a laboratory-demonstration school affiliated with the Eliot-Pearson Department of Child Study and Human Development at Tufts University. The Children's School enrolls approximately 80 children. It has preschool through second grade classes that vary in length and frequency. The school curriculum focuses on inclusion, and the administration has a stated mission of recruiting a diverse student body that is representative of the local neighborhood and context.

Measures

Data was collected using two (2) different 18-item observational instruments called PTD checklists (See Appendix A: PTD Engagement Checklists). These two checklists are designed to capture the participant behaviors and environmental affordances of an active learning environment and categorize findings into the 6 behaviors identified by the PTD framework. The checklists used in this study are based on existing checklists (Sullivan and Bers, 2017; Pugnali et al., 2017), but refined for clarity. Additionally, the "environment checklist" was developed to capture educator and learning space affordances, whereas previous checklists had only focused on children's behavior. All items were rated on a Likert-type scale ranging from 1 (never) to 5 (always), with "not applicable" available as an option for each item. Sample items on the children's checklist included "Children iterate on projects" (content creation) and "Children engage in conversation (verbally or non-verbally) with adults" (communication). Sample items on the environment and educator checklist included "There is evidence in the space of the local location or context" (community building) and "Facilitators engage children in non-judgmental conversation about choices" (choices of conduct). Two researchers observed each of the six total sessions during the 2-week data collection period. Each researcher collected two checklist observations per group visit: one checklist for children's behaviors, and the other for the learning environment and teacher. Twenty-four total checklists were collected, representing 6 hours of observations.

Researchers also collected data in the form of video footage of all makerspace interactions, with two cameras capturing opposite angles of activity in the space. To address the small sample and enrich the quality of conclusions drawn from the data, researchers transcribed and coded interactions from all three teachers and a random selection of six children to serve as single-case study subjects (Guest et al., 2011; Saldaña, 2015). These transcripts and videos were coded using confirmatory thematic analysis to identify and code patterns of actions and behaviors that children engaged in while using technology (Guest et al., 2011). These behaviors were categorized into the research constructs of the PTD framework, with a positive or negative valence to indicate when children were exhibiting pro- or anti-construct behaviors. For example, sharing with peers was a positive valence of collaboration, while withholding materials was a negative valence. Through this hypothesis-driven coding process, researchers arrived at several case stories to contextualize and describe findings from the quantitative PTD checklist observations.

Addressing Bias

This study is a sub-project of the Making Engineering Playful in Schools project, a collaboration between the Developmental Technologies Research Group at Tufts, the Center for Engineering Education and Outreach and Tufts, and the LEGO Foundation. The current protocol for this research has been ethically approved by the Tufts University Institutional Review Board (IRB). Consent forms to have their child's data and image used for research purposes were distributed to parents through outlets in their school community, with no consequences for parents who declined consent. Since the study was also providing an educational service for the host school, the principal granted consent as the curricular custodian to allow all Kindergarten children to participate in the makerspace intervention, even if data was not being collected on their progress. This was done to avoid the ethical issue of removing a child from an educational experience freely offered at the school.

Procedure

All data was collected within the Early Childhood Makerspace at Eliot-Pearson. Although children attended sessions during the school day, their visits in the makerspace were unstructured and more like free-play time. The makerspace was designed to support PTD behaviors through its space arrangement and the technologies offered (Bers et al., 2018). There are tools and materials for children to explore large-scale and small-scale building, robotics, programming, circuitry, simple machines, and traditional arts and crafts. Additionally, the furniture is modular and movable, so children can work sitting, lying, or standing up, and can even construct new furniture out of large building kits (see **Figure 2**).

Figure 2. Children from the Eliot-Pearson Children's School engage in unstructured making at the Early Childhood Makerspace (Image reprinted with author permission from Bers et al., 2018)

The three Kindergarten teachers collaborated with researchers to plan makerspace sessions. At the teachers' recommendation, children came to the makerspace for weekly 60-minute sessions over the course of four weeks. This allowed children enough time to become deeply involved in personal making projects. Teachers recommended that children come in groups of about 5-6 so that they could engage in collaborative making experiences without being interrupted by chaotic group dynamics. They decided that each group should only come with one teacher at a time, to encourage child-directed activities. This resulted in three consistent groups (named 1, 2, and 3) that visited the space each week.

Three teachers participated in the current study. To clarify results, teachers will be referred to by the group of children that they worked with (e.g. teacher 1 worked with group 1). The teachers represented a diversity of teaching experience. Teacher 1 had over 20 years of experience working with early childhood, teacher 2 was in her first teaching year, and teacher 3 had four years of experience.

Although groups visited each week, data was only collected during the second and third weeks of makerspace visits. Researchers wanted to give children time to become accustomed to the space during the first visit, but also wanted to capture children as their making community was being formed before unseen social dynamics developed among the children and educators. The data collected represented a cross-sectional 2-week segment of each group's total makerspace activity.

Analysis

PTD Checklists were analyzed to determine children's PTD behaviors and the PTD affordances of the environment. Interrater agreement across the checklist items was sufficiently high (36 items; $\alpha = .67$) to evaluate average ratings. No items were marked "Not Observable," and there is no missing data. Due to the small sample size ($n = 17$) and the pilot-nature of the observational instruments used in this study, results were not analyzed using statistical tests. Instead, descriptive statistics were calculated from checklists. Scores from the PTD checklists were averaged and compared for trends, and compared with ethnographic observations to clarify findings.

RESULTS

In this section, statistics and trends from the PTD checklists are explored, and situated in the context of relevant observations. Researchers examined ethnographic field observations and videos of children's making activities to find examples of teachers and space supporting children's engagement in PTD behaviors. Illustrative vignettes are provided throughout to demonstrate children's activities. Results are presented in order of the research question they address. All names used are pseudonyms.

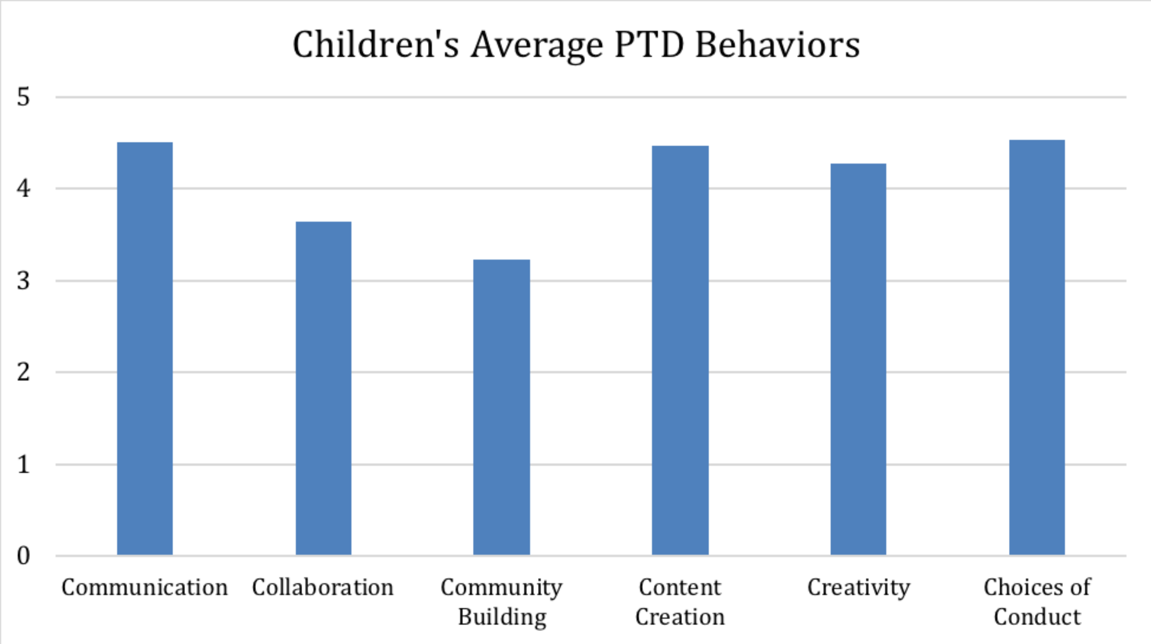

Figure 3. This chart displays the average number of times per sessions that each child displayed each of the "6 Cs" behaviors of PTD

Figure 4. A child works with a circuit set to build a "light that will stay on even when my finger isn't pushing the button

Children's PTD Engagement

This section addresses the first research question, "How can Kindergarten children in a makerspace engage with the different behaviors identified by the PTD framework?" Scores from children's PTD checklists were averaged across all child participants (see Figure 3). Children earned a score between 4 and 5 on behaviors aligned with communication, content creation, creativity, and choices of conduct, meaning they exhibited those behaviors often (4) or always (5). Children showed collaboration and community building "Sometimes". None of the behaviors earned averages of 2 (almost never) or 1 (never).

Children demonstrated deep engagement with many of the aspects of PTD. The three vignettes below describe real examples of children engaging in collaboration, content creation, and choices of conduct in the makerspace.

Collaboration. Sonya asked her teacher for help because she wanted to make a wheelchair. Teacher 3 reminded her that Tony made car during their last visit, so she might ask him. Tony began to help Sonya, saying "you have to start with four wheels." She got to work, showing him her blocks and saying "I need four wheels. Is this four?" The boy held the wheels, saying "this is how it's supposed to be" and tried to connect them. When his construction fell over, he laughed and said "sometimes it doesn't go the way you want it, so you have to be flexible." He continued screwing and unscrewing wheels onto her construction while she tied a rope to one end of her

Figure 5. Children built constructions for injured or disabled people, including crutches (foreground right) and a pull-along wheelchair (background center), while Teacher 3 (left) observes

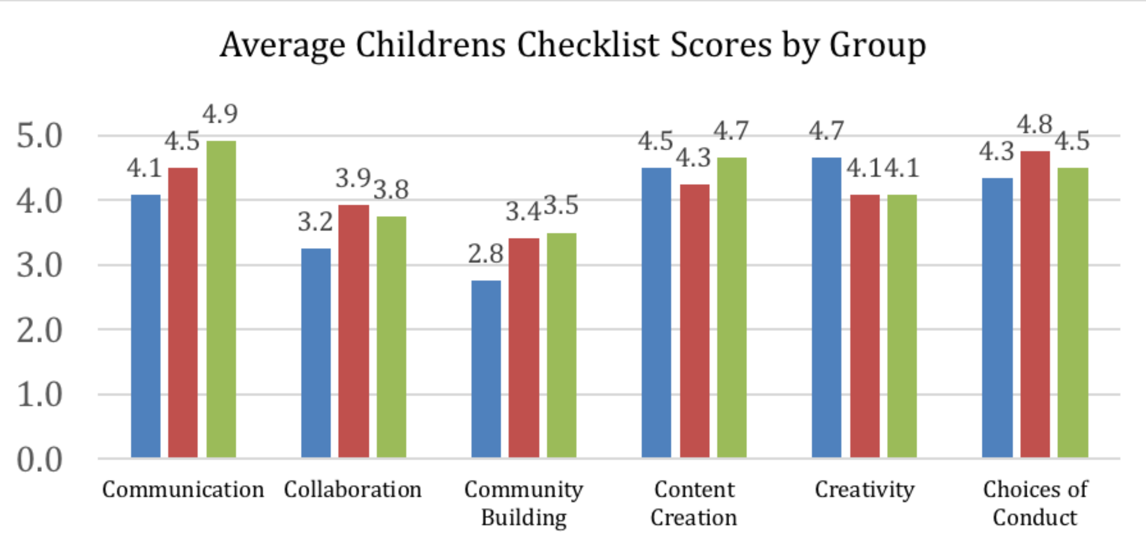

Figure 6. This chart displays the average number of times per session that separate. Group 1 is shown above in blue, group 2 is in red, and group 3 is in green

wheelchair, which she explained was there "so someone can pull it behind them." Tony and Sonya worked together toward a shared goal, to make a wheelchair, through their collaborative building.

Content Creation. A young boy named Leo became very interested in a small circuitry set (see Figure 4). He began to work alone on the kit, explaining that he loved electricity, and soon two friends were working with him. He often shouted exclamations like, "look what I made!" and "Yes! We did it!" When his teacher asked why he used a certain part in his circuit, he explained, "the switch is what I want, because then the light stays on even when my finger isn't pushing the button!" In this example, Leo was engaging deeply in content creation, as he built his circuit set to fit his goal.

Choices of Conduct. In group 3, Eloise was very curious about injuries, and frequently played make-believe games about medicine and healing. One day she decided to make crutches. Other children became curious about her crutches and after watching her work for a few minutes, another girl began to build a wheelchair (see Figure 5). While they worked, teacher 3 asked what they were building and Eloise replied, "engineers make things to help people so we are helping people also. People who can't walk might need this." Although she could have built anything, she chose to construct a helpful creation to solve a problem that someone else might have.

When it came to differences across children in separate groups, the average number of behaviors was only slightly diverse from the overall trend (see Figure 6). The similarities across groups are probably due to the fact

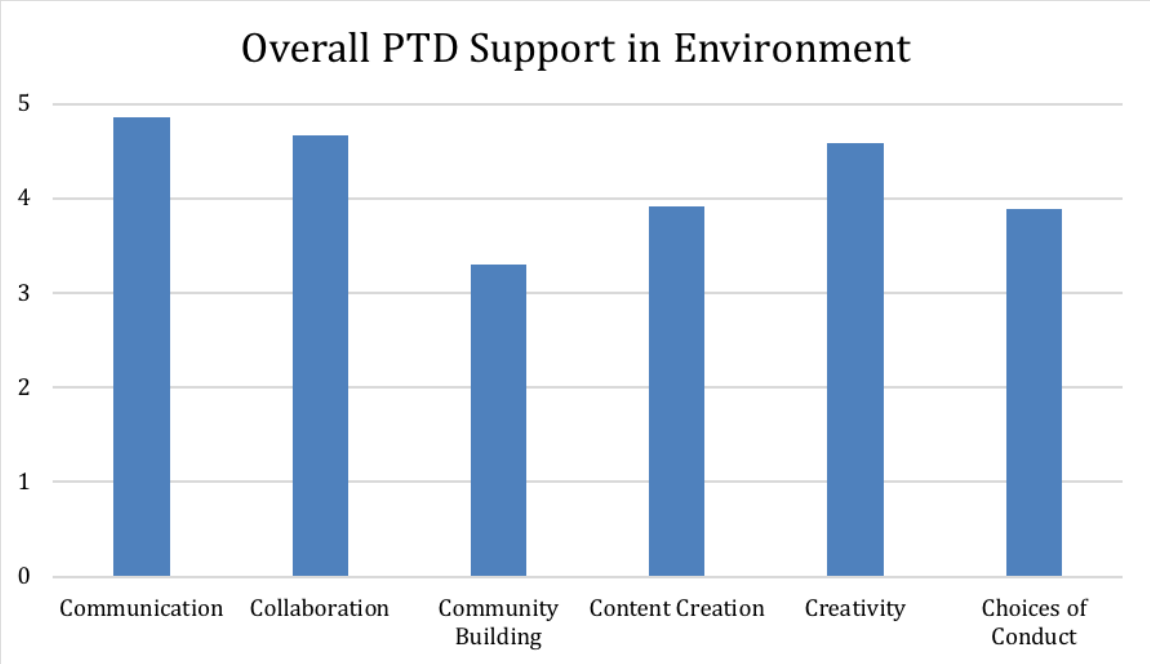

Figure 7. This chart displays the average amount of support for each of the "6 Cs" behaviors of PTD that the overall physical and teaching environment provided per session

that children all came from the same Kindergarten class and spent much of their time involved in the same instructional activities. However, there were slight differences. Group 1 showed relatively higher than average scores for creativity, but somewhat lower than average scores in all other PTD areas. This may seem surprising, since teacher 1 had much more teaching experience (over 20 years) than her teaching assistants. However, the trends in her children's behavior may be explained by the fact that she assigned herself the children who required the most specialized attention and were more demanding to work with than children in the other groups. Group 2 and group 3 were very similar in almost all behaviors, with group 3 scoring very slightly higher in communication and content creation. In general, these trends suggest that within each group, children followed the same overall trend of sometimes demonstrating collaboration and community building behaviors, and often (4) or always (5) showing the four other PTD behaviors. Although it is likely that children demonstrated similar trends because they came from the same classroom, the next section explores whether the learning environment and teachers could account for any of the variation in children's behaviors.

Environmental PTD Affordances

In this section, we turn to the second research question, "Which elements of the learning environment specifically supported children's PTD?" Scores for the amount of environmental PTD supports were averaged across all 6 sessions (see Figure 7). Observations from this checklist capture a combination of the physical environment (the room, the materials, the furniture) and the teaching environment (the teacher's behaviors and interactions with children). Overall, the physical and teaching environment always (5) or often (4) supported communication, collaboration, and creativity. Content creation and choices of conduct were often (4) or sometimes (3) supported, and community building was supported sometimes. None of the PTD aspects were "Never" or "Almost Never" supported.

The learning environment was instrumental in supporting children's PTD engagement. The three vignettes below describe real examples of teachers and the environment supporting children's communication, community building, and creativity in the makerspace.

Communication. During an early visit to the makerspace, teacher 1 prompted children to look around and record their observations before beginning to work (see Figure 8). She also remarked on their activity with comments like, "I see you are so excited about that funny robot. I wonder what you will make with it?" or "I want to know what's that in your hand. I see you are holding something, what will you make with it? What will it be?" Through her words, teacher 1 modeled for children how to observe and use descriptive words, and supported a plurality of expressive forms by allowing them to communicate their observations by speaking, writing, or drawing.

Community Building. During circle time at the end of one makerspace visit, teacher 1 asked to shake hands with girls Zoe and Hanna, saying "I want to congratulate your teamwork – so peaceful! Did you tell each other your ideas?" Zoe replied, "Yes, I said why don't we make a race car and she said why don't we make a house?" In this exchange, teacher 1 showed that in addition to the traditional teacher role of mediating social challenges, she

Figure 8. Teacher 1 asked children what they see and what they are drawing

Figure 9. Teacher 2 listened enthusiastically and asked questions while a child explained his building design to her

also rewarded social successes. By waiting until circle time, she allowed the whole group to take part in this moment of social harmony and strengthened their shared community.

Creativity. Teacher 2 observed while Louis balanced two pieces of cardboard. After looking around, he used a piece of plastic to join the two pieces. He was about to take it apart when Teacher 2 said, "Louis I had no idea you could build like that! You are so creative; do you have a plan about what you're working on?" He considered his building, and then said "no, but it's going to be a house. Look what I'm going to do next" (see Figure 9).

Teacher 2 validated Louis's building endeavor and gave him the confidence to continue with his creative exploration.

Observations from this checklist capture a combination of the physical environment (the room, the materials, the furniture) and the teaching environment (the teacher's behaviors and interactions with children). In the next sections, PTD support scores for the physical and teaching environments will be explored separately.

When it came to teachers, all three showed high support for PTD behaviors (see Figure 10). Checklist scores revealed that all three teachers always (5) or often (4) supported all aspects of PTD, with the exception of content creation. All three teachers only sometimes supported this behavior.

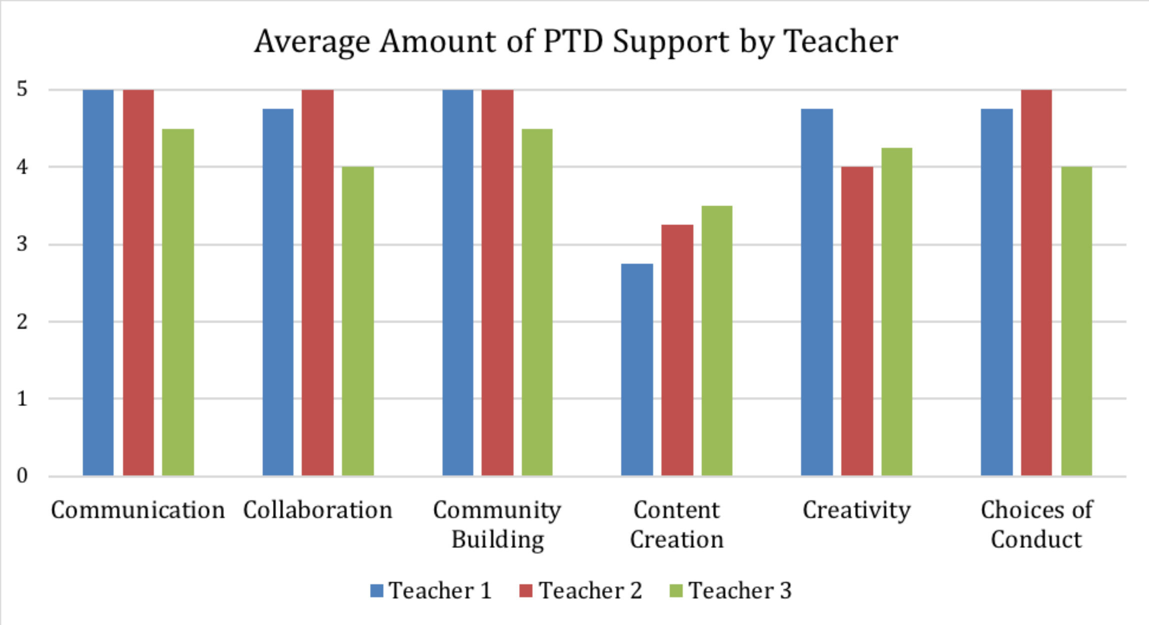

Figure 10. This chart displays the average amount of support for each of the "6 Cs" behaviors of PTD that each teacher provided per session

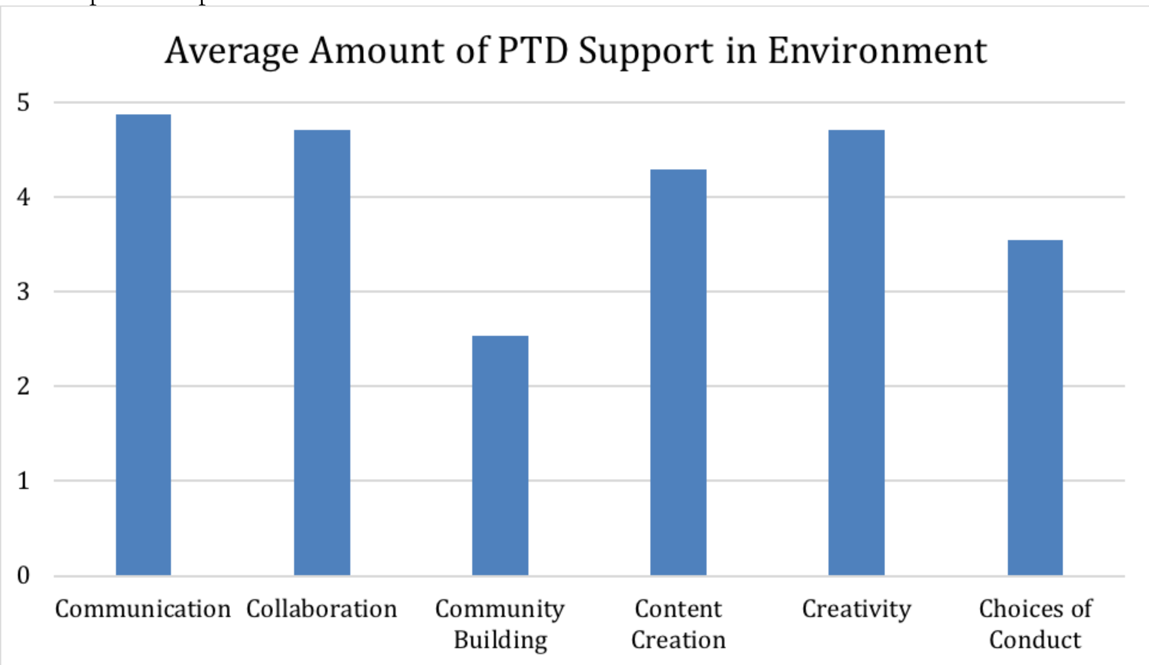

Figure 11. This chart displays the average amount of support for each of the "6 Cs" behaviors of PTD that the physical environment offered

When it came to the physical environment, the space afforded many opportunities for PTD engagement (see **Figure 11**). The materials and furnishings often (4) or always (5) supported communication, collaboration, content creation, and creativity among children. The physical space sometimes (3) or often (4) supported children to make positive choices of conduct. The space was less supportive of community building behaviors, with community-building décor and materials evident only sometimes (3) or almost never (2).

Overall PTD Engagement

Taken together, the findings reflect a few overall trends. **Figure 12** shows a visual representation of the relationships among the environment, the teachers, and the children across each aspect of PTD. In general, there was moderate-to-high PTD support in the environment and from teachers, which corresponded with moderate-to-high PTD engagement from children. Specifically, Teachers (represented in red) showed the highest support for choices of conduct and community building, over and above what the environment supported. The environment (shown in green) afforded the most opportunities for creativity and content creation, even beyond teacher support. Finally, although children (shown in blue) experienced high support for all aspects of PTD from

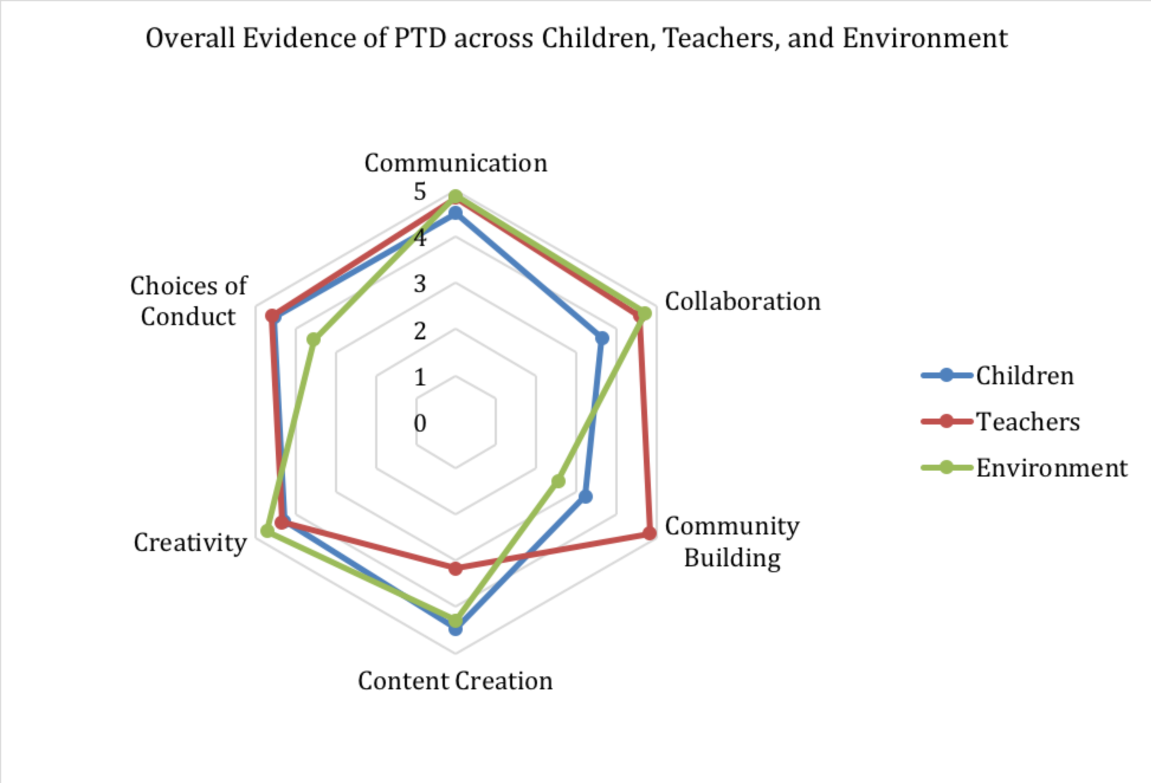

Figure 12. This chart represents relationships among children, teachers, and the environment across all dimentions of PTD

either teachers, the environment, or both, children still showed somewhat less evidence of collaboration and community building compared to other behaviors. In the next section, we explore possible explanations for these relationships.

DISCUSSION

Summary of Findings

In this study, we sought to address findings related to the following research questions:

1) How can Kindergarten children in a makerspace engage with the different aspects of Bers' (2012) PTD framework?
2) Which elements of the learning environment specifically supported children's PTD?

Regarding question 1, we hypothesized that children would engage in all aspects of PTD equally. In fact, we found that children engaged in most PTD aspects, but showed somewhat less evidence of collaboration and community building. For question 2, we hypothesized that the space would support all aspects of PTD. Contrary to our hypothesis, the space demonstrated support in most areas except for community building. We hypothesized that educators might show diverse levels of support for different aspects of PTD, but in fact all three educators supported the different aspects of PTD in similar amounts to each other. Finally, we hypothesized that teachers would show lower support of creativity and content creation, based on prior research that teachers can be unconfident and hesitant when using new technologies (Bers et al., 2013). Although all three teachers showed relatively low support for content creation, they were highly supportive of children's creativity. We've synthesized these findings into three core findings:

1) Children's creativity and content creation can be best supported by offering a unique and technology-rich learning environment. Results show that teachers and the environment offered plenty of opportunities for PTD engagement across most constructs, although they did not always overlap in their areas of high support. For example, the environment was more supportive of content creation and creativity than teachers were. This makes sense, since one would expect the tools and materials in the room to inspire children to build, program, and create. Still, children were able to demonstrate high engagement with most of these constructs. This finding is heartening in light of the challenges of technology integration facing teachers, because even teachers who are nervous about using technology can offer an environment that supports children in their digital creation. Additionally, this finding offers support to the claim made earlier in this paper, that a well-designed space can offer learning supports that supplement and complement what teachers can offer.

2) Children's community building and choices of conduct can be best supported by caring and responsive teachers.

As mentioned in the previous proposal, teachers and the physical environment can successfully support children's PTD engagement in complementary ways. In this sample, teachers were more supportive than the space when it came to choices of conduct and community building. This is logical because teachers are human supports, so they are naturally better able to support social and moral development. This proposal is the complement of the above point, which is that in some areas, a good teacher can provide learning supports even when they are absent in the environment.

3) Even with highly supportive teachers and physical environments, children may not be developmentally ready to engage in all aspects of PTD behaviors.

In general, students showed high PTD engagement when both teachers and the environment supported that behavior, but not always. For example, despite strong support from teachers and the environment, children were not often observed in spontaneous collaboration. Further, those children who did regularly collaborate were often older or more socially developed than their more individualistic peers. We suggest that this finding does not reveal a problem, but instead shows the natural diversity of developmental levels in any early childhood class. Children's individual developmental rhythms are highly variable (Phillips and Shonkoff, 2000). From a developmental perspective, it makes sense that Positive Technological Development is also highly individual and diverse among students. In this study, most students were somewhat less inclined to collaboration, meaning that perhaps this aspect of PTD requires more social development than the typical Kindergartener possesses. As children become ready to explore this out-of-reach skill, a strong support system of educators and environment are the best preparation to help them grow (Vygotsky, 1963).

These findings are all supported by the overall trends represented in **Figure 12**. Recall that the environment and the teachers showed slight variation how they supported PTD, and that children demonstrated yet a third pattern of PTD engagement. The overlapping points on that chart suggest that in some cases, it can be enough for only one element of the learning context to support children's PTD engagement. For example, children's engagement with content creation matched the environmental support for that aspect, and the opposite was true for choices of conduct, where child behaviors were more closely aligned with the amount of teacher support. In contrast, children's engagement with community building was somewhere between the amount of support from the environment and the teachers, indicating that children may need more support in this aspect than others. Finally, despite high support for collaboration from teachers and the learning environment, children still showed slightly less engagement, suggesting that children are still developing readiness for this aspect. These findings shed light on the nuanced and complex relationship among children and the many aspects of their learning context. Practitioners and researchers alike can use the results presented here align technology-rich learning experiences with the PTD framework to best support children's psychosocial development.

LIMITATIONS AND FUTURE WORK

The primary limitation of this study is the sample size. With a sample of n = 17 children and n = 3 teachers, it was not possible to conduct statistical analyses on the quantitative checklist data. Conducting this study with a larger sample could shed light on the statistical viability and replicability of the trends observed in this pilot work. However, the small sample also allowed for rich ethnographic observations to contextualize findings, offering credibility to findings from a qualitative perspective.

The PTD checklist instruments used in this study were based on prior research, but heavily adapted for the current study, and this was the first implementation of the environment checklist. Future work should explore this pilot instrument and validate it for research purposes. Despite this limitation, findings from the checklist correspond with qualitative observations. Although it is not validated for research use yet, it is a useful tool for practice-based settings, such as classrooms and makerspaces. Currently, there are few practical tools for evaluating the developmental appropriateness of digitally-enriched or traditional learning settings (Kuh et al., 2013; Olds, 2001). These checklists may be useful for educators and curriculum developers who hope to determine the PTD-alignment of their teachers and learning space.

Additionally, researchers might want to articulate broadly-applicable recommendations for designing spaces to support each of the 6 Cs of the PTD framework. Currently, these recommendations exist for designing tools and lesson activities. Given the findings in this study about the importance of space in shaping the learning experience. Specific strategies should be developed to guide the development of learning spaces, particularly informal spaces where there are relatively fewer policy-level standards and recommendations to look to for best practices.

Finally, future work could apply this study method to a variety of learning settings. The current setting was designed with PTD in mind, but the vast majority of learning spaces (especially in public schools) are not. Many informal afterschool clubs and extracurricular activities are held in whatever space is available, even in janitor's closets and auditoriums. In order to determine the impact of space on learning, it would be beneficial to compare results from these kinds of spaces, to determine how best to overcome deficits in the learning environment and still support children's PTD engagement.

CONCLUSION

As demonstrated through this ethnographic study of an informal early childhood makerspace, the learning environment plays a critical role in supporting children's positive technological development. Children in this study demonstrated high engagement across PTD behaviors, with somewhat lower evidence of collaboration. Teachers and the physical learning environment worked in complementary ways to support children's PTD engagement, overlapping in key areas of communication and collaboration. Teachers showed better ability to support social aspects of PTD, and the environment was better able to support content creation and creativity. Kindergarten children are experiencing transitional stages of development. Still, teachers in this study clearly felt that it was important to "stack the odds" by proving the best possible opportunities to engage in positive growth behaviors. It makes sense that children's learning environments, too, should be equally intentional and supportive of children's developing skills.

As new technologies and learning approaches develop and schools and informal spaces seek to keep pace with the future of education, it is important to remember the human element of learning. Digital experiences need to support children in character, moral, social, and emotional growth as well as cognitive learning experiences. Tools that narrowly support one domain or skill (sometimes called "drill and repeat" or "edutainment" tools) can lead educators to distrust new learning technologies (Banas, 2010; Bers et al., 2013; Mumtaz, 2000). However, the tenets of Positive Technological Development remind us that we do not need to choose between healthy development and technology-rich learning. Instead, it is up to researchers, policy makers, and practitioners to make choices that forefront developmentally appropriate tools and spaces, so that children reach their developmental needs by using technology and not by avoiding it. Actions like observing children while they use technology to understand their PTD engagement and designing technology-rich spaces and teaching interventions to fit the PTD framework, are the first steps to ensuring that children are engaging in positive development through technology.

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APPENDIX A

Positive Technological Development (PTD) Engagement Checklist: Environment & Facilitator

What is the Checklist?

The PTD Engagement Checklist is based on the theoretical foundation of Positive Technological Development (PTD). The PTD framework guides the development, implementation and evaluation of educational programs that use new technologies to promote learning as an aspect of positive youth development. The PTD framework is a natural extension of the computer literacy and the technological fluency movements that have influenced the world of education, but adds psychosocial and ethical components to the cognitive ones. From a theoretical perspective, PTD is an interdisciplinary approach that integrates ideas from the fields of computer-mediated communication, computer-supported collaborative learning, and the Constructionist theory of learning developed by Seymour Papert (1993), and views them in light of research in applied development science and positive youth development.

As a theoretical framework, PTD proposes six positive behaviors (six C's) that should be supported by educational programs that use new technologies and innovations, such as the Eliot-Pearson Maker Space. These behaviors are: communication, collaboration, community building, content creation, creativity, and choice of conduct.

More information about PTD can be found in Marina Umaschi Bers' book Designing Digital Experiences for Positive Youth Development: From Playpen to Playground (2012).

How is the Checklist used?

The PTD Engagement Checklist is designed for use in a variety of settings where children are engaging with technology. It is divided into six sections (each one representing a behavior described in the PTD framework) and measured using a 5-point Likert scale. The checklist is meant to evaluate a learning environment and teacher/facilitator while children are working within the space. Adults may use the checklist as often as multiple times during each lesson, or as infrequently as once per unit. The goal of the PTD checklist is to provide a lens into how children are engaging with the space and experimenting with the behaviors described by the PTD framework.

On a scale from 1 to 5 (with 1 = Never and 5 =Always), how often do students do the following? Please select one.	1 Never	2 Almost Never	3 Some-times	4 Often	5 Always	N/A or Not Observable
Communication						
The arrangement of the space allows for children to see one another's work. *- There are low or no barriers between activity spaces*						
The arrangement of the space allows for children to talk with one another. *- Workspaces are arranged so that children can facing one another* *- Children in different areas communicate at normal volume*						
The Facilitator(s) is engaging children in two-way conversations *- Facilitator asks children open-ended questions* *- Facilitator pauses to let children respond*						
Comments:						
Collaboration						
The arrangement of the space promotes sharing of tools/materials. *- Materials are arranged in a central area for children to use and return* *- Tools are not designed for one child to use alone (e.g. heavy blocks that need two people, tools with many parts or steps)*						
The arrangement of the space allows for multiple children to work on one project. *- Workspaces include large floor areas, round tables with multiple chairs, etc.*						
Facilitator invites children to work together *- Facilitator suggests that children seek help from peers*						
Comments:						

On a scale from 1 to 5 (with 1 = Never and 5 =Always), how often do students do the following?	1 Never	2 Almost Never	3 Some-times	4 Often	5 Always	N/A or Not Observable
Community Building						
There is evidence in the space of the children who use it *- There are images of children using the space* *- There are objects labeled with the maker's name, or the story of how it was made*						
There is evidence in the space of the local location or context *- There are images, maps, etc that reference the neighborhood, school, or town where the space is located* *- There is material representing holidays, seasons, or activities of the local culture*						
The Facilitator has a warm and friendly relationship with children *- Facilitator carries personal conversations with children (e.g. asking a student about their new pet)* *- Facilitator provides support and encouragement as children work*						
Comments:						
Content Creation						
Tools and materials are visible and accessible to children *- Materials are in clear containers, low baskets, or presented on tables* *- Materials are stored at children's height and can be easily reached*						
There are locations in the space to present or document children's work. *- There are pictures and explanations of children's work* *- There is a space for ongoing work to stay*						
Facilitator models content creation *- Facilitator works on projects alongside children, or assists when asked* *- Facilitator shares mistakes openly and models how to cope with them*						
Comments:						

On a scale from 1 to 5 (with 1 = Never and 5 =Always), how often do students do the following?	1 Never	2 Almost Never	3 Some-times	4 Often	5 Always	N/A or Not Observable
Creativity						
There are areas and materials within the space that encourage wonder *- There are beautiful, colorful, or textured objects clearly located around the room* *- There are spaces for children that are cozy, soft, or private*						
Materials/Tools are presented that can be used in more than one way *- There are bins of miscellaneous crafts* *- There is evidence of the same material/tool being used in many ways*						
Facilitator encourages a diversity of approaches in children's work *- Facilitator models using criteria to compare work (e.g. "I see that this method is more X, but your other idea is more Y")* *- Facilitator allows children to change ideas as they work*						
Comments:						
Choice of Conduct						
Tools/materials are offered that require children to use with care *- Materials and containers that are breakable or delicate* *- Tools that have sharp edges, or require focused attention to use*						
There is evidence in the space of the values of those who use it *- There projects or wall art related to value words (e.g. Respect, Caring)* *- There are rule charts or images of behavior choices*						
Facilitator engage children in non-judgmental conversation about choices *- Facilitator moderates children having a disagreement to observe and converse with each other to reach a solution* *- Facilitator reinforces children's sense of character, e.g., "You're the kind of girl who knows how to be nice to her friends"*						
Comments:						

Positive Technological Development (PTD) Engagement Checklist: Children/Child

What is the Checklist?

The PTD Engagement Checklist is based on the theoretical foundation of Positive Technological Development (PTD). The PTD framework guides the development, implementation and evaluation of educational programs that use new technologies to promote learning as an aspect of positive youth development. The PTD framework is a natural extension of the computer literacy and the technological fluency movements that have influenced the world of education but adds psychosocial and ethical components to the cognitive ones. From a theoretical perspective, PTD is an interdisciplinary approach that integrates ideas from the fields of computer-mediated communication, computer-supported collaborative learning, and the Constructionist theory of learning developed by Seymour Papert (1993), and views them in light of research in applied development science and positive youth development.

As a theoretical framework, PTD proposes six positive behaviors (six C's) that should be supported by educational programs that use new technologies and innovations, such as the Eliot-Pearson Maker Space. These behaviors are: communication, collaboration, community building, content creation, creativity, and choice of conduct.

More information about PTD can be found in Marina Umaschi Bers' book Designing Digital Experiences for Positive Youth Development: From Playpen to Playground (2012).

How is the Checklist used?

The PTD Engagement Checklist is intended to be used in a variety of settings where children are engaging with technology. It is divided into six sections (each one representing a behavior described in the PTD framework) and measured using a 5-point Likert scale. The checklist is meant to evaluate a group of children or an individual child they work in a space. Adults may use the checklist as often as multiple times during each lesson, or as infrequently as once per unit. The goal of the PTD checklist is to provide a lens into how children are engaging with the space and experimenting with the behaviors described by the PTD framework.

On a scale from 1 to 5 (with 1 = Never and 5 =Always), how often do students do the following? Please select one.	**1 Never**	**2 Almost Never**	**3 Some-times**	**4 Often**	**5 Always**	**N/A or Not Observable**
Communication						
Children are observing and/or engaging each other's work *- Children watch as others work on a project* *- Children touch or play with each other's projects while they work*						
Children are playing with each other or talking to each other *- Children speak or sign to each other* *- Children ask each other what they are doing, request tools to be passed, etc.*						
Children engage in conversation (verbally or non-verbally) with adults *- Children speak, nod their head, etc. when adults pause to let them respond*						
Comments:						
Collaboration						
Children share tools/materials. *- Children to use materials and return them when done* *- Children do not "collect" tools that they are not using*						
Children are working together on the same project. *- Children are actively engaged in the same play/work activity* *- Children are adding elements to the same project*						
Children seek assistance from peers *- Children ask each other to hold things in place, help them move objects, etc.* *- Children make suggestions to each other, ask each other to show them how they made something, etc.*						
Comments:						

On a scale from 1 to 5 (with 1 = Never and 5 =Always), how often do students do the following? Please select one.	**1 Never**	**2 Almost Never**	**3 Some-times**	**4 Often**	**5 Always**	**N/A or Not Observable**
Community Building						
Children share work with others *- Children show work to peers or facilitators* *- Children place work on display somewhere in the space (or, they request/allow facilitators display their work)*						
Children work on projects related to their local environment *- Children make robots to help their school, plows for the winter snow in their neighborhood, etc.* *- Children read books, ask questions, or role play about local holidays, events, or locations*						
Children are warm and friendly with each other *- Children ask each other about home, or speak about each other's personal details (e.g. "I saw your sister in the hallway")* *- Children laugh and play together*						
Comments:						
Content Creation						
Children gather tools and materials without much assistance *- Children reach for crafts or turn on computers without needing help* *- Children open boxes or bring tools out on their own*						
Children show focus and sustained attention while working *- Children build a tower, color and craft a flower, program a story* *- Children work steadily on this project over several minutes,*						
Children iterate on projects *- Children return to projects again and again, over one or more sessions* *- Children change their artifacts without starting a new one*						
Comments:						

On a scale from 1 to 5 (with 1 = Never and 5 =Always), how often do students do the following?	**1 Never**	**2 Almost Never**	**3 Some-times**	**4 Often**	**5 Always**	**N/A or Not Observable**
Creativity						
Children are observing, touching, or manipulating objects in the space *- Children run their fingers over a plush cushion or hold glass beads up to the light* *- Children comment about the properties of an object (e.g. "this wood is rough")*						
Children use a variety of materials while they work *- Children use wires, glitter, and cloth in a collage* *- Children mix materials from different areas (e.g. blocks with crafts)*						
Children try a variety of approaches in the same task *- Children try tape, paper clips, and hot glue guns to attach paper* *- Children try building a tower on a table, a chair, and a cushion*						
Comments:						
Choice of Conduct						
Children handle tools/materials with care *- Children carefully hold/use scissors, glass, etc.* *- Children return dangerous tools safely after using them.*						
Children show respect to the space *- Children clean up materials after they are done working* *- Children use furniture, technology, etc. in safe ways*						
Children show respect to each other *- Children take turns, share materials, and give each other space* *- Children show signs of character (e.g. hugging someone who is crying, helping someone else clean up a mess)*						
Comments:						

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Examining Student and Teacher Talk Within Engineering Design in Kindergarten

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ABSTRACT

Quality science, technology, engineering, and mathematics (STEM) experiences during the early years provide young learners with a critical foundation for future learning and development. Engineering design is a context that can be used to facilitate connections and learning across STEM, however there is limited research examining the use of engineering design-based STEM integration within the early childhood classroom. This study examines how an engineering design-based STEM integration unit was enacted across three kindergarten classrooms. Classroom observation and video data were collected and a coding scheme was used to document the ways that engineering and engineering design were enacted as well as the role of the teacher and students within the lessons. Results suggest that kindergarten students were able to meaningfully engage in and with multiple stages of an engineering design process while also building understanding of scientists and engineers related to teacher and student interactions, there were multiple instances of student-initiated talk, student to student response, the use of explicit engineering language and of students making connections to prior learning. This suggests that the enactment of engineering design in early childhood should incorporate multiple aspects of engineering and engineering design, include interdisciplinary content and provide a context for STEM integration.

Keywords: early childhood, engineering design, STEM integration

INTRODUCTION

Within STEM education, there remains a call for the use of a more integrated approach to STEM that allows educators and researchers to cross disciplinary boundaries and engage students in more integrated and interdisciplinary thinking and experiences (e.g. English, 2016; NRC, 2012; 2014). This focus on a more interdisciplinary approach to teaching and STEM has not only been found to increase student learning and motivation (Brophy et al., 2008) but also lays an important foundation for future learning (Kuhn and Pearsall, 2000). Furthermore, an integrated and interdisciplinary approach aligns with developmentally appropriate practice in early childhood that recommends that "teachers plan curriculum experiences that integrate children's learning with and across… disciplines" (Copple and Bredekamp, 2009, p.21). Within these early integrated STEM experiences, the interdisciplinary nature of engineering provides a link across STEM disciplines and is an ideal vehicle for advancing the natural curiosity and problem-solving skills that characterize early childhood classrooms (Tank et al., 2018; Brophy et al., 2008). However, there is limited research within the areas of early childhood

STEM and engineering (English, 2015; Lippard et al., 2017), and as these areas continue to grow there is a need for more research examining integrated STEM with a special attention to engineering, and the ways and types of engineering experiences and interactions that can be highlighted within an early childhood classroom.

Recommendations from emerging research in the area of early childhood engineering and STEM suggests that engineering experiences at this level should include a focus on engineering design as that provides opportunities and contexts for learning about and applying science & mathematics content (Tank et al., 2018; Wendell and Rodgers, 2013), engages students in real-world problem situations (Brophy et al., 2008; Cunningham and Lachapelle, 2014) and capitalizes on young learners' natural curiosity to solve problems and see how things work (Bairaktarova et al., 2011). While design is a key component of engineering, it is also important to present experiences that help to show that engineering is more than just design (Moore et al., 2014) as these experiences can provide opportunities to develop engineering thinking skills (Brophy and Evangelou, 2007; Adams et al., 2011; Lippard et al., 2017) and an understanding of engineers, engineering and the problems that engineers face (Adams et al., 2011; Lachapelle and Cunningham, 2014; Watkins et al., 2014). Furthermore, when thinking about the translation of engineering into the early elementary classroom, Evangelou in Adams et al. (2011) notes the importance of setting up experiences that assist learners in self-initiated, but adult-supported learning. This focus on the importance of providing carefully planned experiences that promote interactions with adults as facilitators and supporters of their learning was also echoed in the systematic literature review by Lippard et al., 2017.

Although this emerging body of research around early childhood engineering and STEM presents recommendations for early engineering, the field is still working to understand how these recommendations are translated into practice in real classrooms and the types of engineering experiences that can be successfully integrated into an already tightly-packed curriculum. Within this study, we were interested in learning more about how engineering is enacted in an early elementary classroom. To do this, we conducted an exploratory, descriptive research study in which we wanted to know, within the context of an integrated STEM unit that emphasizes engineering design, what does engineering look like in a Kindergarten classroom? More specifically we were looking to better understand the role of teacher and student talk within this context, what types of interactions around engineering were occurring in the classroom and if these interactions were student or teacher-initiated.

METHODS

This study employed a naturalistic inquiry approach (Lincoln and Guba, 1985) in which the goal is to observe, describe, and interpret the actions and experiences of people within their natural setting. Meaning arises out of social situations and therefore the context of the kindergarten classrooms and the events and interactions that occurred within these classrooms were an important part of the research setting. This type of approach is valuable for exploratory and descriptive research in which little is known about the people or social context that is being investigated, as is the case for early childhood engineering which is a newly emerging field.

Conceptual Framework

Engineering design-based STEM integration was the conceptual framework that guided this study. Engineering design-based STEM integration is defined as the use of learning objectives that are composed of engineering design and at least one of the other STEM disciplines within the same classroom activity, unit, or learning experience for students. The engineering design challenge in the STEM integration learning experiences acts as the integrator for all of the other subjects (Moore, Stohlmann et al., 2014; Grubbs and Strimel, 2015). The Grand Challenges for Engineering (National Academy of Engineering, 2008) are the greatest engineering challenges facing our planet. These challenges epitomize the interdisciplinary nature of engineering problems, particularly the problems that are facing engineers of the 21st century. To meet these problems, today's students must become engineers who can meet these challenges. To prepare today's students to meet the problems of tomorrow, opportunities to engage with authentic, real-world, and interdisciplinary problems and ideas must be available to spark interest in STEM fields. Powerful, engaging experiences within rich, integrated STEM contexts must be provided to engage, interest, and support students as they prepare to meet the problems of our increasingly technological society. The core of engineering practice is often considered to be engineering design, a way of thinking and engaging with problems to meet the needs of society. This purposeful thinking, or engineering design, is the "distinguishing mark of the engineering profession" (Dym, 1999). When state standards incorporate engineering, they commonly incorporate engineering design as part of their science or standalone engineering standards (Moore et al., 2015). Engineering design is also incorporated into the Next Generation Science Standards alongside engineering habits of mind and an acknowledgement of the intersection of engineering within science education standards. From these standards, however, there is little guidance or structure for engineering integration, and this need is not yet met by policy makers or researchers across the P-12 education landscape. In relation to this study and engineering design-based

Table 1. *Designing Paper Baskets* curriculum unit summary

Lesson	Literacy Lesson Focus	STEM Lesson Focus
1: Paper	While reading *If You Find a Rock* by Peggy Christian, students work on identifying beginning and ending sounds of words	Identify the properties of the paper samples and sort using those properties.
2: Paper and Water	The first part of *I Get Wet* by Vikki Cobb introduces students to water while allowing students to blend three letters in sound boxes that represent the phonemes of a word	Learn about properties of paper when wet and dry through the water drop test, wax and water test.
3: Paper Strength	The second part of *I Get Wet* by Vikki Cobb provides background science knowledge as students work to summarize text using interactive writing	Test the strength of dry/wet paper with rocks.
4: Patterns and Your Design	In *Pattern Fish* by Trudy Harris students practice their patterning while also being introduced to rhyming words	Identify and create patterns, explore the patterns that can be used as they identify a weaving pattern for basket plan.
5: Testing your Basket	*Rocks, Jeans and Busy Machines* by Alane & Raymundo Rivera leads a lesson on summarizing narrative text with interactive sentence writing	Engage students in the second part of the engineering design process as they test baskets with wet and dry rocks and communicate solution to clients.

STEM integration, the learning objectives for the entire unit came from all four STEM disciplines, but each lesson focused on engineering design and at least one other content area.

Participants and Context

This research is part of a larger project that is examining engineering design and computational thinking within integrated STEM experiences for K-2 students. As part of this larger project, the three teachers agreed to implement the same integrated STEM curricular unit, *Designing Paper Baskets* (described below) that was developed by the research team (Tank et al., 2018). This particular study was focused on examining the implementation of this curriculum in three kindergarten classrooms and specifically looking at student and teacher talk and the types of interactions around engineering that were occurring and who was initiating these interactions. The data for this project were collected from all three full-day Kindergarten classrooms at a K-8 public charter school located in a small city in a Midwestern state within the United States that includes 57% students on free-reduced lunch (lower socio-economic status) and 22% students of color (not identified as 100% Caucasian). Each of the Kindergarten classrooms were taught by one of three Caucasian, female teachers who were within their first five years of teaching and representative of early elementary teachers in that they had not received specific coursework or training related to integrated STEM. Additionally, these teachers only received a one-hour, on-site introduction to the curriculum as they implemented this curricular unit prior to any participation in professional development around engineering and integrated STEM. This allowed for the researchers to gather data that was somewhat representative of the typical early elementary classrooms where teachers do not have access to specific STEM professional development prior to implementation (Banilower et al., 2013). While the choice of where and from whom to collect data was meant to be somewhat representative of Kindergarten classrooms, these data are specific to this school and these three classrooms, teachers, and students; therefore, while the lessons we learned from this study are likely to be true elsewhere, caution should be taken when making such generalizations. Data were collected from 32 students across the three classrooms in accordance with IRB #1401014380.

Curriculum as the Research Setting

The integrated STEM curriculum unit, *Designing Paper Baskets* that was implemented in all three of the Kindergarten classrooms is part of the *PictureSTEM* curriculum project that uses picture books, an engineering design challenge, and student-centered pedagogies to provide authentic, contextual activities that engage learners in specific science, technology, engineering, and mathematics content. There are four primary components that serve as a foundation for this curriculum: 1) engineering design as the interdisciplinary glue that is present throughout the integrated STEM unit, 2) realistic engineering contexts to promote student engagement, 3) high-quality literature to facilitate meaningful connections and 4) instruction of standards-based STEM content using student-centered pedagogies, with a particular focus on evidence-based reasoning as a means to tie the subjects together (Tank et al., 2018). The implementation of this engineering design-based STEM integration curriculum is the context for observing evidence of engineering experiences, talk, and interactions that occur within these three Kindergarten classrooms. Since the focus of this study was to explore what engineering looks like in practice within an actual classroom, asking the teachers to all use the same integrated STEM curriculum was an attempt at providing a consistent curriculum and instructional approach across the classrooms.

The particular curriculum unit, *Designing Paper Baskets*, that was implemented in this study focuses on the development of the mathematics concept of pattern recognition and the science concept of exploring physical properties and materials. In addition to the five lessons shown in **Table 1**, there is an introductory lesson where engineering, specifically the engineering design process, and the overarching engineering design challenge is introduced to students. The engineering design challenge for this unit, asks students to assist two fellow

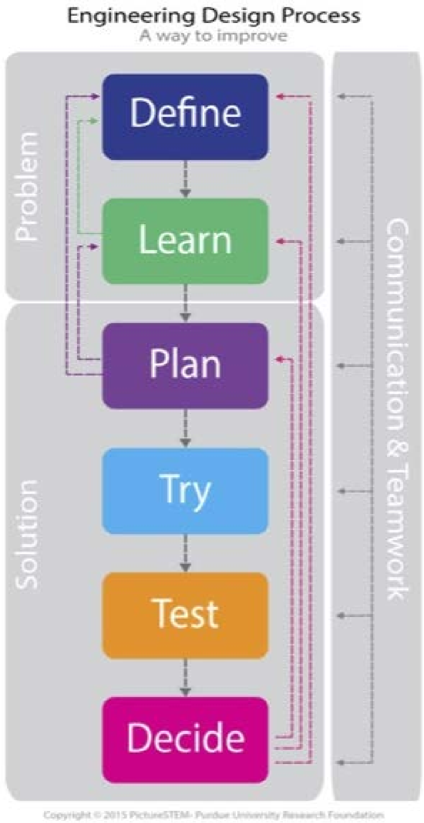

Figure 1. Engineering Design Process

kindergarteners, Max and Lola, in creating a design for a paper basket that can be used to transport wet and dry rocks for other children interested in starting a rock collection.

Data Collection & Analysis

The video data were collected using three cameras on tripods during the *PictureSTEM* curriculum lessons, one per classroom. When a member of the research team was available, they would set up the camera and take field notes during the lesson. When no researcher was available, the teachers themselves set up the tripod in a reasonable location for the duration of the lesson. Video data was collected for all five literacy and STEM lessons for each of the three teachers. Videos were analyzed using the Dedoose qualitative analysis software (www.dedoose.com) and uploaded to the secure Dedoose platform for researchers to access the videos for asynchronous coding. For each of the individual lessons that make up the larger curriculum unit researchers watched each of the classroom videos and identified excerpts, or small clips, within the videos that were focused on activities or interactions related to engineering. In this study, an excerpt is defined as the full interaction rather than by a specific time. This allowed for a condensing and categorizing of the data around the research question of examining what engineering looks like in a Kindergarten classroom. These excerpts became the unit of analysis and the focus of the coding and analysis for this study.

Initially, all researchers reviewed a selected subset of the video data (Derry et al., 2010) Using the engineering design process, presented in **Figure 1**, as a provisional analytic framework, researchers deductively and inductively created a coding scheme to analyze the video data (Miles et al., 2014). This version of the engineering design process was developed through multiple research and curriculum studies (e.g., see Moore and Tank, 2014; Tank et al., 2016; Tank et al., 2018). The first of these studies, the Framework for Quality Engineering Education (Moore et al., 2014), defined the engineering design process as the following six phases: problem, background, plan, implement, test, and evaluate. Through our research and curriculum development with young children, we found that these terms were difficult for the young students to understand. Therefore, we changed the language to be more accessible by making "problem" into "define the problem", "background" into "learn about the problem", "plan" into "plan a solution", "implement" into "try your plan", "test" into "test your solution", and "evaluate" into "decide if your solution is good enough." Throughout this manuscript, we will shorten these definitions into the just the colored words shown in **Figure 1**. These phases as defined in Moore et al. (2014) with the new names from Tank et al. (2018) were used to guide the first round of coding.

Further analysis of the data and iterative cycles of coding allowed for the emergence of additional codes and sub codes that related to the research questions but were not captured in the provisional framework (Miles et al., 2014), such as connections to curriculum, student talk and teacher talk. The resulting coding scheme was used to document the ways that engineering and engineering design, were framed and enacted in the classroom as well as the role that the teacher and students played within the lessons. The set of codes, sub-codes, and an example of each that made up the final coding scheme are divided by category and presented in **Table 2**.

Table 2. Final coding scheme and representative examples

Codes	Key terms or actions	Example(s)
Engineering Design Process		
Define	Criteria, Constraint, Client, End-user Problem	Now who are we helping? Max! Max and Lola, right, we're helping Max and Lola. *C1, L0* We're going to design a basket, we want it to? Look pretty! *C1, L5B* Well, what was the letter about? Rocks! Yeah, what do we need to do? Make a rock activity! *C3, L0*
Learn	Science, Math, Materials exploration, Other solutions, Defining specs (trade-offs, criteria, constraints, end-user, client), Past Experiences	Okay, so we're going to read this book called *Pattern Fish* to help us learn about patterns. *C1, L4A* I'm curious, what happened with the tissue paper? The tissue paper? Our tissue paper {lifts it up} Had a hole in it? Yeah. *C2, L3B*
Plan	Brainstorm solutions, Consider constraints & trade- offs, Choice of plan, Develop physical plan, Defining/Modifying Specifications	I am going to partner you up and then you are going to talk. You are going to tell me what you and your partner decided to do, why you chose the papers, and how it's going to meet Max and Lola's needs. It has to look pretty and has to hold wet and dry rocks, right? *C3, L4B* I know which type of paper to use! Well, what kind of paper do you think? It's the first paper we tried! Wax…it holds wet and dry! *C2, L3A*
Try	Consider Risk, Create prototype, Trade-offs	Done! You guys used the over under pattern, right? Over-under, over-under. Yeah, you did, good job! *C3, L4B* Now what you guys have to do is fold it in half and tape the sides. Okay this is ours! *C1, L4B*
Test	Collect & Analyze Data, Defining/Modifying Specifications Failure	Three…four…five…Ours broke! *C3, L5B* …nineteen, twenty, twenty-one {basket breaks} Oh! Twenty rocks. *C1, L5B*
Decide	Share results, Failure, Criteria, Constraints, Improve, Redesign	We didn't have more weaving so there's a hole but it didn't break. I think it will have more weaving. *C3, L5B*
Interaction Type		
Teacher-focused	Teacher talk, action, response, teacher initiated, provides knowledge	We're going to read this book *If You Find a Rock* and we're going to read about it because this is Learning about some of the things that we need for our engineering process, we're going to learn some about rocks. *C1, L1A* I already see some people who are thinking in their head about what's happening and thinking about what they're going to do differently next time. *C1, L5B*
Student-focused	Student talk, action, response, student providing knowledge	Now we're done with papers. We're done with testing. *C1, L4B* So what did you make it out of? Construction paper! *C1, L5B* My basket looks almost done! No, our basket. My basket. Your basket looks fantastic! No our basket. *C3, L4B*
Other Areas of Interest		
Connections to Curricula	Refers back to engineering design process, Book (literacy), Math lesson/content, Science lesson/content	Let's think back to when we read *If You Find A Rock* and who can remember what kind of rock was in the story that you like, what was your favorite? *C1, L1B* Now in the book *Pattern Fish*, they talked about "yellow black, yellow black, yellow black" is an AB pattern, right? *C2, L4B*
Explicit Engineering Language		We're moving down to Plan, we get to Plan the design of our baskets *C1, L4B*
Conceptions of Engineers and Engineering	Identifying what engineers do, identifying self or others as engineers	We're gonna be like a scientist! We are, we're going to be like engineers. *C1, L3B*

All four coders for this project were already familiar with the initial codes and their definitions from prior research that had been conducted. Prior to coding all of the data, the four coders rated common video clips to assure that our coding was calibrated. After coding the clips, we used Randolph's free marginal kappa to calculate the interrater reliability (IRR) for the four coders. Randolph's free marginal kappa is a variant of Fleiss' kappa (Fleiss, 1971), which is the most common replacement for Cohen's kappa when there are more than 2 raters. We chose to use Randolph's free marginal kappa to also take into account that there were not specified numbers of each category that must be coded. Our IRR for this study was multi-rater $\kappa_{free} = 0.941$, which is almost perfect agreement according to Landis and Koch (1977).

Following the establishment of interrater reliability with the coding scheme, the research team divided the data to analyze and coded individually. The codes represent instances of engineering related actions, interactions and conversations that were seen throughout the enactment of the lesson. This allowed for the categorization and identification of reoccurring patterns within the data based on the clustering of similar codes, which led to a smaller number of patterns codes that could be grouped into larger themes (Miles et al., 2014). Through this process of coding, organizing, and clustering the data, several themes emerged related to the bigger categories of engineering design, talk and interactions as well as several unexpected themes that will be presented in the subsequent section.

RESULTS

When looking at the results of the coding and analysis, there were several themes that emerged related to the larger research question examining what engineering looks like in a kindergarten classroom by looking at the talk and types of interactions that were occurring during instruction. Across the three classrooms students, with the support of the teacher, were seen to engage in and with all of the stages of an engineering design process with an emphasis on the learn stage where they were building knowledge of the problem and content. Additionally, there was evidence that as students were participating in these engineering design-based STEM experiences that they were also building their understanding of scientists and engineers, as well as some early self-conceptions of being scientists and engineers. Finally, when looking at the role of the teacher and students within this context, even though there was a lot of teacher talk throughout the lessons, there was also evidence of a large number of unprompted student talk, student to student response, the use of explicit engineering language and student connections to prior learning and experiences seen across the curriculum. Additional description and examples around each of these larger themes will be discussed in the following sections. Excerpts are noted by classroom and lesson; for example, *C1, L3B* would be an excerpt from Classroom 1 during Lesson 3B. See **Table 1** for lesson descriptions.

Overview

Using the internal analysis available in Dedoose (version 7.5.9), a word cloud portraying the relative number of each code applied during the coding analysis is shown in **Figure 2**. This word cloud provides a picture of the patterns that were seen as this engineering design-based STEM unit was enacted in the three kindergarten classrooms. When looking across the stages of the engineering design process, the unit focused heavily on the Learn stage with 218 total coded excerpts identified for that stage. This is expected as STEM lessons 1 – 3 and all Literacy lessons have been designed to help students to build background knowledge around the problem and content necessary for solving the engineering design challenge and therefore would be in the Learn stage. Learning specifically about the materials that would be used to weave their baskets and the strength and how the materials interacted with water was found to be the largest single aspect of the lessons with 145 coded excerpts.

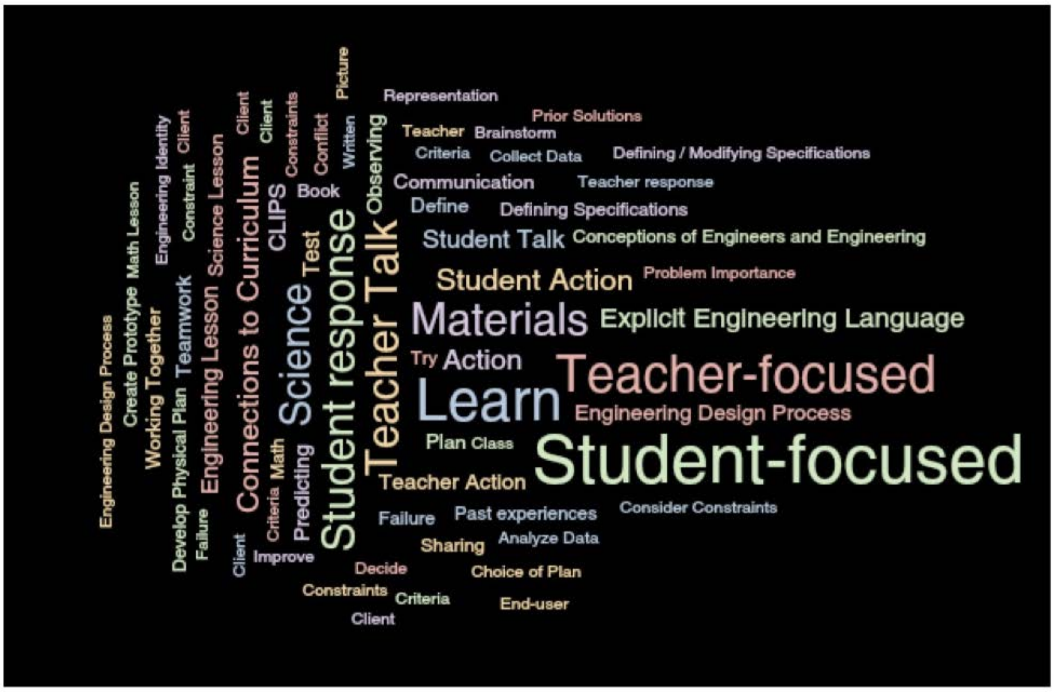

Figure 2. Word cloud indicating number of times each code was used in relation to all codes

Another interesting pattern that emerged, that was related to the student-teacher interactions around engineering, and revealed that there were more student-focused excerpts, 265, compared to the 182 teacher-focused excerpts across the unit. As seen in the word cloud in **Figure 2** above, there were two other areas of interest that appeared within the data. "Explicit Engineering Language", language that was either engineering-specific (e.g., *engineer, prototype,* or *criteria*), or language that was specific to the curriculum and used in an engineering context (e.g., *plan, try,* or *test*) was noted with 59 separate excerpts coded as using engineering language. The other area of interest was "Connections to Curriculum" with 80 distinct excerpts. Excerpts were coded as "Connections to Curriculum" when prior lessons or concepts learned within those lessons were referenced either by the teacher or students.

Engineering Design Process

When looking more closely at the types of engineering and engineering design experiences, the progression follows the intended engineering design process as designed for this curriculum and seen in **Figure 3**. The progression is driven by the curriculum and mainly forwarded by the teacher, with the Define stage occurring in the introductory lesson and tapering as the classroom comes to a well-defined consensus on what the problem is, followed by multiple lessons where learning necessary background to solve the problem is the focus. Planning and building their basket design is found in the Plan and Try stages in Lesson 4B, while the Test and Decide stages occur in Lesson 5B in the curriculum. The students test their baskets with wet and dry rocks and decide whether their design meets the client's needs. A breakdown of the code counts for the different stages of the engineering design process that were seen within this unit can be found in **Figure 3**.

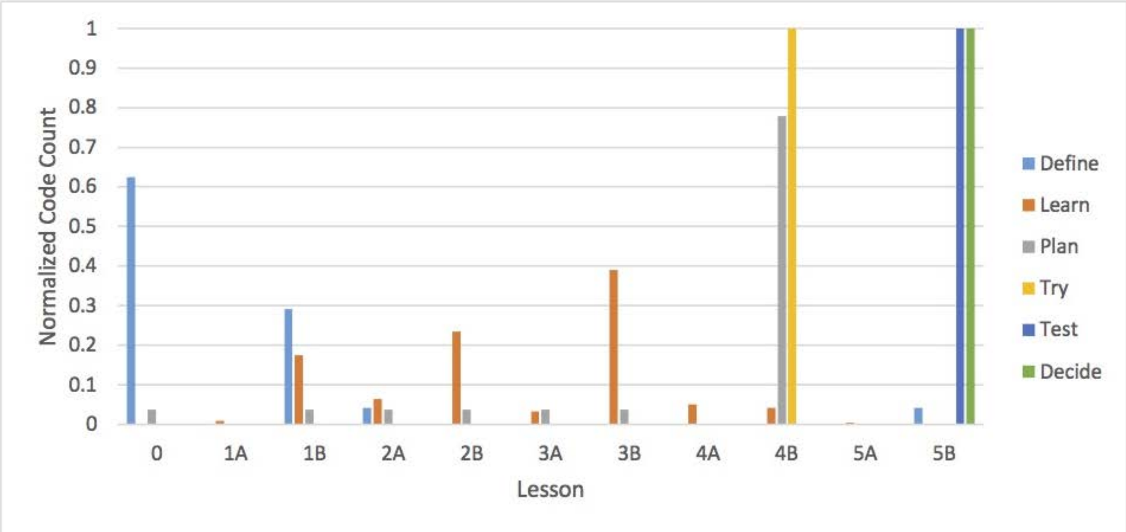

Figure 3. Normalized code count for Engineering Design Process steps across curriculum

Overall, the classrooms followed the expected engineering design process as it was designed to be implemented. However, engineering design is not a unidirectional procedure to be strictly adhered to, and while there is a definite progression through the process, there was evidence of kindergarten students engaging in design as an iterative process as seen in **Figure 3** above. Aspects of defining the problem, learning about the problem and planning for solutions were seen to occur across multiple lessons throughout the curriculum. There were aspects related to Planning that occurred before the intended planning-focused lesson (4B) and were often prompted by students using the problem scenario set up in the beginning as a context for generating and discussing potential solutions related to this problem. One place where this occurred can be seen in the following teacher-initiated example, when the teacher was wrapping up the first lesson by asking students to relate their learning about paper back to the problem context and start to thinking about possible solutions:

> Teacher: If we were making a basket, what would you want to make a basket out of? What paper would you choose?
> Student: The see-through one
> Teacher: Why would you choose this?
> Student: Because it can get wet. *C3, L1B*

Students were able to explore a variety of STEM subject matter through this project. The other common place where this more iterative nature of engineering and design was seen was with those instances coded as part of the Learn phase of the Engineering Design Process. While there is a focus on the Learn phase within lessons 1, 2, and 3 in the curriculum, analysis revealed that there was evidence of the Learn phase seen in varying degrees across the lessons. When looking at little more closely at who was initiating and engaging in this learning, **Figure 4** presents the breakdown of student and teacher talk and response across the "Learn" stage codes.

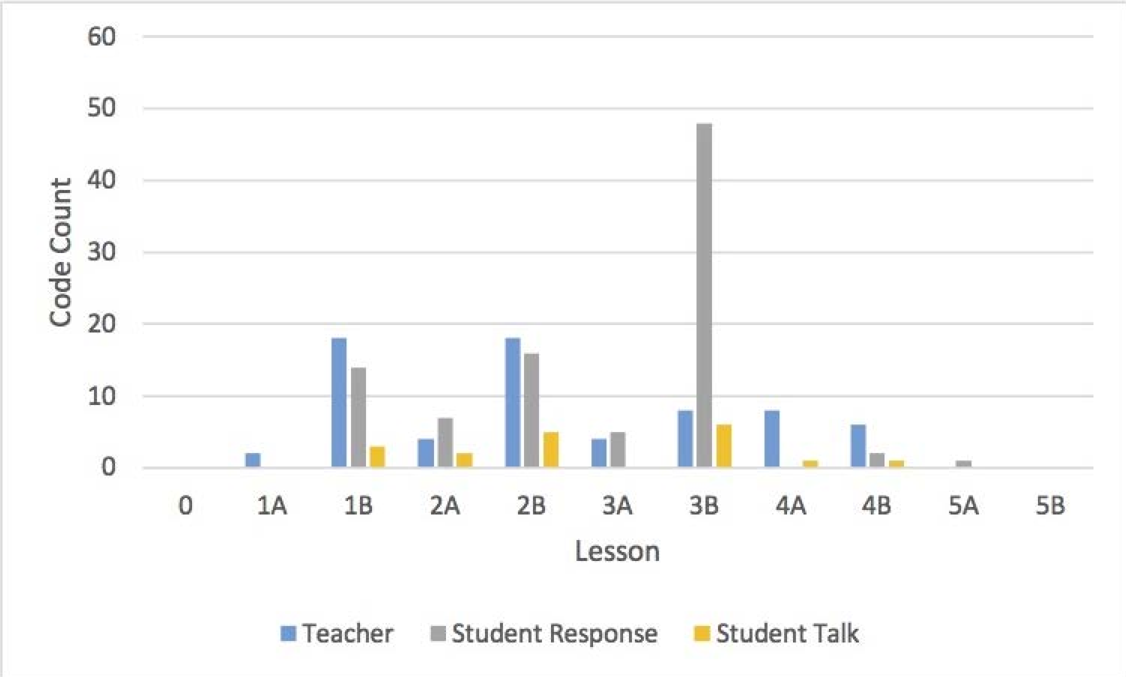

Figure 4. Instances coded as being directly a part of the "Learn" stage of the EDP

Fifteen percent, or seventeen out of 110 total student interactions, were coded as "Student Talk". Students need the guidance and prompting of the teacher to help them through the process of learning the background behind their engineering design project, scaffolding the lessons and encouraging students to share their findings.

As students explored the STEM lessons and learned more about the background information required to complete the design project, the following excerpt presents an example of a student developing experiments that could be used to learn more about the materials.

> Student: Because I want to see, I want to do both and see which one is better
> Teacher: Oh, so you want to do both pieces of paper to see which one works best? Why?
> Student: Because so I could give the basket one of the papers.
> Teacher: So you're seeing which paper would be the best for the basket.
> Student: So I'm doing both. *C3, L2B*

Another theme that emerged related to engineering design was that even though the Kindergarten students were eager to jump into planning and building their basket designs they were able to keep a focus on the larger problem and working through the Engineering Design Process over many days. Additionally, both the teachers and students were seen using the engineering design process as a thread that connected the pieces of the curriculum. All of the teachers followed the curriculum as it was written and typically at the start of each lesson they would note where in the Engineering Design Process the class would focus for that day's lesson. The following example occurred at the start of the third STEM lesson:

> Teacher: And we are right now in the process of….
> Student: Learn!
> Teacher: Learning, that's right! *C1, L3B*
> Teacher: So we're still on the Learn part, you're learning about how to weave to make your basket. *C3, L4A*

Furthermore, in the classroom where the Engineering Design Process was consistently and prominently displayed, the following examples showed students commenting on where they were and where they would be going in the design process.

> Student: And you need to define it! Don't forget to define! *C1, L0*
> Student: We're still on learning, are we on learning? *C1, L1B*
> Student: Can we do plan? *C1, L4B*

In all of these examples, the students were sharing their ideas after the teacher had introduced the goals of lesson and then directed their attention back to the engineering design process, but before the teacher explicitly identified where they were in the process.

Teacher & Student Interaction

When considering the types of interactions seen throughout the unit, there were more student-focused excerpts, 265, compared to the 182 teacher-focused excerpts. Of the 182 teacher-focused excerpts, 148 were coded as "Teacher Talk" where the focus of the teacher's interaction is to guide the lesson by initiating conversation or providing knowledge. The remainder were often coded as "Teacher Action", 32 excerpts, where the teacher was primarily showing students how to do something or helping students to engage in a physical activity or "Teacher Response", 2 excerpts, where the teacher was primarily providing information or a response to students' prompts. With respect to the 265 student-focused excerpts, 144 were coded as "Student Response" where students were primarily responding to prompts from the teacher with information related to the project (e.g. "What are we designing?" "Baskets!" *C1, L1B*), 46 were coded as "Student Talk" where students were supplying information or inciting an engagement with the teacher or other classmates without outside prompting, and 75 were coded as "Student Action" where students were primarily focused on physical actions.

Conceptions of Engineers and Engineering

Another pattern that was seen during the analysis of the engineering experiences was that throughout this curriculum, students were building their understanding of the work of scientists and engineers, including beginning to identify themselves as being or being like engineers and scientists. Many of these instances were seen when the teachers facilitated this belief by helping students to prepare: "Now we are going to think like engineers, put on your invisible engineer thinking hats" *C3, L0*. There were also instances where students are the ones to recall their role as scientists and engineers during future lessons with minimal prompting:

> Student: We're gonna be like a scientist!
> Teacher: We are, we're going to be like engineers. *C1, L3B*
> Teacher: "This bridge must have been created by an engineer," explained Pedro
> Student: That's what we are! C1*, L5A*

Both of these examples were unprompted and provided by female students. These unprompted student responses, taking on STEM self-conceptions, help to facilitate students' beliefs that one of their future selves could be as an engineer or other STEM professional. Students are eager to take on these STEM roles as they move through the curriculum.

> Teacher: It's an engineering kids story book, written by…
> Student: We're going to be engineers? *C1, L5A*
> Student: Can we do another experiment? *C3, L2B*

Explicit Engineering Language

Explicit engineering language, language that is either uncommon for kindergarten students to use (e.g. engineer, prototype, criteria, etc.) or that is specific to the EDP and used in that sense (e.g. plan, try, test, etc.) was coded when it was seen in the curriculum. The most common occurrence for explicit engineering language was at the beginning and end of the lessons, when the teacher was reminding students of the context or connecting what they had learned to the engineering design context. Students also used explicit engineering language, but not as often as teachers did as seen in **Figure 5**.

Explicit engineering language was often used when discussing or describing the engineering design process. Approximately half of the excerpts coded as explicit engineering language were also coded with "Engineering Design Process", meaning they occurred when directly discussing the engineering design process. Some instances of explicit language use reminded students of where they were and what they needed to do for the engineering design project, "Where's your plan, I need to see your plan before you come up to me" *C1, L4B*.

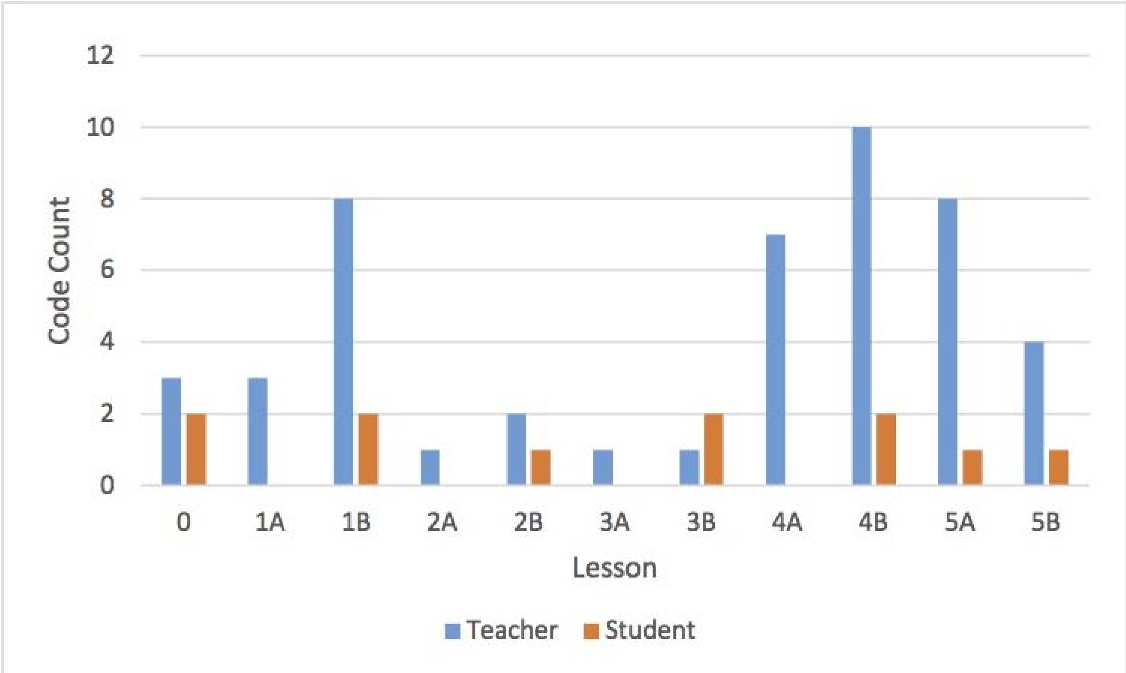

Figure 5. Instances coded as using curriculum-specific engineering language

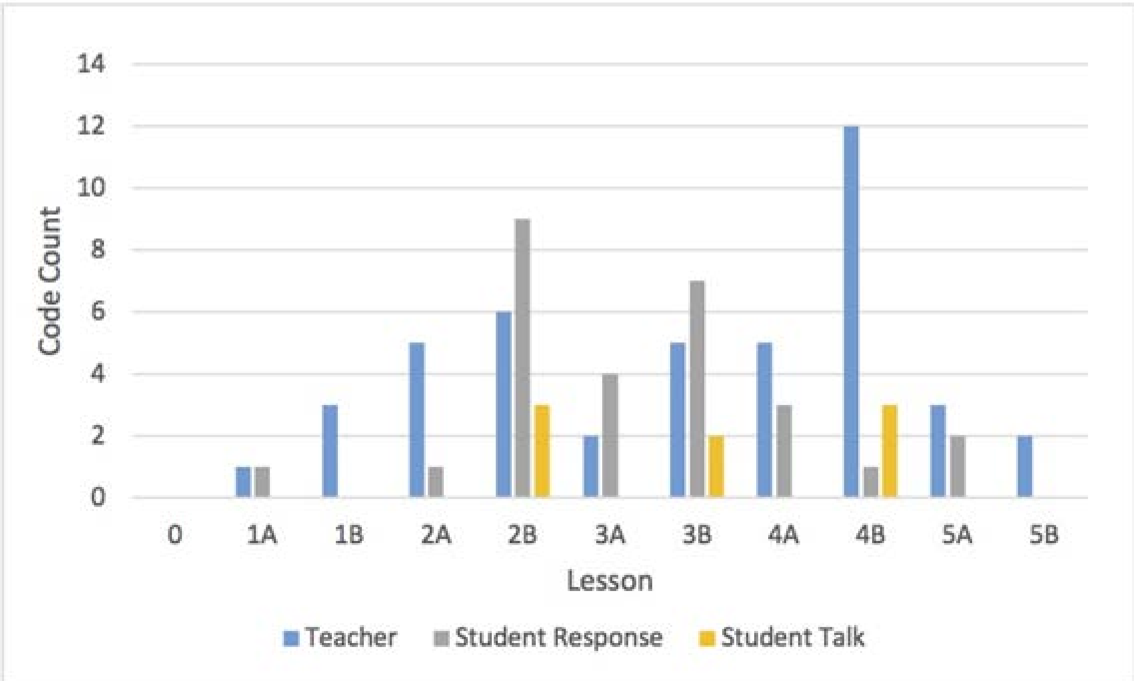

Figure 6. Instances where earlier lessons from the unit were recalled during later lessons

Connections to Curriculum

Teachers and students connected lessons across the curriculum to their design projects as seen in Figure 6. The integrated curriculum was designed so that students would be introduced to an engineering design problem, then learn what they needed to know to solve the problem through books and STEM lessons, and finally complete the engineering design project using the knowledge they had learned to help the client. In order to build upon each lesson, referring back to and transferring knowledge across the different pieces of the curriculum is necessary.

Twenty-two percent of the student-focused excerpts (8 of 36) were coded as "Student Talk", where students connected back to aspects of the curriculum in an unprompted manner. Students were able to make their own connections back to the books they had read, the experiments they had done, and to the context for the engineering design project. Connections to the curriculum often connected to a book that was read in preparation for a STEM lesson.

Teacher: Earlier today we read *Pattern Fish* and we learned about patterns, right? Why did we learn about patterns? Raise your hand if you want to tell us why we learned about patterns.

Student: Patterns on our baskets. *C1, L4B*

Connections back to the curriculum also occurred when teachers and students were remembering where they were and what experiments they had done.

Teacher: We have talked about five different papers. We have talked about construction paper, we have talked about regular copy paper.

Student 1: No, I don't remember doing construction paper.

Student 2: I do.

Teacher: I think on the very first day we each had little squares and you had to feel the difference between them. You are right we haven't talked a whole lot about the construction paper but it's going to come in handy today. So construction paper, copy paper, oh, our favorite! Our favorite!

Student: Wax!

Teacher: Wax paper with that wax coating, we have tissue paper, we have paper towels, our five different papers. These are all papers you can find at your house if you looked really hard and Max and Lola want us to use some paper you can find at home, so this is some of the paper that you can find at home. *C2, L3B*

Connections across the lessons was also seen in un-prompted, or student-initiated instances when students would make their own connections between the subject-specific activities they conducted and the engineering design problem. In this example, the teacher had finished reading the second part of the book, *I Get Wet* by Vikki Cobb which is about the properties of water and was asking the students about what they learned from the book to move towards summarizing the text and a student replied, "I know what, which kind of paper to use!" *C2, L3A*. As expected, more connections were seen in the later lessons as students created a plan for solving the engineering problem using the knowledge from prior lessons. Some additional connections occurred as students talked about their plans and designs, however while many students described why they used specific materials they did not directly attribute their reasoning to the lesson or content where they learned the material properties, so these instances were not coded as directly connecting back to the curriculum.

CONCLUSIONS

As we looked at the implementation of an engineering design-based STEM integration unit in three Kindergarten classrooms, the goal of this exploratory, descriptive study was to gain a better understanding of how engineering can and should be integrated into early childhood classrooms. As engineering continues to expand into classrooms and contexts with young students, the question of what developmentally-appropriate engineering is and what does it look like for the teacher and student in classroom practice continues to be asked. Based on the results of this study, the authors assert that developmentally-appropriate engineering can: 1) incorporate multiple aspects of engineering and engineering design, 2) be scaffolded by the teacher to promote student talk and action, 3) include interdisciplinary content and connections, and 4) take place over an extended period of time, especially when using a visual representation of the engineering design process as an organizing tool and place marker.

Throughout the unit, the teachers and students were seen engaging with engineering and engineering design across the different lessons in an iterative manner, especially with defining the problem, learning about and planning for their design solutions that is more realistic of engineering. While this was largely teacher driven, these results suggest that kindergarten students are able to engage in problems that have multiple layers and require learning and revisiting ideas and possible solutions, which is an important aspect of engineering design and solving engineering problems (Tank et al., 2018; Lachapelle and Cunningham, 2014). This learning and revisiting of ideas and solutions was especially evident within the Learn phase of the EDP. Even though the curriculum was designed to have students learn the relevant background knowledge and revisit this knowledge in the context of students' ideas across multiple lessons, it was unclear how this would translate into practice and how much of an emphasis it would be given by the teachers and students. It was therefore encouraging to see knowledge building related to the problem and possible solutions across multiple lessons.

Additionally, kindergarten students were not only engaging with the engineering activities, but they were also seen building their understanding of scientists and engineers as well as developing a better understanding of the work that engineers do (Adams et al., 2011). While this was commonly seen following teacher prompting or scaffolding, there was also evidence of student-initiated instances of building their own self-conceptions as engineers and scientists.

When looking at the teacher and student talk that occurred during this unit, the use of engineering design-based STEM integration was seen to promote the practices of language skills as it encouraged frequent instances of student talk and student response alongside with student action. While there was evidence of a larger number of student-focused excerpts identified within engineering, the teacher-student interactions within these lessons were found to be important for scaffolding and modeling of appropriate engineering language and practices which is similar to what has been recommended within the early engineering literature (Lippard et al., 2017).

Additionally, when looking at the enactment of engineering design-based STEM integration, this study suggests that engineering design provides a space and context not only for teachers to integrate and make connections across content areas, but also for students to make their own connections across disciplines. This was evident by the large number of excerpts that were dedicated to building background knowledge within mathematics and science content, but also seen with the frequent identification of connections across the literacy and STEM lessons and to their design projects by both students and the teachers. This is important when thinking about models of STEM and engineering as those recommended models would ideally encourage and support both student-directed and teacher directed interdisciplinary learning and thinking. Furthermore, when thinking about the student-initiated and interdisciplinary thinking, some students were able to independently make connections to the classroom lessons when designing their basket however many of the students needed more direct prompting from the teacher in order to make these connections.

Finally, these results suggest that kindergarten students are able to complete long-term, multi-part engineering design projects that include integrated STEM lessons and that students can have high levels of understanding and engagement as seen by high levels of project-focused student responses. However, teachers are needed to facilitate and guide, but not constrain students during an engineering design-based project. This was especially true in the classroom, where the teacher and students frequently referred to the visual representation of the engineering design process that was hanging in their classroom as an organizing tool and place marker for where they were and what their next steps would be in solving their problem. Additionally, while some students were able to move more independently at this age (e.g., two students created experiments to test the paper, some students were independently following and keeping track of the EDP, some students made connections to being engineers and the engineering project without teacher prompting), all students appeared to benefit from the guided engineering experience.

IMPLICATIONS

When looking at the emphasis that is being placed on STEM and engineering at all levels, it is important to have a deep understanding of what these constructs mean at the various levels and what can and should be expected of teachers and students when put into practice. However, this is difficult with the limited body of research within STEM and engineering at the early childhood level. As the field is working to understand STEM and engineering at this level, this study sheds light on how engineering design can be used to facilitate STEM integration and how this can be enacted in early childhood classrooms in developmentally appropriate ways. Gaining a better understanding of engineering design-based STEM integration has several implications or the field. Time and space within the curriculum is limited, so adding more content is a challenge. This study was focused on the engineering that was present in early childhood classrooms within this engineering design-based STEM integration model, and it did not explicitly examine the literacy component. However, there was evidence of student and teacher-initiated talk and connections between STEM and literacy which suggests the potential for using engineering design-based STEM integration as a context for student learning in areas outside of STEM. Therefore, if engineering design can be used to facilitate learning in other content areas, such as STEM or literacy there is a greater chance of meaningfully making its way into and staying in early childhood classrooms where the day and content is already tightly packed. This indicates that additional research is needed to further examine this connection and the extent to which an engineering design-based STEM integration model could be used for content learning in non-STEM areas like literacy. Furthermore, when thinking about the preparation of future teachers and support for current teachers, gaining a better understanding of what STEM and engineering look like in practice can help with teacher preparation and professional development efforts for teachers who have limited background, experience and confidence in teaching STEM and engineering.

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Engineering Design Challenges in Early Childhood Education: Effects on Student Cognition and Interest

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ABSTRACT

This mixed methods study is one of the first to evaluate the effects of the incorporation of dramatic inquiry, dance, visual arts and physical education into preK-3 science, technology, engineering and mathematics units on student conceptual understanding of technology and engineering. The study used data collected from over 200 student surveys and focus group interviews with 14 teachers. The use of integrated STEAM units supported significant improvement in 4 to 8 year old students' understanding of engineering and technology. We report an average 55% increase in student understanding of what engineers do, and a 36% increase in their understanding of technology. The effect sizes for both assessments showed mostly large effects for all grade levels. The pre test scores across all grade levels were not significantly different. By implementing these integrated units with our younger students, we aimed to nurture their interest and understanding of engineering and technology across grade levels. This study results imply that students may not learn about these important topics outside of school hours; thus, it is important they become acquainted with these topics during school hours. Our work suggests that engineering units with dramatic inquiry should be introduced beginning in kindergarten.

Keywords: early childhood STEAM, engineering design challenges, dramatic inquiry, integrated STEAM-units, STEM instructional units

INTRODUCTION

Worldwide there has been an historical decline in the number of college students pursuing engineering and science undergraduate degrees, especially in industrialized nations (NSB, 2018; OECD, 2014; Pretz, 2016). For example, the Organisation for Economic Co-operation and Development reported that only 15% of students are awarded engineering degrees in OECD countries whereas 32% are awarded degrees in social science programs (OECD, 2014). While these numbers have started to rise, this is extremely discouraging for countries as many reports have shown that there is and will remain a shortfall in the number of engineers available to fill highly technical jobs for years to come (e.g. Becker, 2010; Holdren et al., 2010; Sjøberg and Schreiner, 2010).

To help mitigate these statistics, science, technology, engineering and mathematics (STEM) projects in schools introduced consistently from early childhood onward could help to shift not only student interest in STEM but also enhance self-efficacy with respect to STEM careers (Parker, 2018). Ultimately, this strategy might encourage young people to consider careers in engineering. Positive shifts in interest have been observed internationally when incorporating engineering projects into secondary schools (Malone, Schuchardt and Schunn, 2018) and informal outreach programs to K12 schools (Johnson et al., 2013; Karp and Maloney, 2013; Shahali et al., 2017). The incorporation of engineering at the early elementary school level (students five to 10 years old) has included the use of engineering picture and trade books to introduce engineering challenges (Milto et al., 2016; Pantoya et al., 2015), engineering design projects (Lachapelle and Cunningham, 2014; Silver and Rushton, 2008b), and animated videos (Johnson et al., 2013). The lack of inclination to become an engineer may be caused by the negative stereotypical images held by students rather than enjoyment of science and engineering (Silver and Rushton, 2008a; Wang and Degol, 2017). Alternatively, lack of interest in engineering careers might be simply caused by the lack of awareness of what engineers do. Several studies have shown that elementary students consider engineers to be laborers, technicians, or train drivers (Capobianco et al., 2011; Chou and Chen, 2017). The question may be how to introduce engineering to young children in a way that brings forth their creativity and helps to develop their identity as budding engineers while also helping them to understand the concepts of engineering and technology.

A possible method that would develop young children's identity as potential engineers is the use of dramatic inquiry (DI), a dialogic inquiry and dramatic play-based pedagogy (Edmiston, 1998; Edmiston, 2014) and other artistic approaches such as art and dance. Studies have shown that during play students exhibit behaviors that are consistent with those used during the engineering design process (Gold et al., 2015; Park et al., 2018) and earlier engineering play can help them to be more successful in later engineering challenges (Tõugu et al., 2017). Tõugu et al. (2017) asked families with young children in a museum setting to solve an engineering design problem together using spatial play. The children were then asked to solve a second problem on their own and the researchers found that the children experienced even greater success completing the second engineering design problem after first experiencing play and engineering design. The exploratory study described in this paper is a first attempt to fill a gap in the literature by determining the effect of <u>integrated</u> STEAM (i.e., science, technology, engineering, art and mathematics) units incorporating engineering design process units infused with dramatic inquiry, art, and/or dance on student knowledge of engineering and technology in early primary school, ages 4 years to 8 years old (i.e., PreK3).

ENGINEERING IN THE ELEMENTARY STEM CONTEXT

The incorporation of engineering in elementary schools has been on the rise in the last decade. Several studies have shown positive benefits for students when engineering design challenges are incorporated into elementary classrooms (e.g. Guzey et al., 2017; Toma and Greca, 2018; Wendell and Rogers, 2013). The common dominator amongst these research-based projects has been the use of engineering design challenges.

One of the most widely used interventions is the Engineering is Elementary (EiE) project developed in the USA at the Boston Museum of Science (Cunningham and Lachapelle, 2014). The EiE units use guided inquiry to assist students in designing solutions to challenging engineering problems. The units focus on having students use the engineering design process that includes brainstorming ideas, researching, and gathering information in STEM to help solve a problem, test solutions, and then improve a selected solution. This improvement of the solution allows students to confront failure (or partial success) thus supporting the conception that failure is not a reason to quit but to continue to improve on their solutions (Johnson, 2016). A further description of the units is in the methods section.

Research has shown that use of EiE units can produce an improvement in student knowledge of science (Lachapelle et al., 2017), engineering and technology (Lachapelle and Cunningham, 2007) as well as foster increased student interest (Lachapelle and Cunningham, 2017) and identity in engineering (Capobianco et al., 2015) while decreasing negative perceptions of engineers (Rynearson, 2016). However, most of these studies focused on elementary students enrolled in the third grade and up. Only a handful of studies focus on younger grade levels. Lachapelle and Cunningham (2007) did include second graders in a study looking at changes in understanding of engineering and technology of students in grades 2 through 6. Aquirre-Munoz and Pantoya (2016) and Kelly, Cunningham and Ricketts (2017) demonstrated that the use of engineering design challenges resulted in increased engineering related discourse in classrooms with young children. These studies suggest that continually referring to the students as engineers allowed for increases in student engineering identity. In conclusion, there is a definite paucity of engineering design studies at the early elementary level.

ENGINEERING IN THE ELEMENTARY INTEGRATED STEAM CONTEXT

Focusing only on STEM in elementary classes ignores eliminates the positive aspects that inclusion of the arts can bring to the engineering design process. The arts (i.e., dance, visual arts, music and drama) allow students to use other modes of expression such as kinesthetic and physical models that can facilitate learning in science and engineering (Hadzigeorgiou, 2016). In addition, the artistic design process is very similar to the engineering design process (Bequette and Bequette, 2012). Steele et al. (2006) studied the incorporation of dance into a 5th grade engineering unit focused on energy and wind turbines. They found that the students were able to interpret the transfer of energy in terms of dance movements while the teacher reported that student engagement in science had improved. However, student knowledge of engineering and technology was not assessed.

The visual arts also have a positive impact on engagement and student mental development when incorporated with their science lessons as shown by a Malaysian case study conducted in 3rd grade classrooms (Dhanapal et al., 2014). Jakobsen and Wickman (2015) studied two learning sequences in a 1st grade class studying leaves during a science lesson. In the first sequence, the students studied the leaves using a magnifier while in the second they made pictures of the leaves using a rubbing technique. The authors found that the artistic sequence enhanced the students' meaning-making of the science concepts being studied.

One dramatic inquiry pedagogical approach known as 'Mantle of the Expert' positions students as if they are professional people with expertise who need to engage in inquiry to complete a commission (Heathcote and Bolton, 1995). Over time, students take on the "mantle" of "experts" as they dialogue while engaging in the sort of authentic inquiry that professionals engage in. Two case studies in 4th and 5th grade classrooms that incorporated this dramatic inquiry approach in science classes in New Zealand and the UK found that the students were more engaged and enthusiastic about their science classes (Fraser et al., 2012; McGregor, 2017). The use of dramatic inquiry in science classrooms suggests that students develop a deeper understanding of the science concepts in an inquiry oriented classroom where the students are in greater control of meaning-making (Odegaard, 2003). This idea was supported by a case comparison using dramatic inquiry with 2nd graders learning about the science of snails (Warner and Anderson, 2004). In this study one group was taught with scientific inquiry only methods while the second infused dramatic injury. While the two groups learned the same scientific content, the DI group was much more focused, engaged in more dialogue, and made more detailed observations during the final writing task when conceptualizing scientific ideas. During authentic scientific inquiry instruction students need to engage in discursive Dialogue with their peers (Ford and Wargo, 2011). Thus, research shows that dramatic inquiry seems to be able to create pedagogical conditions that allows for an increase in student dialogue about science which might enhance their identity as scientists but none report gains in understanding of technology and engineering. In addition, the use of dramatic inquiry to teach engineering concepts does not appear to have been reported in past literature.

The components of dance, visual arts, music and drama may be associated with positive benefits when individually incorporated into science classes. Graham and Brouillette (2016) studied the combined effects of these techniques in the 3rd to 5th grades (8 to 10 year olds). They developed an integrated arts/science program called San Diego Teaching Artist Project (TAP) and evaluated its effects using quasi-experimental methods. This program integrated dance, drama, music, visual arts and science within nine hours of instruction. The researchers determined that the students in the TAP program outperformed the control group in terms of knowledge of scientific concepts and teachers reported higher levels of engagement in science over that of the control teachers. Thus at upper elementary grades the incorporation of artistic components can enhance scientific knowledge as well as increase engagement in science when used separately or when incorporated together in a format we will call integrated STEAM (science, technology, engineering, arts (visual, dance, drama) and mathematics.

In summary, while current research concerning the use of integrated STEAM (i-STEAM) in the elementary classroom is present in the literature, the majority of the results are anecdotal in nature with very little integration of the arts with engineering design and dramatic inquiry. In addition, very few studies focus on early childhood years (4 – 8 years of age). This study seeks to contribute robust findings to the literature in these areas by assessing the effects of i-STEAM units that incorporate dramatic inquiry, dance, visual arts and engineering design challenges on students' knowledge of and interest in engineering and technology in early childhood classrooms.

GOALS AND RESEARCH QUESTIONS

Research suggests that there should be positive implications on student concept knowledge by including drama and other arts (e.g., dance, 2 and 3-dimensional art, etc.) into an i-STEAM unit, especially at the younger age groups. This study attempts to fill a void by evaluating the use of curriculum grounded in the engineering design process that incorporates the use of dance, artistic design, physical education and dramatic inquiry (i.e., integrated STEAM) in PreK3 classrooms.

The goal of this study was to (1) examine the effects of the STEAM unit on students' conceptual understanding of engineering and technology; and (2) determine teachers' views about student engagement within the context of the i-STEAM unit. To meet the goals of this study a mixed methods approach was designed that included pre/post student assessments about engineering and technology as well as pre/post teacher interviews. The pre/post assessments evaluated students' knowledge about what engineers do in real life (i.e., fix cars vs design bridges) as

Table 1. High Needs Elementary School Sites (Ohio School Report Card)

School	Year started in the study	Number of Students (K3)	% Economically Disadvantaged	% Black	% Hispanic	% Multi-racial	% at or above Proficient in Science – Grade 5 (2014-15)	% at or above Proficient in Math – Grade 3 (2014-15)	Letter Grade of Performance Index
School 1	2015-16	318	49	88	3	6	26.7	55.3	F
School 2	2015-16	183	100	80	5	8	18.9	63.6	D
School 3	2015-16	175	99.7	83.5	6	5	24.1	57.4	F
School 4	2016-17	173	95.4	22.4	5.8	5.6	37.1	37.1	F
School 5	2016-17	242	100	28.2	5.7	8.5	67.5	65.8	F

Table 2. Number of students participating at each grade level by research question

Research question: engineering (RQ1) or technology (RQ2)	Pre Kindergarten	Kindergarten	First	Second	Third
Engineering (RQ1)	18	20	55	106	91
Technology (RQ2)	0	14	55	77	68

well as what types of objects are considered technology (i.e., lightening vs forks) by engineers. The following research questions guided the study:

1. How do integrated STEAM units impact PreK3 student conceptual understanding of what engineering is?
2. How do integrated STEAM units impact PreK3student conceptual understanding of technology?
3. How do integrated STEAM units impact PreK3student interest in engineering?

METHODS

Participants and Settings:

This study targeted five PreK8 schools in an urban district located in a Midwestern state in the USA. The schools targeted were low achievers in science according to standardized testing earning performance grades of D or F and considered to be struggling schools by their district. After obtaining permission from the targeted school's principals to participate in the project, teachers were recruited to be part of the study. The recruited teachers included self-contained classroom teachers as well as subject specialists. The self-contained classroom teachers usually taught mathematics, science, social studies, literacy and reading to their students. Some of the specialist teachers taught dance, art and physical education (PE) to the students for a few hours each week depending on each individual school. Some reading and mathematics specialists were also part of the teacher team and served as consultants for the classroom teachers within the area of these two subjects. School demographic data is in **Table 1**. The table includes not only the ethnic background of students but also the percentage of students considered proficient in math at grade 3 and in science at grade 5.

In these five schools, a total of 14 teachers participated in the study from PreK to 3rd grade. Convenience sampling was used since the teachers were volunteers and their students were assigned to them by a registrar. **Table 2** denotes the number of students at each grade level who participated in the engineering part of the study as well as the numbers that participated in the technology portion of the study in order to answer research questions 1 and 2.

Classroom Materials and Practices

STEM Instructional Units - Engineering is Elementary

The instructional units from Engineering is Elementary (EiE) were chosen as the basis for our i-STEAM curriculum units (Cunningham and Lachapelle, 2014). The EiE units were designed by interdisplinary teams to incorporate engineering design as well as science standards. The units were aligned with standards across all states in the United States as well as the United States' Next Generation Science Standards (NGSS). The NGSS

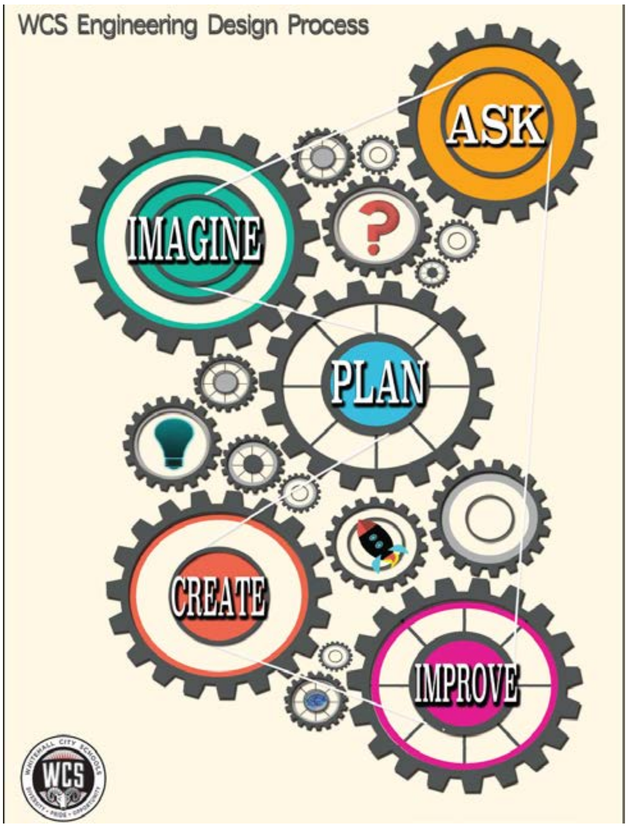

Figure 1. Engineering Design Process developed by Kristy Rothbrush and Whitehall City School District teachers

specifically has standards for both engineering design challenges as well as science standards (NGSS Lead States, 2013). These units utilize story books designed to engage the students in an engineering problem. The books set up the context of the problem and introduce the engineering field as well as relevant vocabulary. In one example unit, the story is situated in the Netherlands and the students are presented with the need to design a windmill to aerate fish ponds. The multicultural settings of the story books support both student literacy, as well as world geography.

This introduction leads to a second lesson that exposes them to the engineering field being investigated. For example, in the case of the windmill unit the students are introduced to egg beaters, glue sticks and mechanical pencils. They are encouraged to consider what a mechanical engineer does and how they might use machines to design a windmill. Next the students are presented with the engineering design process similar to that shown in **Figure 1**.

The students are then introduced to the materials and science concepts needed to be successful in the engineering design project. For example, in the windmill unit the students are given kits with different samples of materials that they can use to investigate how wind would affect the materials when they are used to catch the wind. They are encouraged to build and design sails with the varied materials. The students can then test their sails by fixing them onto Styrofoam food trays which can be set in a small tub of water to see how the wind from a fan affects their sails. At this point they also learn basic physics about how the angle of the sail relative to the wind can affect how fast the sailboat moves across the water. Based on the results of these activities the students can choose the materials they think will work best on a windmill blade.

In the last lesson, students work on designing the windmill blade. To test the blade, it is attached to a dowel rod that can be turned as the blade spins. The dowel rod is attached by a string to a cup. The goal is for the windmill blades to lift as many bolts placed in the cup as possible. After the students build their first prototype, they test it. After the initial testing they are encouraged to identify strengths and weaknesses of the initial prototype and then to improve their design. Thus, the students experience failure and revision as normal parts of the engineering design process.

The books that come with the EiE units require a reading proficiency well above the ability of many of the students in our high needs PreK3 classrooms. Teachers can use many scaffolds to introduce the story to their students including reading only sections to the students, using gallery walks with pictures of the story, and using projected images as the story was read out loud.

Dramatic Inquiry in the Context of the Integrated STEAM Units

Dramatic inquiry was presented to the teachers during their professional development days as an alternative to using the books as an introduction to the units. Teachers using dramatic inquiry positioned the students as if they were already engineers with expertise who were presented with a problem to solve. Through dramatic playing, students took on the role of an engineer. In doing so there was a significant shift in the classroom atmosphere to become both playful and exploratory as well as seriously focused on professional inquiry.

One example of the i-STEAM units incorporation of dramatic inquiry occurred within the EiE windmill unit discussed in the last section. For this unit the students were introduced to *The Boy Who Harnessed the Wind* (Kamkwamba and Mealer, 2012). This true story tells about a young boy in Africa whose village suffered a severe drought. By positioning students as if they were designers in the story world, they took on more ownership of the problem as they engaged in the design challenge. An adult, sometimes the teacher, would take on the role of the young boy, William from Africa, and have students posing as engineers ask questions about the problem his village was experiencing. The village did not have electricity to run irrigation pumps thus their harvest each year was minimal. However, the village usually had a strong wind current. Thus, William wanted to harness the wind to produce electricity. After participating in the asking phase of the engineering design process the teacher would give the young engineering teams the challenge of helping the village by producing a windmill that would harness the wind in order to run the irrigation pumps. The student teams are now part of William's project serving as the engineers who will help the village produce more crops. As engineering teams the students test out different materials that can be used, choose the materials, then design and test their windmill prototypes. These prototypes are then improved based on the data the students collect concerning how well they functioned.

A second example dealt with bridge building. The students were positioned as if they were a team of scientists with expertise in rebuilding after natural disasters. The problem they would encounter was introduced via YouTube: the tragedy of Typhoon Haiyan (2013) in the Philippines. Students created a model of one of the islands in the Philippines archipelago using colored paper (brown to represent land and blue to represent sea) and blocks. Blocks were used to make bridges connecting the islands, hospitals, and airports. Making the sounds and movements of weather and buildings, the students imagined what might happen to the islands when the typhoon arrived. Students then moved the blocks to show how bridges between islands might be damaged and how buildings might collapse. Embodying what might have happened to people inside the buildings the students demonstrated the destruction of the typhoon. They were then asked to brainstorm what help might be needed after the storm. Students suggested hurt people needed transportation to the hospital and food from the airport, but with the bridges broken this would be difficult. With the problem clearly defined, students were then assigned to engineering teams as if they were working for an international group, Engineers without Borders. The engineering teams conducted activities with a variety of materials to determine how much mass diverse types of bridge designs could hold. Then students used the materials they predicted would work the best to build a bridge prototype. The bridges were built and tested to failure. Students then returned to their designs to improve their bridge prototypes to hold as much weight as possible. Using a metric for 'best bridge', student engineers selected what they identified as the best bridges to help the people of the Philippines.

A kindergarten example situated children as experts in playdough. They were given the problem to chemically engineer the best possible playdough for a schoolwide STEM night. A group of parent volunteers arranging the night came to the class and asked the students to participate in helping them make a recipe for playdough. The students were shown the parents failed low quality playdough and were asked to help improve upon it. The students then took on the mantle of chemical engineer and worked to formulate the best playdough possible. They developed a rubric of high quality versus low quality playdough and as a class decided on the three best playdough recipes. They presented these formulations to the parent committee who as the clients chose the one they liked best. The students mass produced the playdough for sale at the STEM night. They had to calculate the cost of the materials and decide upon a price that would allow for some return on the investments. To decide the colors for the playdough they would sell they decided as a group to survey the parent committee (see **Figure 2**). These students took this task very seriously and were engineers in the true sense of the word.

In these examples, the students imagined they were interacting in a real-life engineering context. In all three cases, in their bodies and minds they could 'become' an engineer and develop innovative technologies to help people. This allowed the students to take up the professional position of an engineer who works to improve other peoples' lives through technology.

Using Artistic and Physical Education Specialists to Produce Integrated STEAM Units

Normally, the elementary teacher in a self-contained classroom does not interact with the arts specialists at the school. In the i-STEAM unit, the teachers put into place truly integrated units where both specialist and classroom teachers would participate in an explicit manner to assist students in achieving their engineering goal.

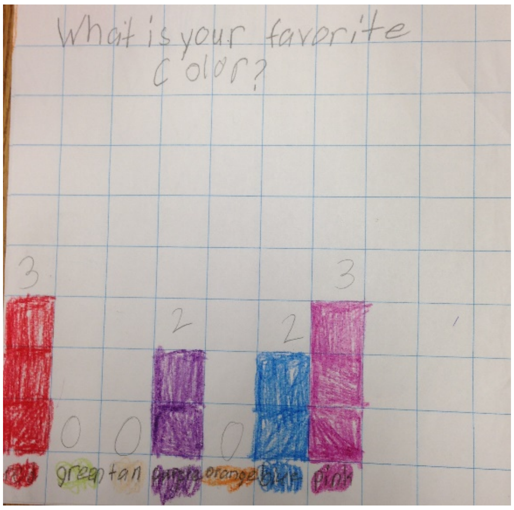

Figure 2. Student graph of survey data to determine the most popular playdough color (Kindergarten Class)

Dance and art teachers connected with the engineering design process as it was very close to that of the design process that is used by art professionals. The dance teachers developed interpretative dance lessons to go along with the units being studied. For example, in the case of the windmill the dance teachers designed an activity that asked the pupils to interpret what would happen to the windmill when wind with different amounts of energy encounters the windmill blade. The students were divided into small groups to develop their dance that they would then perform for the class. The class would need to interpret what the dance meant in terms of the windmill unit and the dance assignment. In another unit on designing playdough in the classroom, the students determined a rubric of high quality and low-quality playdough. When the students went to their dance class, the dance teacher would ask them to develop an interpretive dance that would demonstrate the differences between high quality and low-quality playdough. Students would create dances that would show how the high and low-quality playdough moved.

In the art class the teacher would help students incorporate drawings and sculpture into the unit. For example, in the bridge unit the art teachers were the ones who helped the students' think about the aesthetics of the bridge and ultimately design the bridge models. In another unit using casts, the art teacher taught the students about casting and then the classroom teacher connected that knowledge to the engineering design challenge they were working towards.

The PE teachers in the schools were also active in the integration of the units. The activities they designed for each unit had the students kinetically becoming involved in the activity. To support a unit on parachute design, the PE teacher introduced the students to juggling. She allowed the students to use a number of materials. However, the students had to predict based upon the material testing that occurred during the implementation of their i-STEAM unit inside their self-contained classroom which materials would be best to use when learning to juggle. Thus, the students were able to put into play in a new context their knowledge of hang time.

Teacher Professional Development

The Teacher Professional Development program included two distinct tiers. In the first tier, a team of teachers and university personnel were sent to the Science Museum of Boston to complete a training course to become certified EIE teacher leaders. During this four day experience, the leadership team met each other and began the process of planning the summer PD programs. In the second tier of the PD program, the EiE Leadership team planned and implemented both the summer PD program and year-long follow-up sessions for teachers at their schools. The other members of the team consisted of faculty from science education (one of whom was a EiE certified Teacher Educator), drama education, science, and engineering departments. This interdisciplinary team was able to confirm that the final i-STEAM units developed incorporated the appropriate science, technology and engineering.

The first week of the Summer Institute focused on training the teachers in engineering design projects using an EiE unit led by the teacher leaders from their schools. The participants learned about technology, mathematical problem solving, data analysis, and graphing as well as engineering and scientific practices. These workshops stressed hands-on learning with the participants in student mode. Student mode facilitated the urban school district participants' learning of the content focus as well as introducing them to the hands-on active pedagogy that stresses engineering and scientific practices and increasing student discourse. The workshop incorporated teacher mode discussion as they negotiated how they would implement the units as well as training in the use of Dramatic Inquiry. The first part of the summer workshop culminated with the participants working within school groups to choose

Table 3. Unit Engineering and Conceptual Focus by Grade Level

Grade Level	Units	Engineering Focus	Content Focus
Prekindergarten (4 year olds)	Playdough	Chemical	Properties of matter
Kindergarten (5 year olds)	Pollinators	Agricultural	Structure and Function of Plants
First Grade (6 year olds)	Playdough	Chemical	Properties of matter
	Windmills	Mechanical	Energy and matter and its interactions' Forces and interactions
	Walls	Material	Matter and its interactions; Properties of Matter
Second Grade (7 year olds)	Bridges	Civil	Forces and interactions
	Windmills	Mechanical	Energy and matter and its interactions; Forces and interactions
	Water Filtration	Environmental	Matter and its interactions; Earth and human activity
Third Grade (8 year olds)	Landscaping	Geotechnical	Landforms; Weathering; Erosion
	Bridges	Civil	Forces and interactions
	Machines	Industrial	Simple Machines; Forces and interactions
	Solar Ovens	Green	Energy, fuels and the environment

the EiE modules that align with their state science standards based on grade band as well as cultural fit for the diverse learners at each school site.

The second week of the summer workshop occurred right before the start of the school year. At this session the teachers worked in school based teams to determine how to use the units at their schools as well as to start incorporating the arts into the EiE units. The Summer Institutes were offered in two experiences in an attempt to allow for teacher reflection throughout the summer so that many of their concerns could be answered before the start of the school year. Thus, at the beginning of the second session, teachers had the opportunity to pose questions and concerns that needed to be addressed regarding implementation of the units in their classrooms. During the follow-up year the participating teachers met several times after school and as a whole group on three Saturdays.

At the Saturday follow-up meetings, the participants presented a summary of the implementation of the units in their classrooms and their successes and challenges as well as worked on new ways to incorporate DI into existing EiE units. At the end of the school year cohorts discussed how they could utilize the knowledge of student learning to reflect back over the year to determine what they could do in the future to improve the implementation at each school.

SCHOOL IMPLEMENTATION

During the school implementation the teacher leader at each school met with teachers regularly to discuss implementation issues and to maintain fidelity of implementation of the units at after school meetings. The graduate students on the project also visited the schools to observe the implementation of the units as well as assist in any issues. The graduate students did not participate in the actual teaching of any of the units. In addition, the science education faculty visited the schools throughout the year of the implementation.

Each teacher completed at least one i-STEAM unit. The units and the engineering focus was quite broad. Table 3 lists the engineering and conceptual focus of units implemented by grade levels, at times units were used for multiple grade levels. The units covered many different concepts so they were taught by teachers when it was appropriate to do so. All of the units followed the EiE format described in an earlier section of this paper but some teachers taught the unit straight through all day for several days while others only taught parts of the unit per day or even per week thus stretching the unit over several weeks. The engineering content was consistent across implementations of the same unit, but the length of time varied with each teacher. The science content changed based upon grade level. This was the first year that all the teachers, including teacher leaders, had implemented these types of i-STEAM units. However, two of the teachers in this study were teacher leaders at their school and did experience the three-day EiE training. The teacher leaders taught in two different grade levels, second and third. The third grade teacher leader had prior training in dramatic inquiry.

Research Tools

Student Conceptual Assessments – What is Engineering? and What is Technology?

The students were given two assessments to test their conceptual understanding of engineering and technology. The assessments were designed to be given prior to the unit as well as a post assessment. If students were absent for either assessment they were not asked to complete them. The teachers were asked to give the assessments a week before and a week after the unit was taught. The units were taught at various times throughout the school year to best align with the school curriculum. Teachers selected units appropriate for their grade levels and curriculum needs. Since students at different grade levels participated, a variety of EiE units were taught. As a result, no common conceptual assessment was produced to assess students on science content. However, all students completed the pre and post instruction engineering and technology assessments.

The engineering assessment utilized for the study was the "What is Engineering?" assessment produced by the Museum of Science for the EiE project since it had been tested and revised (Lapachelle and Cunningham, 2014). This instrument was initially assessed using 1126 third and fourth grade students attending public schools located in a midwestern state located in the United States. Each survey item showed a picture and a textual description of an activity kids might think an engineer would engage in. The students were asked to circle "yes" if an engineer would do that or "no" if an engineer would not. The yes and no answers were converted to a 1 or 0, respectively. These scores were totaled and used in the factor analysis as well as being analyzed for internal reliability. The Cronbach alpha score determined for this assessment was 0.881. An exploratory factor analysis was conducted by Lachapelle and colleagues' (2012) using a principal components analysis (PCA) with oblimin rotation. The factors determined by the factor analysis included works with electronics (i.e., develops cell phones), works with construction (i.e., roofs houses), works with non-electronic (i.e., develops better bubble gum), works with the environment (i.e., designs ways to clean polluted air), repairs or installs items (i.e., installs cable), or industrial (i.e., driving a truck). These factors accounted for 49.37% of the variance they observed.

The final assessment presents students with 19 activities engineers can participate in. For example, the students see both a picture of a person driving a truck with the words "drives a truck" under the picture. The students then are asked to circle which pictures contain an activity in which engineers would engage. The following activities are examples included on the assessment:

1. Develop better bubble gum
2. Steer ships
3. Fix headlights on a car
4. Drive trains
5. Develop smaller cell phones
6. Invent warmer kinds of cloth

A number of these highlight known misconceptions that students have about engineering. For example, draw an engineer studies have shown that student's think that engineers would drive trains or build houses (Capobianco et al., 2011).

The technology assessment utilized for the study was the "What is Technology?" assessment produced for the EiE project since it had been used to compare STEM student performance (Lachapelle and Cunningham, 2007). This instrument underwent validity and reliability testing with elementary students (Lachapelle et al., 2013). The instrument was judged to have strong construct validity. To test for reliability paired pre and post assessments were collected from 550 students in grades 3 to 5. The students took the post assessment after completing an EiE STEM unit appropriate for their grade level. The pre assessment Cronbach's alpha was 0.729 while the post assessment alpha was 0.858.

The technology assessment used in this study has a set of 20 pictures. The pictures consist of items that may or may not be considered as examples of technology. The students are asked to circle which items are examples of technology. The following items are examples from the assessment:

1. Wind-up toy
2. Bird
3. Volcano
4. Fan
5. Windmill

Since the ability levels of students may not have allowed for easy reading of either of these two assessments, teachers could opt to read the descriptions of the activities and names of the technology aloud to the students and have them select yes or no. In lower level classrooms, a card sort was provided as another option for assessing preliterate children. The card sort had detailed pictures of either activities that engineers might participate in or pieces of technology or non-technology placed on 3x5 cards. Students were asked to place the cards that showed an activity an engineer might do on the "yes" card or the "no" card. The results were then tallied by counting the number of cards in each location that were correctly placed and well as the types of activities. The outcomes of both of these types of assessments in the younger grade levels were combined with other scores in the final scores seen in **Table 3** and **4**.

Teacher Interviews

A subset of the participating school's teachers' were interviewed in the context of focus groups prior to the professional development they attended in the summer and again after the implementation year. The interviews were semi-structured such that there were a standard set of questions used for both pre and post interviews, but the interviewees also guided where the interview went based on their comments.

Table 4. Code book

Main code	Sub codes/Definitions
Teacher Collaboration	Student Collaboration – discussion of students working together as a team to complete a design challenge
	Teachers discuss working together on STEM activities
Cross-curriculum	Teachers discuss ability of students to relate their design challenge to other subjects
Teaching methods to engage students	Engineering – methods used to develop students' engineering cognition
Engineering Design Process (EDP)	Teachers discuss the use of EDP in the classroom either as an entire process or a specific step of the process (such as failure)
Student Interest in Engineering Challenges	Teachers discuss student interest/response to engineering challenges.

Table 5. What is Engineering? Assessment Results

	Grade levels				
	Pre-K	K	1	2	3
Pre test Average	9.06	9.21	7.93	7.01	7.44
Post test Average	11.50	17.11	11.13	10.43	13.18
Mean of Gain	2.44	7.9	3.20	3.42	5.74
Number of students	18	20	55	106	91
Std dev	3.22	3.84	4. 07	4.49	5.25
p-value	.005	.000	.000	.000	.000
Effect size (Cohen's *d*)	0.71	2.71	1.16	0.82	1.38

The interviews were conducted in focus groups consisting of one to five teachers. The focus group format allowed teachers who were accustomed to working in an integrated fashion to provide more detail about their experiences. The focus group interviews were recorded and transcribed. All transcriptions were checked for accuracy by the researchers.

All interview transcripts were coded by members of the project team using a grounded theory approach (i.e., constant comparative method) where meaning was derived from the data (Glaser and Strauss, 1967). The open-coding consisted of segmenting the transcript into sentences, selecting each sentence and commenting with a word or phrase that captured the sentence meaning. After coding (one pre-transcript and one post-transcript), a computer macro developed by Fredborg (2013) was used to extract coded segments into a separate document. Initially, two researchers completed this task and then were able to compare their individual coding to find similarities in the transcripts. This process led to the creation of a codebook, consisting of sixteen codes with corresponding definitions (Porter, West, Kajfez, Malone and Irving, 2018).

This initial code book was then turned over to two different researchers who individually attempted to use the codebook with two additional transcripts after they had been re-segmented into idea chunks. During this process the researchers developed additional codes and sub codes that they thought should be added to the codebook using grounded theory (Strauss and Corbin, 1990). After they discussed the transcripts they agreed on deleting several main codes and added sub codes. In addition, the definitions were expanded. The final codebook had 12 main codes with 20 sub codes.

These two inter-raters then coded all seven of the transcripts. Their coding was compared for inter-rater reliability using Cohen's Kappa. The Cohen's Kappa for all the transcripts was 0.723, an adequate level for analysis. However, the inter-raters then compared any codes upon which they disagreed and arrived at a consensus on all codes. Thus, the final agreement was 100%. For this paper a sub section of the codes was analyzed to answer the research questions. **Table 4** details the five main codes utilized in this analysis, as well as their respective sub-codes.

FINDINGS

Conceptual Assessment: What is Engineering?

Five schools and 14 teachers participated in the pre/post assessment entitled: What is Engineering? Statistical tests were performed between the average pre and post test scores to determine the effect of the i-STEAM units on student conceptual understanding of what engineers do. Paired *t*-tests were conducted for each grade level. The results were significant for all five grade levels. Through the use of a Games-Howell test, it was determined that the pre tests across grades were not statistically significant from each other. The effect sizes in each grade level are considered large (i.e., a shift of 0.8 of a standard deviation) with the smallest effect of 0.71 showing a high moderate effect (Cohen, 1988). The overall findings from the five elementary schools are presented in **Table 5**.

The assessment items were categorized based upon the groupings determined by Lachapelle and colleagues' (2012) factor analysis study discussed in the methods section. The factors analyzed in this study include the following: works with electronics (i.e., develops cell phones), works with construction (i.e., roofs houses), works

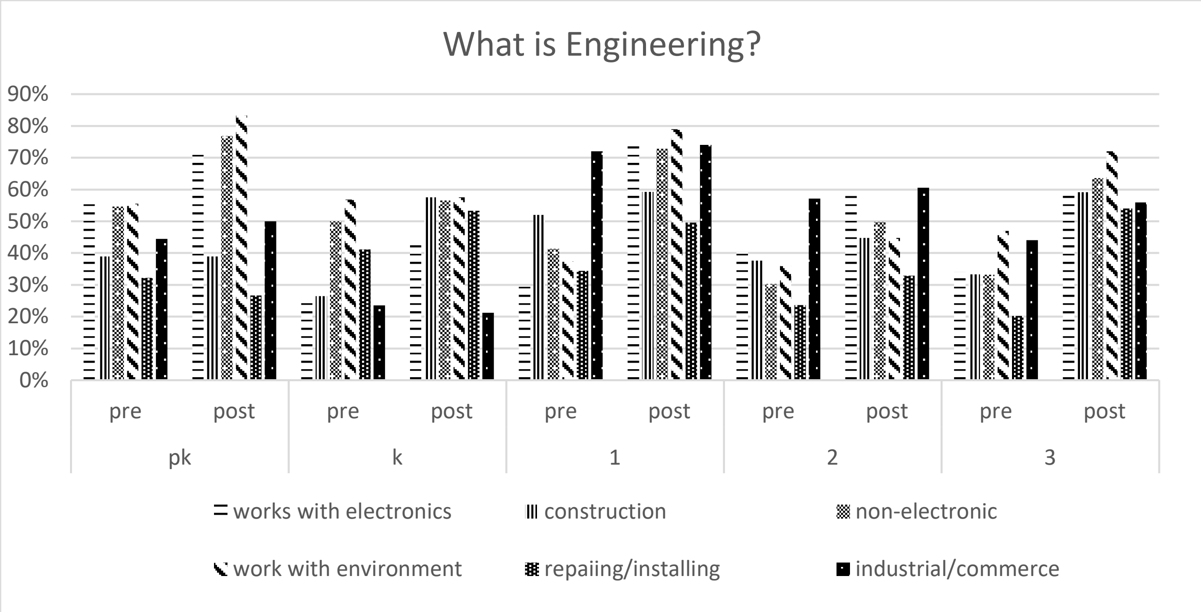

Figure 3. Student Conceptions about What Is Engineering?

Table 6. What is Technology? Assessment Results

	Grade levels			
	K	**1**	**2**	**3**
Pre test Average	9.21	10.98	9.70	9.93
Post test Average	12.43	13.75	11.84	16.06
Number of students	14	55	77	68
Mean of the Gain	3.21	2.76	2.14	6.13
Std dev	3.77	3.39	5.05	4.95
p-value	0.007	0.000	0.000	0.000
Effect size – Cohen's *d*	0.94	0.85	0.52	1.78

Table 7. Items in Technology and Non-technology Categories

Electrical	**Natural**	**Non-electrical**	
Computer	Volcano	Bonnet	Broom
Mp3 player	Bird	Sandals	Basket
Cell Phone	Oak tree	Running shoes	Handheld fan
Keyboard	Dandelion	Piano	Wind-up toy
Game controller		Bicycle	Roller blades
		Windmill	

with non-electronic (i.e., develops better bubble gum), works with the environment (i.e., designs ways to clean polluted air), repairs or installs items (i.e., installs cable), or industrial (i.e., driving a truck). In **Figure 3** the pre and post scores for each category can be seen by grade level. **Figure 3** demonstrates that there was improvement in students' conceptual understanding of engineering and across grade levels a greater percentage of students considered engineers to work with not only electronics but also non-electronics and the environment. However, student misconceptions about what an engineer does seem to be difficult to shift since students continue to believe that engineers repair cell phones, build roofs and drive trucks for a living. In many cases, these particular misconceptions were enhanced by the units.

Conceptual Assessment: What is Technology?

Four schools and 11 classrooms participated in the pre/post assessment entitled: What is Technology? The students were enrolled in kindergarten through the 3rd grade. Paired *t*-tests using pre and post assessment scores were conducted for each grade level. The results were significant for all four grade levels. A Games-Howell test was used to determine if the pre test scores were significantly different across grade levels. The pre tests across grades were not statistically different from each at the $p<0.01$ level. The pre to post effect sizes in each grade level except for the 2nd are considered large effects (Cohen, 1988), with the 2nd grade demonstrating only a moderate effect size. The number of students from each grade level can be seen in **Table 6** along with their average pre and post test score.

The technological and non-technological objects featured on the assessment were grouped for analysis into three categories as used by Lachapelle et al. (2013) in a study with grades 3 -5. The three categories were electrical

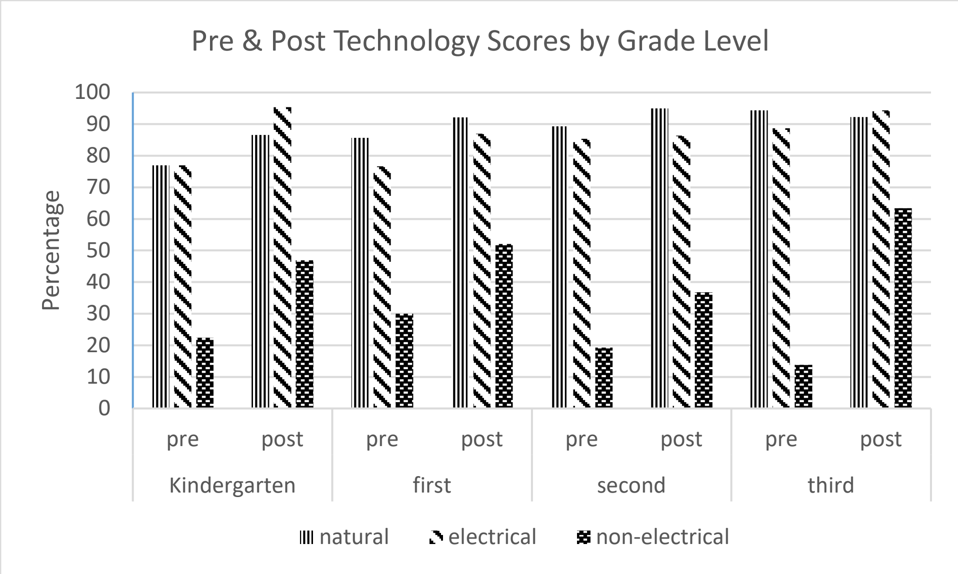

Figure 4. Pre and post Technology Scores by Grade level and category type

Table 8. Normalized Gain Scores (<g>) by grade and technology sub-score

	Grade Level			
	Kindergarten	First	Second	Third
Natural	0.11	0.45	0.53	-0.38
Electrical	0.80	0.44	0.07	0.50
Non-electrical	0.32	0.31	0.22	0.58

technology, non-electrical technology and natural non-technology items and **Table 7** shows the items in each category.

Figure 4 shows that at all grade levels the student post test ideas about technology move towards more correct conceptions and at all grade levels the students are mostly correct about non-technology and electrical technology. At the time of the pre test, students at all levels have less than a 30% chance of recognizing these items as a type of technology. These findings are similar to technology research with 3rd through 5th graders (Lachapelle et al., 2013; Solomonidou and Tassios, 2007). The students had the most difficulty classifying the non-electrical technology items at all grade levels. However, the third graders experienced the greatest jump in this area with a 49% increase in ability to classify non-technological items. However, the third graders also had a much lower pretest in this category. Therefore, to further analyze this situation the average normalized gain was calculated for each technology sub-score by grade level (Hake, 1998). These gain scores are in **Table 8**. The normalized gain was chosen since it differentiates between the amount students learned vs how much they were able to learn based on their pre test scores. Thus it is independent of the pre test score at each grade level. The normalized gains over 0.4 can be seen to occur at different points in each grade. For example, kindergarteners (5 year olds) have the greatest shifts in categorizing electrical technology, first graders (6 year olds) have the greatest change in natural and electrical, while second graders experienced the change in the natural category. However, the third graders greatest gains are in the category or electrical and non-electrical. The third graders actually experienced a drop in the natural category. Unfortunately, the technology assessment items were not evenly divided between the categories with only 4 items in the natural category, 5 in the electrical category and 11 in the non-electrical category.

If the non-electrical technology is further categorized into clothing, household technology (i.e., broom and basket) vs mechanical (i.e., wind-up toy) technology the findings across grade level can be seen in **Figure 5**. When comparing these non-electrical technologies, one finds that students have a tough time distinguishing that clothing and household objects can be technology. Mechanical objects are easier for them to recognize as technology. However, by third grade the students seem to have a stronger grasp of these concepts on the pre assessment compared to the other grade levels. However, there was a large decline in third graders classifications of household objects pre to post. Although the i-STEAM units improved students' conceptual understanding of technological vs non-technological objects overall; the findings suggest that students are still having difficulties distinguishing non-mechanic types of objects.

Teacher Focus Groups:

To determine if there were differences in teacher's comments pre to post the statements transcribed from each focus group were coded and then the percentages of difference coding types were computed. This was done since some focus groups simply talked much more than others. Thus, the proportions of comments being assigned each

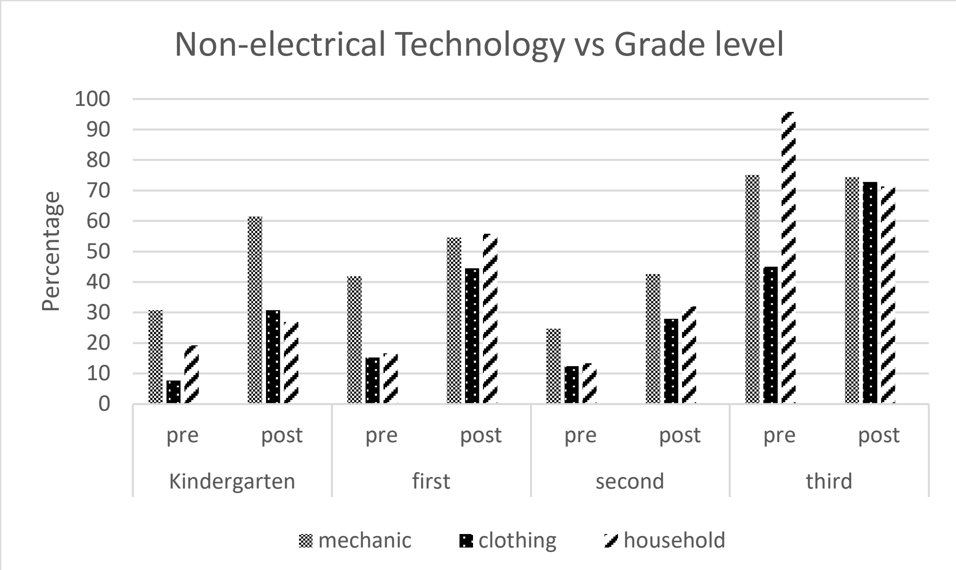

Figure 5. Non-electrical Technology by grade level

code allowed for a macro level look at differences pre to post. This method allowed us to be able to focus on the differences between the two sets of focus groups.

Collaboration, Cross-curricular Activities and Fidelity of Implementation

When looking at the codes focused on collaboration and cross-curricular activities there was no change in the number of codes pre to post. However, there was a large difference in the substance of the comments. In the pre-interviews the comments about teacher collaboration were mostly general in nature and not STEM specific. For example, teacher 1 said in the focus pre-interviews:

> "I think we always share ideas, like if we find something that's really creative, oh, do you want to do this kind of thing, you know."

However, in the post interviews they were much more specific and targeted towards STEM. For example, teacher 2 said:

> 'We have a group of ten people who (…) worked together to help (….) school learn about engineering design process.'

One school did a bridge building unit across all grades in the school thus fostering collaboration between teachers and students. As one specialist at that school stated in the post interview about the relationship between classroom teachers and specialist teachers:

> Yes, it really helped, I think, bond their relationships. Because as an art teacher or a gym teacher, it's just you take your kids and you go. And it's your free period, it's your planning period, you don't stick around to see what's going on. But they were involved together, working together to support those students as they were working on their projects.

Several teachers made comments about how they changed their class instruction in terms of cross-curricular activities due to the project allowing for students to experience cross-curricular connections. Such as:

> "I know that I added literature in ways that I not necessarily would have prior to this unit." T1

> "And I made more of a point to talk about the engineering design process when we were doing other things, including writing. And so, I'd put the thing up on the board and we'd talk about each of the steps that we worked through in order to get things done." T5

> 'I also worked with social studies as an integration part of it. Not only place and geography. But also, timeline and specifying what would happen [if] things changed, if we change one variable in time. What might've happened, so I used it different ways.' T3

> 'Our third grade art [teacher] she also had them doing bridges while we were doing bridges.'T4

While many teachers mentioned integration in the pre-interviews the comments focused mostly on integration of math and science except for one, where the teacher said:

> "I'm the art teacher and I do a lot of "read alouds that integrate science into art. So, they first see a book and we talk about what we learned, and then they create something about it." T6
>
> And,
>
> "We talked about the process of clay and the science of clay and the chemical change that happens with clay, and then they create sculptures out of it." T6

Thus, prior to the i-STEAM project, students did not experience cross-curricular activities where teachers of different disciplines were explicitly working on the same project. At best prior to the i-STEAM units, individual teachers might attempt to do an activity like the clay pot suggested by the art teacher that integrated the concepts within their individual classrooms. From the interviews we can see that the implementation of the i-STEAM units produced greater collaboration across classroom and specialist teachers in the elementary schools.

Student Interest in Engineering

The differences in the proportion of statements dealing with student interest and use of EDP between the pre and post interviews was quite large (5% vs 20%, respectively). As two teachers said in the post interview

> "The improved process, yes. Yeah, we did that for several days, because they just, they were so determined to get it. They all got the windmill to spin, but then it was the lifting up the weights. And so, they were so determined to get it to lift weights. And so, they were so into it and I couldn't tell them no, so we worked on it far longer than planned and pushed other things. So, I mean they loved it. Loved it." T1
>
> And….
>
> 'They're just designing up a storm and they loved it.' T7

In the pre-interviews the mentions of the engineering design were usually attached to students building something and no discussion of the EDP steps such as improvement phase. Thus, the i-STEAM units seemed to pique students' interest in engineering as perceived by their teachers.

GENERAL DISCUSSION

Students Develop a Greater Understanding of Engineering and Technology

The use of the integrated i-STEAM unit supported significant improvement in PreK3 students' conceptual understanding of engineering and technology. Overall, there was on average a 55% increase in student understanding of what engineers do, and a 36% increase in their understanding of technology. The effect sizes per grade level for both assessments exhibited generally large effects.

Unfortunately, the scores on both assessments cannot be compared to other interventions using the Engineering is Elementary STEM units as there are no published articles to our knowledge that show average scores per grade level and in the studies we found grade levels were usually collapsed together. Lachapelle et al. (2011) reported the technology pre and post scores for third graders in an internal report. The assessment used in the report was similar to the one used in this paper, both had 20 questions, but some objects were slightly different (for example, their assessment had a picture of an ecosystem where ours did not). In addition, the students in both studies are from urban school districts located in the Midwest of the United States. The report showed a shift in assessment scores from 8.7 to 11.0, a 26% increase overall. The third graders using our i-STEAM unit showed an increase on average from 9.93 to 16.06, a 61% overall increase. This large increase in the third grade was very much due to the large normalized gain third graders had in categorizing non-electrical technological objects. However, it is difficult to point out why this might have occurred. In the third grade multiple units were taught; however, second grade also taught multiple units. Therefore, it is not a dosage effect. The only teachers who had additional training were the teacher leaders and two of them participated in this study. However, they taught in two different grade levels. The other possibility for the large effect size in third grade is that teacher leader in this level had had previous training in dramatic inquiry in terms of literacy. Therefore, the prior training in dramatic inquiry could have caused the greater effect. All of the curriculum unit effect sizes demonstrate the powerful impact that the integrated STEAM units may be having on students above and beyond that of typical STEM units.

Students' Misconceptions of Engineering and Technology Show an Overall Decline

All students demonstrated increases in their conceptual understanding of technology from kindergarten to 3rd grade. Students had the greatest difficulty recognizing clothing and household items as pieces of technology especially from grades K to 2. These are new findings as early elementary students have not been assessed previously in this area to our knowledge.

Student misconceptions about engineers being fixers and installers continued to surface both pre and post the i-STEAM unit. The unit did produce a shift in student understanding that engineers are involved in the design of non-electronic items, however, several misconceptions especially in the area of clothing and household technology remained and, in some cases, increased. This dilemma may have occurred because while the students learned about real engineering work via the units, their misconceptions were not specifically addressed. For example, if a class did not use an i-STEAM unit that focused on clothing or household technology then these misconceptions would not have been addressed. In **Table 3** the units taught did not focus specifically on household technology except for the playdough, and solar ovens, all of which used common household items in their construction. All of these units except for solar ovens occurred at the lower grade levels and then only in one classroom. This might have caused the third graders to demonstrate the negative change in household technology shown in **Figure 5**. None of the units focused on clothing as a technological advance. This should be an avenue of future unit and lesson development.

Students Develop Greater Interest in Engineering

Using interviews, we were able to show that the i-STEAM units did indeed produce greater collaboration between teachers. In addition, the teachers perceived that student interest was heightened due to the enactment of the i-STEAM units. The proportion of comments concerning student interest and work with engineering was four times greater in the post interviews.

The use of the i-STEAM unit allowed the students to not only experience the engineering design process but to also see it enacted in multiple contexts from art, dance to literature. We believe, these experiences allowed students to see the importance of engineering thus piquing their interest. In many cases the students had difficulty disconnecting from the process and not continuing to improve their designs. As one teacher said: 'They were mad at me when I sent [*them*] home.'

CONCLUSIONS AND IMPLICATIONS

This study is one of the first to demonstrate how dramatic inquiry, dance, visual arts and physical education can be incorporated into STEM units that focus on the engineering design process. In addition, the data demonstrates that these types of units can be quite successful even with our earliest elementary grade levels.

By implementing these integrated i-STEAM units with our younger students, we should be able to nurture their interest and understanding of engineering and technology at the primary educational level. It may not be surprising that the students achieved so well in this context since it parallels the use of techniques appropriate for their developmental age and learning. Our work suggests that engineering units with dramatic inquiry and art infusion should be introduced across the grade levels. This study demonstrates that the pre test scores across grade levels for engineering are not significantly different from each other implying that students may not learn about these important topics outside of school hours. By increasing the number of young children interested in engineering, we may be able to sustain their interest across the grade levels and contribute to a growing number of college students succeeding in STEM majors. At the very least, the students will be able to appreciate the skills they learned and possibly transfer their perseverance in engineering into other disciplines.

LIMITATIONS

The main limitation of this study is the ability to generalize across context since the number of participants is limited and they are all from Midwestern urban schools in the United States. However, the results do demonstrate the possibility of this pedagogy to impart an understanding for engineering and technology. Researchers might consider a quasi-experimental study in the future by adding a control group. The other limitation is that the students were not assessed for changes in aspirations towards future careers in engineering or science. Therefore, the study could have been improved by conducting interviews with the student participants to further gauge their understanding of engineering and technology. In addition, if a technology assessment is used it should be developed such that the questions are balanced across types of technology (i.e., mechanical vs clothing). These suggestions might be an excellent addition to future studies.

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Social Learning with Mobile Devices in Preschool Classrooms

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ABSTRACT

How do prosocial sharing behaviours of preschool-aged children progress or diminish when interacting with mobile devices? Participants include five children (ages 3-4) within a preschool setting in Vancouver, British Columbia. Design-based research and video ethnography were used for qualitative and quantitative data collection and analysis. Data collection included two researcher cameras for participant observation as well as multiple personal point of view cameras (Snapcam Ion) worn by participants. To record observations of sharing, the Observational Measure of Prosocial Incidents (OMPI) was used. Procedures included a teaching intervention for data collection and analysis: 1) Reading *Mine,* a digital story*,* 2) Demonstration of *Chatterpix Kid*, and 3) Limited iPad-to-children ratio using *Chatterpix Kid* to animate pictures taken. Nuanced in various ways, results indicate a higher frequency of incidents of prosocial behaviours compared to nonsocial or antisocial behaviours when interacting with mobile devices. The research underscores the importance of investigating children's uses of mobile devices and the utility of point of view wearable cameras.

Keywords: preschool-aged children, prosocial behaviours, science and technology education, mobile devices, cameras

INTRODUCTION

Challenges of prosocial behaviour are pervasive across STEM education. This article addresses children's (ages 3-4) prosocial behaviour with iPads in a preschool setting. With a focus on technology, mobile or tablet devices, such as iPads, and smartphones are increasingly used in a variety of settings. A number of researchers associate negative effects resulting from over-exposure to technologies, such as attention deficits, cyberbullying, physical inactivity, and selfishness (Adams and Thompson, 2016; Clayton et al., 2013; Papadakis et al., 2018; Rosen et al., 2013). While, media and technology (M&T) have been associated with negative effects, there is also ample evidence of positive outcomes. These include: deeper or higher level learning, increased motivation, more independent work, and increased confidence and curiosity (Bullock et al., 2017; Flewitt et al., 2014; Herodotou, 2018; Lynch and Redpath, 2014; Zhou and Yadav, 2017). As we move into the third decade of the 21st century, with M&T ubiquitous in early childhood education (ECE), it is especially important to empirically investigate children's interactions with devices. Relatively few studies have explored the impacts of STEM, and in particular of technology, on young children between the ages 2-5. Although some research has been conducted analyzing how young children share technology (Medvin et al., 2000; Muller and Perlmutter, 1984), for the most part this research focuses on computers, prior to the prevalence of mobile devices. Mobile devices can impact learning at various times and spaces (Chang et al., 2018). Technology, mobile or tablet devices, such as iPads, and smartphones are increasingly used in diverse settings. In the UK, children, at an average of eight years old, use the internet and have their own smartphones or tablets (Mascheroni and Ólafsson, 2014). Children understand how to "watch videos" and "play games" (Dashti and Yateem, 2018, p. 128; Mascheroni and Ólafsson, 2014, p. 16). The emergence of prosocial behaviours can be positively or negatively shaped by the introduction of technology (De Simone, 2013; Edwards and Pye, 2011; Luzón, 2011); however, it is unclear how prosocial sharing behaviours of young children are reinforced or suppressed through the use of devices, such as iPads.

This empirical case study explored how preschool-aged children interact and share with each other while using iPads. In particular, *how do prosocial sharing behaviours of preschool-aged children progress or diminish when interacting with mobile devices?*

BACKGROUND: SOCIAL LEARNING THEORY

Social learning theory addresses a series of social processes through which we learn and learn how to act (Bandura, 1977). In particular, it addresses learning by observing another person's behaviours and the consequences of that behaviour. For example, a younger sibling may observe that the consequence that happens when their older sibling does not do their chores is to have their video game taken away. People are able to control their own behaviour, but that behaviour is often influenced by environmental factors. Self-regulatory capacities are generated from cognitive supports and consequences for one's own actions (Bandura, 1977). Self-regulation is the "self-directive process by which learners transform their mental abilities into academic skills" (Zimmerman, 2002, p. 65). In other words, self-regulation means being self-aware, intrinsically motivated, and having the skill to apply knowledge appropriately. For example, early in education children are taught to walk and not run in the hallways at school and at some point, most children are able to regulate themselves without reminders from their teachers to walk not run.

Overall, social learning theory suggests that learned behaviour from an authority figure or cultural norms dictates behaviour (Berkowitz, 2004; Eisenberg, 1982). In other words, when we behave a certain way, for example sharing a cookie, we aren't doing this because we have learned about sharing; rather we share because that is what the teachers or parents expect us to do. According to Bierhoff (2002), socially approved behavioural modeling is strongly linked to prosocial behaviour because "[behavioural] models frequently function as releasers that contribute to the performance of prosocial behaviour in children" (p. 74). Children may have learned a behaviour previously but now rely on modeling or cues to facilitate behaviours. The next section explains in more detail the manifestations of prosocial behaviours with preschool-aged children.

Preschool Children's Prosocial Sharing Behaviours

Prosocial behaviours are defined as one person or persons acting to benefit another or others. Children's prosocial behaviours include: sharing, comforting, helping, and cooperating; and generally, emerge in preschool years (ages 2-5) (Belacchi and Farina, 2012; Eisenberg et al., 2014; Radke-Yarrow et al., 1976). Researchers have noted that parents and teachers prompt children to share by the age of two (i.e., food, toys, etc.) (Brownell et al., 2013; Chernyak and Kushnir, 2013; Dunfield, 2014; Paulus et al., 2013). Young children readily share physical objects, such as toys or stickers (Hay et al., 1999; Paulus et al., 2013) and can self-initiate sharing with computers (Medvin et al., 2000; Muller and Perlmutter, 1984). However, it is unclear *how* prosocial sharing behaviours of young children are reinforced or suppressed through the use of mobile devices, such as iPads.

Children exhibit a variety of behaviours at a very young age by mimicking adults' (e.g., their parents) actions, or language and watching every move that everyone makes around them (Bandura, 1977; Dashti and Yateem, 2018; Plowman et al., 2008). These early behaviours are positive *and* negative. They could be learning please and thank you. They could be learning how to pick their nose. They could be learning how to say hello or goodbye or learning curse words. Learned behaviours are based upon the social situation in which they are immersed. In many social situations, whether at home, interacting with television and videos on devices, or at school, children are learning both prosocial and antisocial and aggressive behaviours.

Early in life, reciprocity occurs between parents and children that supports early socialization skills (Feldman et al., 2013). In particular, Feldman et al. (2013) studied 86 families observing mother-child and father-child reciprocal behaviours. They found that children who had experienced mother-child or father-child reciprocity demonstrated lower aggression and higher social competence in social situations at school. As infants become toddlers, sharing reciprocity transfers from parents to the inclusion of peers. Children are more likely to share with their friends as they progress throughout ECE (Paulus and Moore, 2014; Warneken and Tomasello, 2013). Moreover, friendship and reciprocity are affiliated with the balance of social contracts in which children expect a reciprocal friendship (Fujisawa et al., 2008).

As children enter preschool and ECE classrooms, their exposure to social situations expands. Essential to cognitive development, socialization skills or lack of can create a division amongst children (Brownell et al., 2013; Dunfield, 2014; Eisenberg-Berg, 1981; Vygotsky, 1978). Children who exhibit prosocial behaviours may not want to affiliate with antisocial or aggressive children and often form friendships based on peer affiliations (Dahl et al.,

Table 1. DBR characteristics definitions and usage in research study

DBR Characteristic	Characteristic Defined	How it was used in our research
Interventionist	This approach introduces an innovative intervention design or practice to disrupt current education practices (Anderson and Shattuck, 2012)	A designed teaching intervention was created using iPads to encourage sharing behaviours through designed sharing scenarios.
Pragmatic	This approach allows researchers to connect theory to practice (Reimann, 2011; Wang and Hannafin, 2005)	Based on social learning theory, a designed intervention connected the theories to practice in ECE classrooms.
Collaborative between researchers and practitioners	This allows researchers and teachers to co-construct the intervention by identifying the problem and designing the solution (Dede, 2005; Jacobson, 2014; Wang and Hannafin, 2005)	An early pilot stage was designed and tested with teachers.[1]
Iterative and flexible	There are multiple iterations or phases that are flexible as they may change throughout the study based on analysis and feedback from the researchers and participants (Anderson and Shattuck, 2012; Design-Based Research Collective, 2003; Jacobson, 2014).	Each phase allowed for analysis and feedback from the researcher, as well as the participants. Iterations allowed for analysis and refinement until a 'successful' intervention was developed.
Integrative	This method employs a multi-methodological approach that collects data through multiple methods that is both formative and summative (Barab and Squire, 2004; Edelson, 2002).	Data were collected iteratively to allow for formative assessment, which influenced the following phases and iterations.
Situated in authentic 'real-world' settings	This method captures data outside of traditional laboratory settings, in authentic classrooms or in situ settings (Brown, 1992). Authentic 'real-world' settings can be single classrooms, multiple classrooms at a school, or even multiple classrooms across a district or districts.	Data were captured in authentic ECE classrooms. The two sites that were visited were the children's ECE classroom that they attended every day or every other day.[1]

[1] Note: This paper focuses on one group of preschool-children only.

2013; Eivers et al., 2012; Fabes et al., 2012; Fujisawa et al., 2008; Liao et al., 2014). In other words, children will share toys with other children who also share toys. Children who display antisocial behaviours often affiliate or play with other peers who also display antisocial behaviours. Peers who are aggressive tend to associate with other children who are also aggressive (Eivers et al., 2012; Persson, 2005).

This section explored prosocial sharing behaviours of preschool aged children in ECE classrooms. The next section will describe the methodologies used for this research.

METHODOLOGIES

Design-based research (DBR) and video ethnography were used for qualitative and quantitative data collection and analysis. DBR was initially developed to refine innovations and create iterative methodologies that link theory to practice (Brown, 1992; Collins et al., 2004). The paradigm has evolved into a methodology for studying innovative learning environments, which often include technologies, in authentic, real-world classroom settings (Sandoval and Bell, 2004). The characteristics of DBR are essential to its use (**Table 1**).

Video ethnography was initially developed to record naturalistic experiences and habits that can be analyzed and re-analyzed (Heath et al., 2010). With the advent of M&T, the concept of space has been transformed from a physical space to an online virtual space. Hammersley and Atkinson (2007) suggest that "ethnographies of digital life itself are important aspects of contemporary social research" (p. 137) and many ethnographers attempt to employ the use of audio and video technologies to support data collection (Creswell, 2013; Erickson, 2011; Erickson and Wilson, 1982; Fetterman, 1989). Video recording devices have become relatively inexpensive and allow researchers to record in 'natural' settings, such as classrooms (Heath et al., 2010). The examination of digital spaces can include: virtual classrooms, social networks, various websites, and blended learning environments. When conducting research with preschool-aged children, video recordings of the ECE classroom should be a part of data collection to understand, explore, and research digital aspects of education. The use of video in qualitative research allows an ethnographer to enhance their study because video recordings have an increased capacity for analysis and manipulation of data, and it is possible to reanalyze footage even after work has been published (Hayashi and Tobin, 2012; Pearce et al., 2010). Using video recordings and manipulating digital data demand "new capabilities and knowledge" that early ethnographies didn't allow (Adams and Thompson, 2016, p. 114). Video enables a "fine-grained scrutiny of moments of social life" (Heath et al., 2010, p. 3), which could be quite limited in a researcher's hand-written notebook in the chaotic setting of the ECE classroom. In the current study, the audio portion of the data was quite difficult to understand because many of the participant's voices had a similar tone, and several had speech difficulties. The video recording assisted in analysis by enabling views of the children's mouth and vocal gestures; transcribing and analyzing footage facilitated an understanding of what was said.

This section described, DBR and video ethnography, the two methodologies used in this research. The next section explains the methods used, including data collection, the participants and ethical considerations, and data analysis.

Figure 1. Participants reading an iPad story with the researcher.

Methods and Data Collection

The study included two researcher cameras for participant observation as well as multiple personal point of view cameras (Snapcam Ion) worn by participants. Field notes, semi-structured interviews, open focus-group discussions, and artifacts from children's drawings and animations on the iPads using the *Chatterpix Kid* app were also collected. *Chatterpix Kid* app was chosen based on the four pillar model of Hirsh-Pasek et al. (2015) and reflective of the rubric from Papadakis et al. (2017) (Ralph, 2017a).

This article reports one scenario, based on the most successful parts of an intervention developed in a prior phase of a larger study (Ralph, 2017b). The scenario had three activities: reading the digital story, *Mine,* researcher demonstration of *Chatterpix Kid*, and limited iPad-to-children ratio using *Chatterpix Kid* to animate pictures taken. In the first activity, the first author read *Mine,* a digital picture book. Participants were asked simple questions (i.e., is this good or bad? OR do you know what an iPad is?) to prompt discussion during the reading. The scenario helped facilitate the interview process and a semi-structured interview was conducted after the story was completed. The children then used the *Chatterpix Kid* app for animating pictures they took. First the app was demonstrated to the children. Once there was a basic understanding of the app, the participants worked with each other to take pictures around the room and animate a mouth within the app to talk. Participants worked independently and in groups of two and three. This scenario ended with children watching their animations.

Participants

Participants were preschool children (n=5) who attended the full day of a 12-month registered ECE preschool program (**Figure 1**). There were three girls and two boys. Convenience sampling was used. Located in Vancouver, British Columbia the preschool accommodates a range of families with diverse ethnic backgrounds and socioeconomic means.

Ethical Considerations When Working with Children

When working with children, it is imperative to consider ethical concerns. Researchers in Canada, as guided by the Tri-Council Policy Statement (TCPS) and university research ethics boards, abide to a code of ethical standards. The ethical standards include: attention to privacy, awareness of potential exploitation, acquiring consent, avoiding deception, and understanding the impact of costs to benefits of research (Dockett et al., 2009; Fetterman, 1989; Graham et al., 2013; Hammersley and Atkinson, 2007; Hunleth, 2011; Musante, 2014). The code of ethical standards applies to all human subjects and each standard must be addressed when working with young children, including: consent and assent, privacy, avoiding deception, and being conscious of potential risks and exploitation. The children were underage; therefore, consent and image/video release forms were signed by their parent(s) or guardian(s). Also, verbal and visual checks were used throughout the study to confirm the child's assent.

Data Analysis

Qualitative and quantitative data analyses were used. NVivo software was used for the qualitative analysis of video data (QSR International, 2016). To record observations of sharing, the Observational Measure of Prosocial Incidents (OMPI) was used (Ramaswamy and Bergin, 2009). The social behaviours of the children were initially divided into the following categories: offering, showing, allowing another child to use an object, and turn taking (Ramaswamy and Bergin, 2009). Multiple levels of coding were analyzed using NVivo software (QSR International, 2016). The initial four codes were insufficient because they did not address non-sharing behaviours repeated by the children across the activities. Nonsocial behaviours were observed when the children worked independently. Antisocial behaviours were observed when the children behaved in ways that opposed sharing behaviours, such as pushing another child away or saying no. Nonsocial was established as different from antisocial. Typically,

Table 2. Codes and subcodes for children using iPads

Event code	Event subcode
Nonsocial behaviour	Work independently
Antisocial behaviour	Pull item away
	Push hand away
Prosocial individual behaviour	Allowing use
	Offering
	Showing
Prosocial group behaviour	Taking turns
	Watch together, researcher controls
	Watch together, participant controls
	Multiple hands holding device
	One participant holds, another participant touches the screen
	Touch screen together
	Speak together

Figure 2. Participants sharing iPads

antisocial behaviours have a negative connotation and sometimes the children would work alone, not to be antisocial or isolated, but rather to work independently. Prosocial behaviours included all of the positive sharing events in which the children would share. For finer grained qualitative data analysis, these three main event codes were divided into subcodes (**Table 2**).

For the quantitative results, SPSS software was used (IBM Corp, 2016) to analyze prosocial, antisocial, and nonsocial behaviours. The data were measured based on statistical frequencies and Cohen's Kappa agreement for inter-rater reliability. Qualitative and quantitative data were triangulated.

Cohen's Kappa was calculated to determine inter-rater reliability through a second coder who coded 10% of a random set of events. Cohen's Kappa represents moderate agreement value at .5, good agreement value at .7, and very good agreement above .8 (Pallant, 2010). Values of Cohen's Kappa indicated very good agreement for nonsocial behaviours (Cohen's Kappa =.85, p < .0005), moderate agreement for antisocial behaviours (Cohen's Kappa =.55, p < .0005), and very good agreement for prosocial behaviours (Cohen's Kappa =.82, p < .0005).

This section described the methods and procedures of this study. It addressed video data collection, ethics approval, and qualitative and quantitative data analysis. The next section explains the results of these methods based on three themes of: nonsocial, antisocial, and prosocial behaviours.

Figure 3. Participants 1 and 2 work independently while other participants work together.

Figure 4. Participant 5 playing with other toys

RESULTS

The results of this study focus on the children using iPads independently from the researcher. The results are based on 206 observed behaviours and clustered into three main categories: nonsocial, antisocial, and prosocial. The following sections will describe the occurrences of these three behaviours.

Nonsocial Observations

Nonsocial behaviours occurred throughout the activity and were exhibited when the children worked independently (**Figure 2**). For the majority of time spent in the activity, the children interacted with each other, but at times they would work on their own. Nonsocial time occurred as there were five devices and three children. This did not allow for pairs or groups of three per device. Perhaps if there were fewer devices or more children, this situation would not occur. However, the number of devices was chosen based on prior research in the larger context of this study (Ralph, 2017b).

Sometimes children did not work with an iPad or with any other participants. They were distracted from the designated research activity and played with another toy (i.e., a chick) (**Figure 3**). They continued to work independently and were not involved in playing with devices. Participant 5 exhibited the most nonsocial behaviours, 8 (3.9% of total behaviours). This may have to do with prior peer affiliations, as Participant 5 did not seem to know the other children as well as they knew each other.

Antisocial Observations

Antisocial behaviours observed were: pushing another's hand aside and pulling an item away (**Figure 4**). The children also displayed antisocial behaviours verbally. For example, Participant 3 pushed Participant 4's hand off

Figure 5. Participant 3 exhibiting antisocial behaviours.

the screen and said, "No, no, no. I want to do it. You do this!" Participant 4 said, "No!" in response. This lead to Participant 3 saying "No, no, no, no. No! I want to do it."

Other antisocial behaviours were verbally expressed using "I want." For example, Participants 1, 3, and 4 said, "I want to do it." When antisocial behaviours persisted, the researcher used verbal cues to encourage sharing, as reflective of a teacher in a classroom. For example, the researcher initiated prosocial behaviours for Participants 3 and 4 by reminding them to "take turns". Verbal cues initiated other prosocial sharing behaviours, such as touching the screen together. If the researcher did not intervene more persistent antisocial and perhaps even more aggressive behaviours would occur. However, as an interventionist methodology, DBR allows for researchers and teachers to act as they would in a traditional authentic classroom setting.

Their antisocial behaviours were not influenced by prior peer affiliations or who their friends were but by more reactionary aggression such as pushing or hitting (physical) or yelling (verbal) (Eisenberg-Berg, 1981; Eivers et al., 2012). Our study found that the children who pushed a hand away or said "no" or "I want" related to maintaining or obtaining control of the mobile device.

In another event of antisocial behaviours, Participant 2 took a picture of Participant 4 and proceeded to animate her photo in the app. He made her photo talk and made noises, such as, "Hootoo! Hootoo! Hootoo!" As the other children gathered around the iPad to laugh at Participant 2's funny animation, Participant 4 was becoming visually upset and began to cover her face and tears welled up in her eyes (**Figure 5**). Participants 2 and 3 exhibited the most antisocial behaviours, 3 (1.5% of total behaviours).

The researcher noticed this right away and intervened by saying, "Wow you are a good model. Good picture," to Participant 4. The encouraging words from the researcher stopped the laughing and caused Participant 4 to smile. The researcher attempted to emulate the practice of the teacher, who would also intervene in this scenario. The behaviour of the children in this situation could have persisted to more bullying tactics or moved on to other victims. More longitudinal studies could identify these behaviours in the future. However, the least frequently observed behaviour was antisocial behaviour with only 9 events (4.4%) and with only minor researcher intervention. The boys were two times (1% of total behaviours) more antisocial and nonsocial than the girls.

Relational antisocial behaviour, such as making fun of someone to intentionally upset them (Liao et al., 2014; Renouf et al., 2010; Ronald et al., 2005; Sutton et al., 1999; Yagmurlu, 2014), only occurred once. The child understood what he was doing because he only targeted Participant 4, the smallest and youngest. However, when the researcher intervened and stopped the behaviour, it did not occur again. In this type of designed intervention research, targeted relational antisocial behaviour, bullying, or cyberbullying is likely reduced because researchers and teachers are present and can intervene in problematic negative behaviours, as is reflective of DBR methods (Brown, 1992; Jacobson, 2014). Even though these antisocial or aggressive incidents did occur, prosocial behaviours significantly outweighed the negative behaviours.

Prosocial Observations

Prosocial behaviours observed included: offering, allowing use, showing, watch together and participant controls, one participant holds while the other touches the screen, taking turns, multiple hands on the device, speaking together, and touching the screen together (**Figure 6**).

All five participants exhibited prosocial group behaviours 146 (70.9% of total behaviours) (**Figure 7**). Participants 4 and 5 did not exhibit individual prosocial behaviours. Overall prosocial behaviours were the most common with 177 events (86% of total behaviours). Individually, Participant 1 exhibited the most prosocial behaviours, 14 (6.8% of total behaviours). For prosocial group measures, Participant 3 exhibited the most prosocial

Figure 6. All participants laughing while Participant 4 covers her face

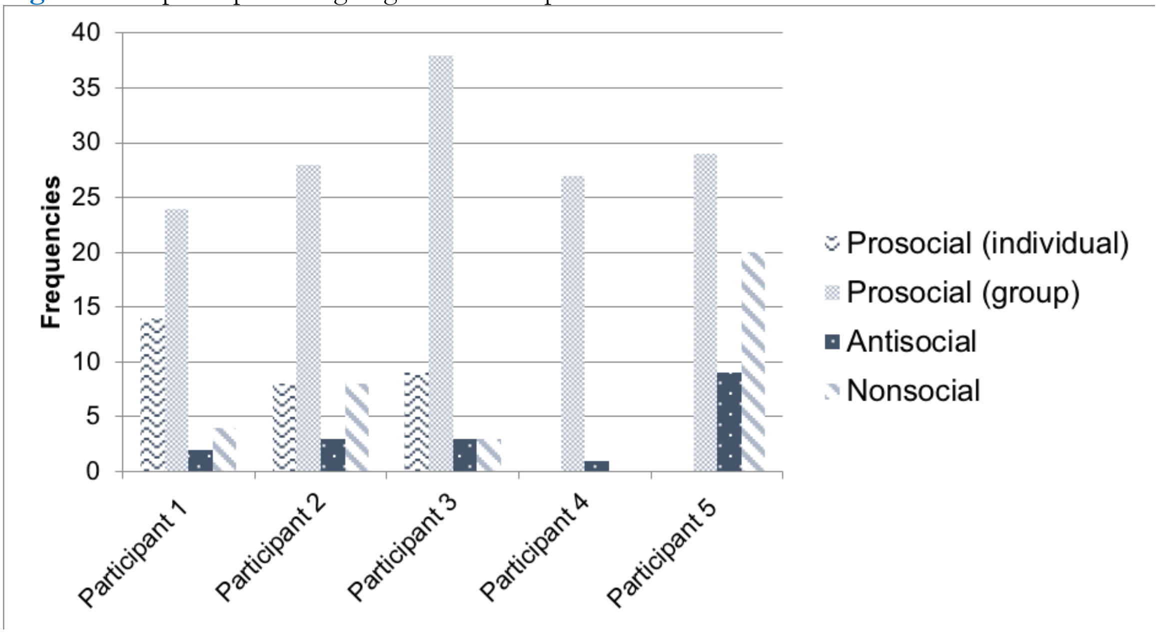

Figure 7. Participant (1-5) social behaviour counts with M&T.

behaviours, 47 (22.8% of total behaviours). On average, the boys exhibited slightly less prosocial behaviours than the girls with 30 to 37 events (15% to 17% of total behaviours).

Figure 8 displays the individual prosocial sharing behaviours of showing, allowing use, and offering. Overall, showing was the most common sharing behaviour displayed, 20 (64.5% of total behaviours). The least common individual behaviour was allowing use, 3 (9.7% of total behaviours). Participants 4 and 5 are removed from the figure as they did not display any individual sharing behaviours.

The children would gather around devices and watch the screen together after an animation was created. They would also sit on the floor together and touch the screen and speak into the device to record their voices together. The children would express the need to share and show their creations. Several times children said "look" and held up their device or pointed to the screen. Showing occurred more frequently when the children discovered the ability to add stickers to their screens. For example, Participant 1 said, "Look I got 2 butterflies."

This research supports other findings, as the children initially chose their groups based on prior relationships (Dahl et al., 2013; Fabes et al., 2012; Liao et al., 2014); however, the children in this study were seen to share with other children based on resource availability. There were three iPads and five children. The children shifted to

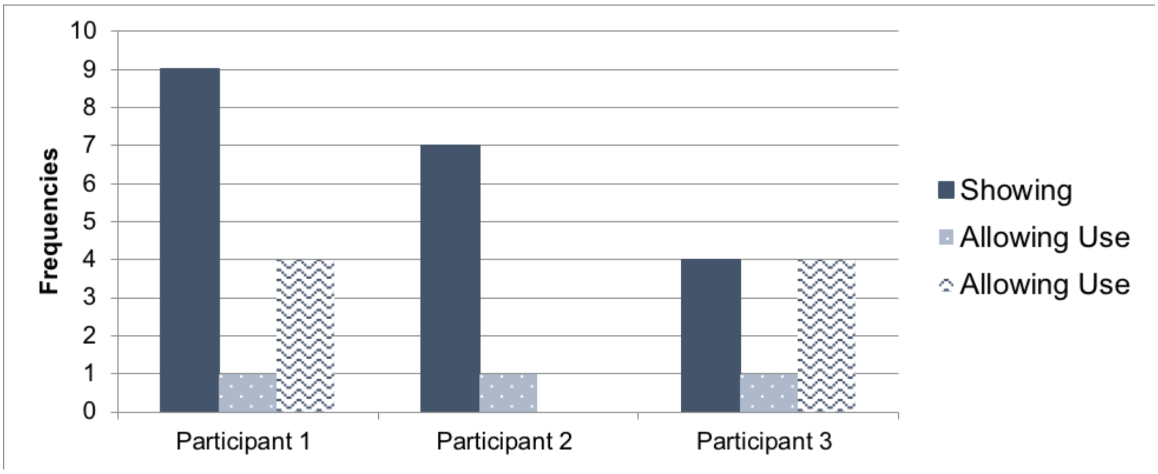

Figure 8. Individual prosocial behaviours per participant (1-3).

different groups based on who was in possession of the iPad and did not choose partners based on prior peer affiliations. In other words, the children clustered around who controlled the mobile device not just their friends.

This section described the results observed during this research, reflective of non, anti, and prosocial behaviours. The next section will discuss these results in more detail.

DISCUSSION

To reiterate, this research explored how preschool children's prosocial sharing behaviours progress or diminish when interacting with mobile devices. The themes that arose from this study include: videos for research with preschool-aged children and using mobile devices in ECE STEM education.

Videos for Research with Preschool-aged Children

As stated above, this study used video ethnographic methods to capture behaviours. Two cameras were used to reduce the partial representation that a video ethnographer captures (Hammersley and Atkinson, 2007). At times, the children moved out of shot and the researcher camera did not capture the behaviours (**Figure 9**). When the children moved out of the shot of the researcher camera, the *Snapcam Ion* continued to capture what the children were doing and was essential to data analysis (**Figure 10**).

At times, the point of view footage was dark or obscured when the children would lie down on the carpet or their shirt would cover the camera lens and some footage was lost. However, a significant amount of video was captured and supported the research camera. Even though there were times when the image was obscured, the cameras continuously captured the audio and the cameras acted as individual microphones. Some researchers recommend that children can capture their own footage in participatory research (Kullman, 2012); however, participatory research in which children use their own cameras is typically for children over six years old. This can extend research that encourages children to understand children's perspectives when using mobile devices (Dashti and Yateem, 2018). It allowed us an insight to the point of view of preschool-aged children. We can use these recordings to gain new knowledge to enhance our ethnographical understandings (Adams and Thompson, 2016). Wearable cameras with preschool-aged children are fairly unique in educational research and should be tested in other ECE settings.

Additionally, some of the children had speech difficulties, making it even more difficult to decipher what they were saying. When transcribing and coding, NVivo and video recordings were central to understand what was being said. Children would often speak at the same time, as is often the situation in preschools. If the voices were similar or unclear, watching the video footage allowed the researcher to look at the children's mouth and vocal gestures to see what words they were trying to say. Although some parents or research ethics boards may be hesitant about children being recorded, researchers need to emphasize the importance of capturing children's authentic behaviours on camera.

As mentioned earlier, video enables a "fine-grained scrutiny of moments of social life" (Heath et al., 2010, p. 3). This is very true for a preschool classroom. There are micro-moments that occurred and were captured. Whether children were saying it or moving around, we were able to capture the day to day, moment to moment experiences of these children. And we were also able to watch and rewatch the footage to get a better understanding of the occurrences. The ability to rewatch also allowed us to improve upon the OMPI measures (Ramaswamy and Bergin, 2009), which can be tested in future research.

Figure 9. Participants 2 and 5 move out of researcher camera shot

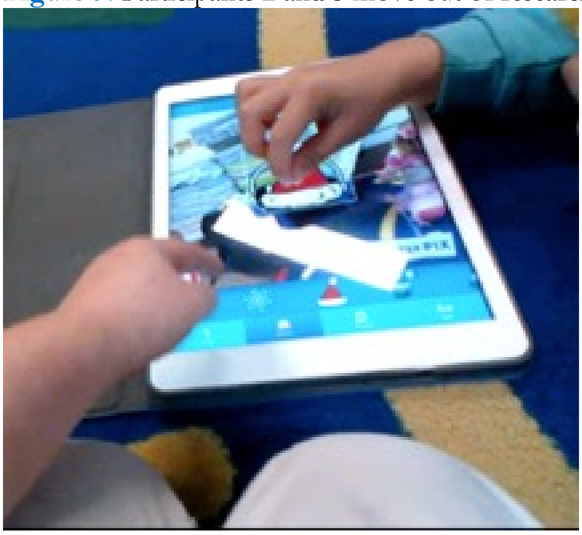

Figure 10. Participant 2's point of view camera

Using individual and other cameras in ECE is one way to include more technology into ECE STEM education. This research suggests more inclusion of mobile devices, which will be discussed in the following section.

Using Mobile Devices in ECE STEM Education

Using technology in ECE has been controversial and yet we are seeing an increase in use and systemic changes in policy. As research and policy suggest there are concerns for too much screen time, especially as many apps focus on drill and practice, which promotes low level and rote memorization style learning (American Academy of Pediatrics (AAP), 2014; Papadakis et al., 2018). Policy for preschool-aged children focuses on limitations of technology, while there is an increasing emphasis on STEM education and more devices in primary and secondary schools (Thibaut et al., 2018). These policies are slowly having an impact on STEM teacher education in post-secondary institutions (Ralph, 2016).

If changes from kindergarten to grade 12 are occurring, changes in ECE should follow. Some changes in ECE have begun to occur based on the National Association for the Education of Young Children (NAEYC) and the Fred Rogers Center. They promote the use of interactive M&T and interdisciplinary approaches like STEM to support the development of children and assist ECE teachers to support learning goals. Even the American Academy of Pediatrics (AAP)'s has changed its initial policy of banning and limiting devices to support the importance of M&T to "allow children opportunities to discover and make choices… to explore, imagine and problem-solve" (American Academy of Pediatrics (AAP), 2016). Even with our small sample size, our research can inform these policies and STEM in ECE. In particular, our research uses STEM practices to promote social learning.

Social learning is a significant part of ECE, as preschool children are not only learning academic skills in these classrooms, but also social skills, including how to share and collaborate in STEM activities. Additional research is needed in the development of STEM literacies using devices, especially as more interactive apps are developed. In particular, Papadakis et al. (2018) suggest the challenges of designing appropriate interactive apps for children, as they need to be designed considering their developmental and cognitive abilities as well as content, including limited text. Even if an educator is informed and able to use the four pillar model or app rubric (Hirsh-Pasek et al., 2015; Papadakis et al., 2017), there are over 2.2 million apps and in particular over 300,000 for children (Apple, 2017). And as Papadakis et al. (2018) also suggest, there are no regulations on what defines an educational app. This is challenging to educators, policy makers, and researchers; however, this current research study and Hirsh-Pasek et al. (2015) alongside of Papadakis et al. (2017) can inform and assist in making these decisions.

This section discussed the results relating to video for research and mobile devices in preschool classrooms. The next section provides limitations, directions for future research, and a conclusion for this article.

LIMITATIONS AND FUTURE RESEARCH

The bias of this study was reduced through the triangulation of the qualitative and quantitative data. Also, to reduce bias, another coder contributed to inter-rater reliability. To reduce bias in the future, the researchers could invite the second coder to do the initial coding with the researcher as the second coder or apply a formal training process until inter-rater agreement is at least .8. A secondary limitation was the small sample size, which reduces generalizability or transferability. One reason for the small sample size was the use of video recordings. Some parents were not comfortable with their child being recorded and did not participate in the study. However, qualitative approaches tend to have smaller sample sizes, which allow for rich data. Also, sample size issues were reduced through the detailed coding which identified high frequencies of observed behaviours/events and multiple iterations until the intervention was deemed successful (over 200 observed behaviours). Small sample size concerns may not be an issue for those considering transferring the design or research findings to other settings that can include larger groups of children and more frequent iterations.

Another limitation was the time frame, as the results measured more short-term effects of the intervention. Due the limited scope of the school year, we do not know the long-term effects. For future research, ideally the intervention would be initiated at the beginning of the school year and continue throughout the year or following children through 2 years in a preschool program.

Implications for future research also include an extension to diverse ranges of ECE centres and a variety of new apps, as well as exploring other variables, and innovating with video ethnographic methods. First, the 'successful' intervention should be carried out in ECE centres in other settings, including rural settings in a range of different countries. In terms of other apps, research can explore the impact of more apps chosen based on the Hirsh-Pasek et al. (2015) four pillar model or on the Papadakis et al. (2018) rubric. Additionally, more research needs to be conducted in the development of digital literacy using tablet devices, especially as new and more interactive apps are developed.

The use of video ethnographic methods was imperative towards data collection and analysis. Although some Research Ethics Board representatives and parents may disprove of the use of wearable, point of view video with young children, the use of researcher and wearable cameras in this setting to capture moment-to-moment behaviours and interactions was imperative to interpreting linguistic and social situations. The *Snapcam Ion* cameras were essential for the data analysis as they captured individual perspectives, with close-up microphones and footage that may not be captured in a researcher camera's angle. This also can assist in exploring children's perspectives while using digital technologies (Dashti and Yateem, 2018). What does interaction with digital technologies mean to the children, from their point of view?

Finally, this type of research on prosocial behaviours should be conducted within differentiated preschool and ECE settings (e.g., Child Care, Head Start, High/Scope, Montessori, Reggio Emilia, and Waldorf).

CONCLUSION

We need to ask what does interaction with M&T mean to the children, from their point of view? What are the most relevant roles for M&T in ECE (Petrina, Feng and Kim, 2008)? How do ECE teachers establish balance between experiential STEM activities and virtual activities, including virtual reality devices (Ralph, 2017b)? This research focused on prosocial behaviours, with an intention of informing educational and familial decisions on children's access to and interactions with M&T. Using DBR, the specific intent was to test interventions that inform the design of activities and apps that facilitate children's prosocial behaviour. In addition to employing devices for an expansion of children's STEM literacies, a challenge is developing scenarios that forefront prosocial behaviours and sharing.

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Experimentation Abilities in Kindergarten Children with Learning Problems

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ABSTRACT

In the present study we investigated experimentation abilities of children with learning problems in early childhood education, i.e. kindergarten (4–6 years old). An essential part of science education is learning via the scientific method, of which experimentation is the central component. We studied experimentation abilities in 28 kindergartners with mild learning problems and compared them to 45 grade-matched typically developing kindergartners. Moreover, it was examined to what extent linguistic and cognitive factors in experimentation could be identified. The results showed that the kindergartners with learning problems scored lower on experimentation, which was due to the difficulty they experienced when the number of variables increased. There was an overlap in performance of kindergartners with and without learning problems, which showed that some kindergartners with learning problems performed similar to typically developing kindergartners on the experimentation task. Similar cognitive and linguistic factors in experimentation were found as in their typically developing peers, namely nonverbal reasoning and grammar. The results suggest that kindergartners with learning problems show a developmental delay in experimentation. Instructional methods for children with learning problems should take these individual differences and developmental delay into account. An important conclusion is that kindergartners with learning problems can design multivariable experiments.

Keywords: scientific reasoning, experimentation, learning problems, kindergarten, individual differences

EXPERIMENTATION ABILITIES IN KINDERGARTEN CHILDREN WITH LEARNING PROBLEMS

To be prepared for the modern, technology-rich society, it is expected that students learn to think independently and critically (Fischer et al., 2014). This mindset has given rise to an increase in the number of students in subjects, such as science, technology, engineering, and math (STEM; Freeman et al., 2017). This so-called STEM education revolves around scientific reasoning abilities. Scientific reasoning consists of generating hypotheses, designing experiments to test them, and evaluating evidence to draw conclusions (Klahr, 2000). Independent learning can take place when these abilities are mastered (Andersen and Garcia-Mila, 2017). In addition, it can help students think critically about presented results or their origin. Therefore, science education should be accessible from early childhood for everyone, including children with learning problems. It is important that the consequences of learning problems are recognized and that appropriate education is provided. This means that the difficulties of children with learning problems should be identified, their education should address specific strategies and skills and their transfer to other domains, address linguistic and cognitive limitations, and use implementation features that optimize instructions (Fuchs and Fuchs, 2015). It is therefore relevant to identify the capabilities of children with learning problems in science education. A key aspect in providing effective science instruction to young children is that it should be based on the child's needs and talents, and even more so for children with learning problems (Alber-Morgan et al., 2015). Children seem to learn more from instruction that is contextualized (Boaler, 1993). For experimentation, the instruction can be contextualized by providing hands-on activities (Bay et al., 1992). In a similar hands-on context, it has been shown that kindergartners without learning problems can correctly design experiments with multiple variables (Van der Graaf et al., 2015). The present study investigated the experimentation abilities of kindergartners (age four to six years old) with learning problems with the aim to assess their difficulties in the specific ability of experimentation (in comparison with kindergartners in mainstream education), to assess the individual differences in order to identify linguistic and cognitive limitations, and to provide suggestions to optimize instruction.

Experimentation

Experimentation abilities consist of designing and conducting experiments. The experiments should be designed in such a way that one can learn from the outcome of the experiment. Experimentation is one of the core abilities of scientific reasoning (Klahr, 2000). Inhelder and Piaget (1954) were sceptical on whether kindergartners could design multivariable experiments correctly, as they refer to themselves as causing the effect. In a similar vein, the ability to incorporate a second variable in their predictions and explanations was expected to be too difficult (Siegler and Chen, 1998), as would be the ability to adjust their own beliefs (Wilkening and Huber, 2004). However, in a dynamic assessment, when kindergartners receive feedback based on their performance, it has recently been shown that they can learn how to design multivariable experiments correctly (Van der Graaf et al., 2015). This indicates that kindergartners can understand the control of variables strategy (CVS). The CVS states that to find out what the effect of a single variable is, one has to manipulate that variable, while controlling all other variables (Chen and Klahr, 1999).

Individual Differences

Individual variation in scientific reasoning in primary school children can be explained to a large extent by cognitive and linguistic abilities. First, experimentation abilities in kindergarten have been shown to be related to inhibition, verbal working memory, and grammar (Van der Graaf et al., 2016). Inhibition can aid in the rejection of intuitively derived misconceptions (Kuhn and Franklin, 2006), which helps to focus on the task at hand, namely to find out the effect of a variable. This way, inhibition allows children to learn to design experiments using the correct strategy (i.e., CVS). Second, verbal working memory and grammar were found to be related to experimentation (Van der Graaf et al., 2016). Verbal working memory was suggested to be a prerequisite to monitor the use of the CVS and applying its rules to determine the settings of the variables. In the case of children with learning problems, verbal working memory might be a critical factor in scientific reasoning, given the limited capacity of the working memory of children with learning disabilities (Siegel and Ryan, 1989). A third feature of science education is that it requires understanding of complex grammatical structures that are needed to ask questions, explain, predict, and reason (Dawes, 2004). Fourth, vocabulary has been linked to performance on an experimentation task. The gains on a transfer task, in which CVS also had to be applied, were found to be partly explained by vocabulary (Wagensveld et al., 2015). Finally, measures of reasoning (verbal and deductive) have been found to explain performance in experimentation and scientific reasoning in general. In 12-year-olds (Siler et al., 2010), and 10- and 12-year-olds (Wagensveld et al., 2015) verbal reasoning was found to explain learning to understand and apply the CVS. In another study, a paper-and-pencil test was used to assess 10-year-olds' scientific reasoning, including how to design experiments (Mayer et al., 2014). In that study scores on this questionnaire were related to performance on a problem-solving task in which planning and deductive reasoning are involved. Whether linguistic and cognitive limitations apply to kindergartners with learning problems during experimentation the same way as for kindergartners in general or differently is yet unknown. The individual differences in experimentation of kindergartners with learning problems can provide useful guidelines for implementation of optimized instruction, so all children can practice relevant skills, such as independent and critical thinking, during scientific activities in the classroom.

Children with Learning Problems

Within the field of science education, Alber-Morgan et al. (2015), argued that children with learning problems should profit from the educational pursuit of excellence, just as their typically developing peers. This can be a challenge as adolescents with learning problems score lower on standardized science achievement tests than regular developing adolescents (Anderman, 1998). With respect to experimentation abilities in children with learning problems, hands-on experimentation has been shown to stimulate learning (Bay et al., 1992). After five sessions of guided hands-on experimentation, a group of nine- to 12-year-olds with learning problems remembered more about the material and applied their experimentation skills more easily to other situations, compared to five sessions of direct instruction. In other words, it seems to be conceivable for children with learning problems to use scientific discovery learning in order to learn domain-specific knowledge and domain-general experimentation abilities.

In a study by Van der Steen et al. (2012) the understanding of scientific concepts in three- to five-year-olds was investigated with a task that consisted of two different topics, namely air pressure and running balls. The experimenter demonstrated to the kindergartners how the materials worked. An assessment with scaffolding was used, which included follow-up questions depending on the child's level of understanding. The results revealed that the kindergartners with learning problems showed comparable understanding overall to the typically developing kindergartners. However, the kindergartners with learning problems gave more incorrect answers in general and they gave fewer answers that indicated a higher level of understanding. As in this study the experimenter demonstrated the materials to the kindergartners and coded their verbal understanding, it remains to be investigated to what extent kindergartners with learning problems can design hands-on multivariable experiments. It might be the dynamic assessment that is suitable for kindergartners with learning problems. The instructional design should manage the cognitive loads of the students with learning problems when performing inquiry learning activities (Lee and So, 2015). This can be done by step-by-step instruction to introduce multiple concepts, by showing worked examples, and by keeping a clear focus on the learning objective (Lee and So, 2015). The assessment of experimentation abilities can also be dynamic, such as using a step-by-step instruction by introducing the variables one by one (Van der Graaf et al., 2015). In addition, they used feedback with worked examples in which the experimenter explained whether an experiment was correct and why. When the design of the experiment was incorrect, the experimenter also explained and showed how it should have been set up. Finally, the kindergartners were provided with clear research questions, which they were asked to answer by designing an experiment. To what extent kindergartners with learning problems have difficulties in using the CVS during experimentation remains to be investigated, as well as whether they experience the same difficulties as kindergartners in mainstream education.

The Present Study

In summary, kindergartners can design multivariable experiments when dynamic feedback is given (Van der Graaf et al., 2015). This instructional approach might have benefits for kindergartners with learning problems (Lee and So, 2015). When it is known whether this instructional method proves fruitful for kindergartners with learning problems, it can be used in science education of children with learning problems. Various cognitive and linguistic factors have been related to scientific reasoning of children in primary school. It remains to be investigated which cognitive and linguistic factors can explain their performance on an experimentation task. Therefore, the present study investigated experimentation abilities in early childhood of kindergartners with learning problems compared to typically developing kindergartners. Moreover, individual differences in experimentation of kindergartners with learning problems were also investigated, as these might provide guidelines for teaching of experimentation abilities. It was expected that kindergartners with learning problems would score lower on the experimentation task than kindergartners in mainstream education. Furthermore, it was explored to what extent cognitive measures (nonverbal reasoning and inhibition) and linguistic measures (vocabulary, grammar, and verbal working memory) would predict the performance of kindergartners with learning problems on the experimentation task.

METHOD

Participants

A total of 73 kindergartners participated in this study. The study included 28 kindergartners with learning problems from one elementary school for special education, and 45 kindergartners from an elementary school for mainstream education. The average age of the participants with learning problems was 6 years and 4 months (SD = 11 months). Among them were 13 girls and 15 boys. Children without learning problems were in the first year of kindergarten, 14 girls and 8 boys, or the second year of kindergarten, 9 girls and 14 boys. These kindergartners were aged 5 years and 4 months on average (SD = 8 months), and had already participated in a preceding study of the authors in 2015. Comparing the two groups, the kindergartners with learning problems were older, $t(70) = 5.53$, $p < .001$, Cohen's $d = 1.34$, and scored lower on the standard score of non-verbal reasoning, $t(70) = 5.19$, $p < .001$, Cohen's $d = 1.25$, than kindergartners without learning problems.

All children were in the first or second year of kindergarten. This is a program of two years in the Netherlands before formal education starts. The special education school did not differentiate between these two kindergarten years. In the Netherlands, there are three types of primary education: mainstream education, special education for children with mild learning problems, and special education for children with severe learning problems (Ministerie van Onderwijs, Cultuur, en Wetenschap [Ministry of Education, Culture, and Science], 2014). In this study,

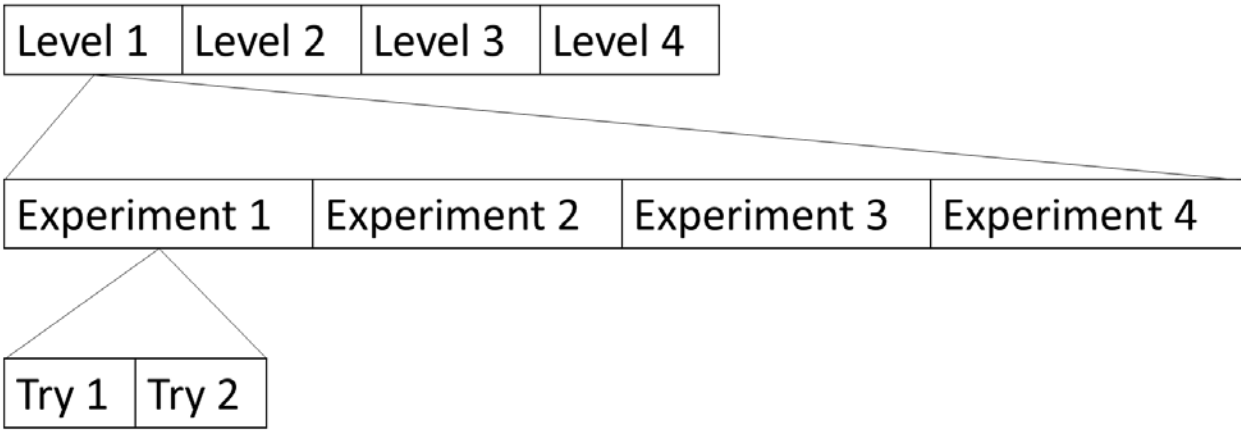

Figure 1. A schematic overview of the levels and experiments in the experimentation task

kindergartners from special education schools for children with mild learning problems participated. These schools have the same end terms as mainstream schools. This means that the children with mild learning problems can continue their education at a regular high school. However, the children tend to have an extended trajectory of finishing school. An independent committee judges whether a child can enter special education for children with mild learning problems. The committee consists of at least one child psychologist (Ministerie van Onderwijs, Cultuur, en Wetenschap [Ministry of Education, Culture, and Science], 2016).

Materials

Experimentation

To measure experimentation abilities, two wooden ramps were used (cf. Chen and Klahr, 1999). The kindergartners were asked to design experiments with the two ramps. Each ramp had four different variables, namely the weight of the ball (light/heavy), starting position on the slope (high/low), steepness of the slope (steep/flat), and the surface of the slope (rough/smooth). To investigate a single variable, the kindergartners had to use the CVS to design experiments with multiple variables correctly. The kindergartners were asked to set up an experiment in order to answer a research question. The research question was given by the experimenter and was about studying the effect of one of the variables. To design an experiment, the kindergartners set up both ramps. Using two ramps has the advantage that the result can directly be seen, because one ball might roll further as the effect of manipulating a variable.

We used the same task procedure as Van der Graaf et al. (2015). This included a gradual build-up of the number of variables, and dynamic feedback was used. There were four levels of difficulty, see Figure 1. At Level 1, the kindergartners were allowed to set only one variable, at Level 2 two, at Level 3 three, and at Level 4 all four variables. Whenever at least one of the four experiments at one level was designed correctly, the kindergartner proceeded to the next level, and if not, testing was discontinued. The four experiments at one level each investigated a different variable. There were 16 experiments in total and each variable could be investigated four times (once at each level).

Regarding the dynamic feedback, the kindergartners were given a second try when their first design of the experiment was incorrect. When the second try was also incorrect, the experimenter explained that it was incorrect and why. The experimenter also showed how the experiment should have been designed by setting the two ramps correctly. Whenever a try was correct, the experimenter explained that the try was correct and why. This means that after every trial feedback was given.

Two scores were obtained: an experiment correct and a variable correct score. The experiment correct score was the sum of the correctly designed experiments, with a maximum score of 16. The variable correct score was the sum of the correctly set variables. A point was given when the variable of interest was manipulated (i.e. set up differently between the ramps). Additional points could be scored from Level 2 onwards for each variable that was not under investigation. A point was scored when such a variable was controlled (i.e. set up similarly between the ramps). The maximum variable correct score was 40. The experimentation task is valid and reliable (Van der Graaf et al., 2015).

Nonverbal Reasoning

Two versions of the same task to measure nonverbal reasoning were used in the present study. Since the sample of the kindergartners in mainstream education was tested earlier, they performed an older version of the test (Bleichrodt et al., 1987), while the kindergartners with learning problems performed a newer version of the test

(Resing et al., 2012). The difference between the two versions was that some items were replaced with newer ones. Therefore, we used the standardized scores to compare the kindergartners from the different types of education, and we used the raw scores to analyse the individual differences in experimentation of the kindergartners with learning problems.

The task used was the exclusion task. An item consisted of four abstract figures of which three figures belonged to a single category and one of them was not a member of that category. The category included figures that shared a property, such as the size and number of the dots in the figures. The non-member then had a larger dot or an extra dot. The kindergartners were instructed to identify the non-member by pointing it out. Inductive reasoning was needed to identify the category and deductive reasoning has to be used to find the non-member. The task consisted of 30 items. In the old version, testing was discontinued if four consecutive items were answered incorrectly. In the new version, testing discontinued when four out of five consecutive items were responded to incorrectly. The raw score was the sum of correct responses. Reliability of both versions is good (Bleichrodt, et al., 1987; Resing, et al., 2012). The standard score was the raw score adjusted for age based on a large sample of children to create the standard scores (Bleichrodt et al., 1987; Resing et al., 2012). Standard scores have a mean of 15 and a standard deviation of 5 (Bleichrodt et al., 1987; Resing et al., 2012).

Inhibition

Inhibition was measured using the Head-Toes-Knees-Shoulders-task (Ponitz et al., 2009). The task consisted of two blocks. In the first block the kindergartners were asked to touch their head or toes, but the child's task was to do the opposite. In the second block the task remained the same, but the shoulders and knees were added. Each block consisted of 10 items. Two points were given for a correct response and one point was given when the child corrected itself. No points were given when the response was incorrect (i.e. when the child did respond as asked and thus did not produce an opposite response). The maximum score was 40 points. The task has been shown to reveal significant variability and construct validity with parent and teacher ratings (Ponitz et al., 2009; Wanless et al., 2011).

Vocabulary

Vocabulary was measured using the verbal meaning test (Resing et al., 2012). The child had to choose one out of four figures by pointing it out. The correct figure resembled the word, which was read aloud by the experimenter. If four out of five consecutive items were answered incorrectly, testing was discontinued. The task consisted of 40 items. The score was the sum of correct responses, with a total of 40. Reliability of the verbal meaning test is excellent (Resing et al., 2012).

Grammar

A sentence-repetition-task was used to measure grammatical abilities (Verhoeven et al., 2013). The child had to repeat the sentence, which was read aloud by the experimenter. An example of a sentence was: "My friend wanted to bike to the city yesterday". The sentences increased in length. There were 12 sentences. When the sentence was repeated correctly, two points were scored. When one error was made, one point was given. When two or more errors were made, no points were given. The maximum score was 24. Reliability of this task is excellent (Verhoeven et al., 2013).

Verbal Working Memory

A word-repetition-task was used to measure verbal working memory (Verhoeven et al., 2013). The experimenter read a sequence of words out loud and the child's task was to repeat the words in the correct sequence. The task started with two sequences of two words. Every two sequences, the length of the sequence increased with one word. There were 12 sequences in total. The final two sequences consisted of seven words. When four successive sequences were repeated incorrectly, testing was discontinued. For each correctly repeated sequence one point was scored. The maximum score was 12 correctly repeated sequences. Reliability of this task is excellent (Verhoeven et al., 2013).

Procedure

The kindergartners in mainstream education only performed the experimentation task and the nonverbal reasoning task, while the kindergartners with learning problems performed all mentioned tasks. The kindergartners were tested individually, at their school in a quiet place. The tests were administered in two sessions of about 40 and 10 minutes (mainstream education) or in three sessions of 20 to 40 minutes (kindergartners with learning problems). Sometimes there was an extra break in the sessions of the kindergartners with learning problems, due to deviant behaviour. Each kindergartner was tested by a single experimenter. There was one experimenter for each school. Parents and/or caretakers were approached via the schools. They were informed about the research and gave consent for their children to participate in the present study.

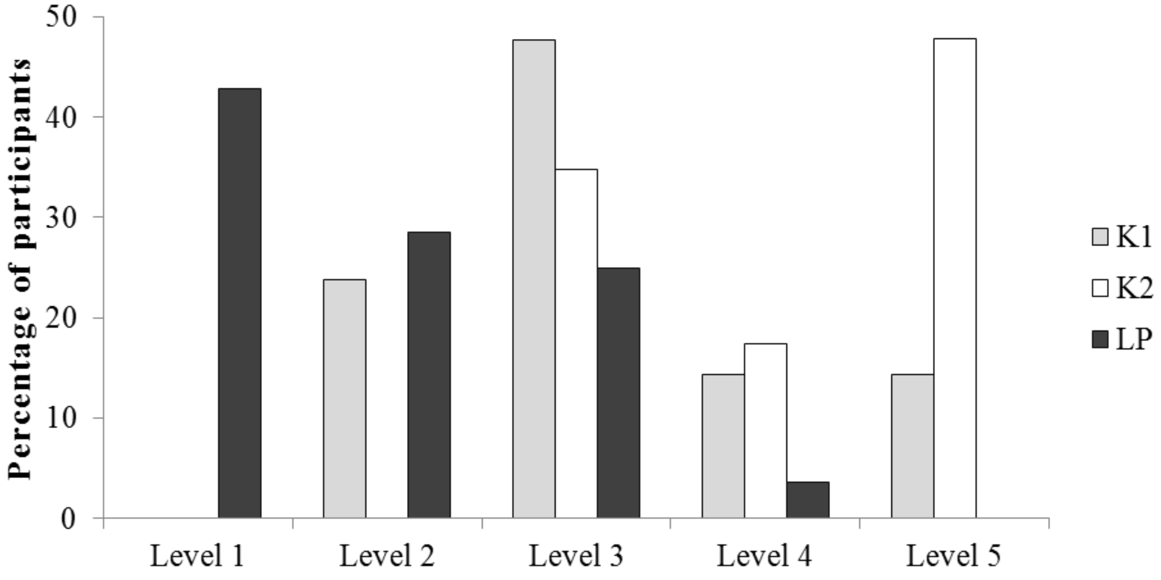

Figure 2. The percentage of participants per group (K1, K2, and LP) and the Level at which testing was discontinued. K1 = mainstream kindergarten year 1, K2 = mainstream kindergarten year 2, LP = kindergartners with learning problems

Table 1. Descriptive Statistics and Contrasts Between Kindergartners with Learning Problems and Kindergartners in Mainstream Education

	Learning Problems		Mainstream education			
	M	*SD*	*M*	*SD*	*p*	Cohen's *d*
Variable correct score	6.11	7.09	28.71	11.49	< .001	2.25
Experiment correct score	2.14	2.41	6.82	3.17	< .001	1.61
Nonverbal reasoning[1]	7.32	5.57	13.61	4.64	< .001	1.25

Note. [1] Standard scores were used for this comparison.

RESULTS

First, the performance on the experimentation task was analysed. Most kindergartners with learning problems could not design multivariable experiments correctly, while most kindergartners in mainstream education could, see **Figure 2.** In **Figure 2**, the number of participants is represented for which testing was discontinued at that level, because no experiments at that level were designed correctly. Level 5 was added as a category for kindergartners that could design experiments correctly at Level 4, so the participants at Level 4 did not design an experiment correctly at Level 4. Some kindergartners with learning problems did design multivariable experiments correctly and about 30 % of the kindergartners with learning problems reached Level 3 and Level 4. To compare the kindergartners with and without learning problems, independent samples t-tests were conducted. The difference in performance with kindergartners from mainstream education was significant, $t(71) = 10.39$, $p < .001$, Cohen's $d = 2.25$ (equal variances were not assumed, Levene's $F = 16.56$, $p < .001$) for the variable correct score, and $t(71) = 6.69$, $p < .001$, Cohen's $d = 1.61$ for the experiment correct score, see **Table 1**. These differences can be considered large, since Cohen's d is larger than 0.80 (Cohen, 1988).

Second, individual differences in experimentation were investigated. Experimentation correlated significantly with two cognitive factors, namely nonverbal reasoning and grammar, see **Table 2**. The correlations with inhibition and vocabulary were approaching significance, $r(27) = .37$, $p = .056$ and $r(27) = .35$, $p = .072$, respectively. Verbal working memory was the only factor that did not show (a trend towards) significance of the correlation with experimentation. The factors were further investigated using multiple regressions. The factors were expected to be positively related to experimentation. As this was a directional hypothesis, one-tailed tests were used to evaluate the independent variables in the regression (Field et al., 2012). To do so, the p-values of the two-tailed tests of the independent variables, provided by SPSS (version 19), were divided by two. The backward-method was used to evaluate the regression models. The first model included all factors. Then, non-significant factors were removed from the model. This resulted in a regression model, adjusted $R^2 = .31$, $F(2, 24) = 6.94$, $p = .004$, with two factors that related to experimentation, namely nonverbal reasoning, $\beta = .41$, $t(23) = 2.32$, $p = .015$, and grammar, $\beta = .33$, $t(23) = 1.87$, $p = .037$.

Table 2. Descriptive Statistics and Pearson's r Correlations of all Measures for Kindergartners with Learning Problems

	M	*SD*	1	2	3	4	5	6
1 Experimentation[1]	6.11	7.09	1					
2 Nonverbal reasoning	17.61	8.50	.54**	1				
3 Inhibition	12.61	13.38	.37†	.47*	1			
4 Vocabulary	22.43	7.09	.35†	.44*	.23	1		
5 Grammar	3.93	2.70	.47*	.36†	.22	.35†	1	
6 Verbal working memory	3.04	1.09	.27	.51**	.14	.17	.55**	1

Note. [1] Experimentation was measured with the variable correct score. ** $p < .01$, * $p < .05$, † $p < .10$.

DISCUSSION

The aim of the present study was to investigate experimentation abilities in kindergarten children with learning problems in order to identify their difficulties in experimentation and address their linguistic and cognitive limitation. The results showed that they score lower on the experimentation task than kindergartners without special educational needs. Nonverbal reasoning and grammatical abilities positively related to experimentation abilities of the kindergartners with learning problems.

About 30 % of the kindergartners with learning problems designed multivariable experiments correctly. On top of that, more than half of the kindergartners with learning problems were capable of performing an experiment in which the effect of a single variable had to be found out. The results revealed that kindergartners in mainstream education score better than kindergartners with learning problems. However, there is overlap in the range of performance of kindergartners with and without learning problems. This is in line with the finding that kindergartners with learning problems perform comparable to typically developing kindergartners, but fewer reach a higher level of understanding (Van der Steen et al., 2012). This indicates that as a group, the kindergartners with learning problems show a slight delay in development compared to typically developing kindergartners.

The linguistic and cognitive factors that could explain variation in experimentation abilities were investigated. Nonverbal reasoning and grammatical ability explained the most individual variation in experimentation. Experimentation as part of scientific reasoning, involves various reasoning processes, such as inductive, abductive, and deductive reasoning (Dunbar and Klahr, 2012). Indeed, results from the present study indicated that nonverbal reasoning was related to experimentation. With respect to learning problems, nonverbal reasoning can be assessed in a screening procedure as it strongly relates to cognitive abilities, such as scientific reasoning in the present study. Another study has found that nonverbal reasoning is a predictor of later reading disabilities, even when other linguistic factors are controlled for, such as phonological processing (Fuchs et al., 2012). This way, early childhood education can be adjusted to the needs and talents of the students (Alber-Morgan et al., 2015).

Based on previous studies, it was expected that linguistic abilities related to experimentation (Van der Graaf et al., 2016). The present results revealed that grammatical ability related to experimentation. They share two properties; recursion and transition. Experimentation involves the recursive application of the correct design strategy to the different variables, and the strategy has to be transformed into a design. Grammar allows us to recursively built sentences and make them endlessly long, and it allows us to transition between phonology and semantics (Jackendoff, 2002).

In line with studies in mainstream education (Van der Graaf et al., 2016; Wagensveld et al., 2015), the present results showed correlations of nonverbal reasoning, grammar, and vocabulary with experimentation. One difference is that the present results revealed a near significant correlation of vocabulary with experimentation, while in typically developing children, a significant effect of vocabulary was found on gains in CVS usage (Wagensveld et al., 2015), but no effect of vocabulary on experimentation was found in kindergarten (Van der Graaf et al., 2016). The present results should be interpreted with caution given the near significance of the correlations and the small sample size. It might be that kindergartners with learning problems did not yet know all the words that were used in the instruction. Although the instruction was designed to be understandable for kindergartners and there was feedback on their performance, the instruction may still have included unfamiliar words. Prior vocabulary knowledge is important for learning new words, such as variable names, as young children rely on existing vocabulary knowledge during the acquisition of new vocabulary (Werker et al., 2002).

Inhibition also showed a near significant correlation with experimentation. In mainstream education inhibition significantly related to experimentation (Van der Graaf et al., 2016). This indicates kindergartners may use their inhibition to reject intuitively derived misconceptions (Kuhn and Franklin, 2006), such as that the ball would roll further when the surface is rough instead of smooth. Hence, making it easier to address the question posed, because their tendency to generate a desirable effect would be less. However, other factors, namely nonverbal reasoning and grammar, appeared to be more relevant in the present study. The role of inhibition should therefore be a topic for further investigation.

Verbal working memory did not relate significantly to experimentation. As was expected, the scores were low on this task. Kindergartners with learning problems could only repeat a sequence of three words correctly. Due to this floor effect, there was less variation that could explain performance on the experimentation task. Therefore, no conclusion can be drawn on the role of verbal working memory in experimentation in kindergartners with learning problems.

Given the large similarity of cognitive factors involved in experimentation for kindergartners with and without learning problems (cf. Van der Graaf et al., 2016), it appears that kindergartners with learning problems participate in scientific discourse in a similar vein as kindergartners in mainstream education, but their development is simply delayed. This means that the kindergartners with learning problems should be taught experimentation strategies in a similar vein as kindergartners without learning problems, but the level should be adjusted for developmental age. A number of suggestions for instruction of experimentation strategies follow from the present results that also apply to kindergartners with learning problems. The difficulty kindergartners experience when the number of variables increase should be taken into account. It might be possible to train inhibition and/or provide external control of their behaviour in order to improve experimentation abilities. The relevant language to talk about science should be taught (cf. Snow, 2010), and/or use the opportunity to explain the new concepts that emerge from the process of designing experiments. Adjusting the language use to the level of the learner can be exemplified by the gradual introduction of variables along with their names in the present study. It might be difficult for the children with learning problems to take the variables into account when they cannot name them. Pointing to objects could be a way to start using variables, but language seems to be needed for complex forms of thought (Luria and Yudovich, 1966). This also seems to be the case for science learning as children with learning problems have limited language abilities that can affect the efficiency of science learning (Parmar et al., 1994) and a similar reliance on language can be found in typically developing kindergartners when designing experiments (Van der Graaf et al., 2016). Therefore, language use should be taken into account when teaching science, but whether kindergartners with learning problems might profit more from such language-infused instruction of experimentation than kindergartners in mainstream education remains to be investigated. It would also be interesting to study to what extent non-verbal communication aids experimentation of kindergartners with learning problems and to what extent this type of communication might stimulate language use when talking about science.

Various interventions have been created that can improve scientific reasoning abilities and the acquisition of scientific knowledge in children with learning problems (Alber-Morgan et al., 2015). This would make science education accessible for everyone and it might allow children with learning problems to become proficient scientists. Another reason to start with science programs in kindergarten is that the children with learning-related behaviour problems fall increasingly behind their regular developing peers through development on key topics, such as in reading and mathematics (Morgan et al., 2011). Besides, some kindergartners with learning problems in the present study showed proficiency in experimentation. It shows that kindergartners with learning problems can be educated in scientific reasoning, which allows them to discover and unravel scientific phenomena. In addition, when children produce evidence using scientific methods, they can acquire scientific knowledge, related to the investigated concept (Dunbar and Klahr, 2012).

A limitation of the present study was the sample of kindergartners with learning problems. First, the sample was relatively small. Second, the sample was heterogeneous, with some kindergartners having a clinical diagnosis, while others were just identified as having learning problems. However, this can also be seen as a strength of the present study, as special education schools in Netherlands have such diverse classrooms. Another limitation is the variability on various tasks, such as the verbal working memory task. This could have affected the relationships between the measures. To be able to relate abilities to each other, there should be enough variability in both measures. One final issue is the robustness of learning and possible transfer (Fuchs and Fuchs, 2005). Whether training of experimentation abilities results in transfer of those abilities to other contexts, as in typical developing children (e.g. Chen and Klahr, 1999), was not studied and should be a topic for future research.

To conclude, as a group the kindergartners with learning problems in our study underperform compared to typically developing kindergartners. However, some kindergartners could design multivariable experiments correctly and the performance of both groups of kindergartners did overlap. This indicates that there might be a developmental delay and that scientific activities that include experimentation can just as well be incorporated in early childhood science education of children with learning problems. The individual differences in experimentation abilities of kindergartners with learning problems can be explained by nonverbal reasoning and grammatical abilities, just as in their typically developing peers. Learning via scientific discovery can thus be regarded a suitable instructional method for children with learning problems, especially when they profit from guidance in their reasoning processes and from additional verbal instruction.

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Using Children's Literature to Teach Mathematics: An Effective Vehicle in a STEM World

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ABSTRACT

Today it is critical to excite young people about mathematics in our high-tech STEM world we live in. Math teachers today need to embolden students to be confident in their ability to solve problems, to think and use their imaginations, to understand mathematical concepts, to be creative, and to see math as a human endeavor. The author feels that as students feel less anxious about, and more confident in their abilities to do math their performance will improve. The author has provided an in-depth literature review and offers background information on using children's literature to teach mathematics; sharing the methods and materials possible to incorporate such literature into such math instruction in a wide range of mathematics strands. The results of using such literature in the teaching of mathematics may help to lower math anxiety and pique students interest and confidence in math and the STEM fields. Teachers need to address this alarming problem and work toward developing mathematically confident young people for a world where Science, Technology, Engineering, and Mathematics (STEM) fields dominate the globe, using literature to teach mathematics can support and cultivate students' math confidence for a STEM world.

Keywords: children's literature, STEM, creativity, bibliotherapy, reading

INTRODUCTION

"I think that children's literature offers a wonderful vehicle for helping teachers teach math well."
-Marilyn Burns

"If you want your children to be intelligent, read them fairy tales. If you want them to be more intelligent, read them more fairy tales." -Albert Einstein 1879-1955

Today math teachers may want to read the children's book and fairy tale *Sir Cumference and the Dragon of Pi, a Math Adventure* (Neuschwander, 2004) See **Figure 1**, the son Radius (the name is referred to but not described in math terms) saves his father's life, Sir Cumference, after accidentally turning him into a fire-breathing dragon. Of course, a math formula is the reason for the solution. Did you know Sir Cumference named Pi in this story? Did you know this story tells how the math formula for ∏ was discovered? This is a fictional story but the author's purpose is achieved when children remember this math lesson and what Pi really means.

BUILDING MATH CONFIDENCE FOR A STEM WORLD

We currently live in an age of advancing technologies that are constantly advancing. Young people need to be literate as well as be very good at mathematics and problem solving in order to compete in a global society. A

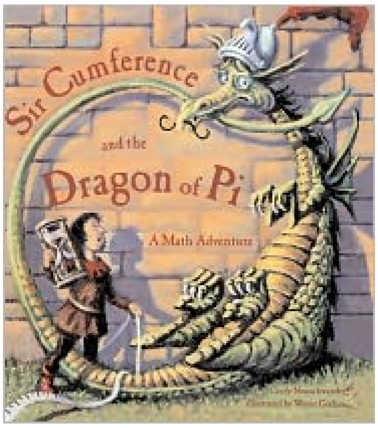

Figure 1. Book Cover Image

young person's lack of confidence and ability to do mathematics may influence his/her entire life forever both in all decisions they make on a daily basis as well as future career choices. Today math teachers need to be equipped to touch all youngsters so to improve their confidence and capacity to do mathematics. Teachers should check to see that all children have positive attitudes and dispositions toward math (NCTM, 1989). In her book, Boaler (2008) feels it is critical to ensure our young people are confident and well prepared in mathematics if they are going to compete for such high-tech jobs today and in the future. Today, the United States is working to lead more young people into the fields of Science, Technology, Engineering, and Mathematics (STEM) so we as a country can better vie globally. If we are to build math confidence in our students, math teachers need to address head on the issue of math anxiety, which often manifests itself as uncertainty or learned helplessness in perceived math achievement (Furner, 2016). Burns (1998) and Jackson and Leffingwell (1999) both found that Americans do not care for mathematics. Burns cited that two-thirds of Americans loathe math and research done by Jackson and Leffingwell revealed that only about 7% of Americans reported having positive experiences while taking math classes at the Kindergarten through college levels. This is alarming in our information age where mathematics plays such a critical role in the world. Sparks (2011) feels that as the STEM areas become more important for our students to study, our schools and teachers need to do more to address math anxiety so that our students are self-confident to study areas related to STEM fields. With the NCTM Standards pushing for more communications in mathematics instruction (NCTM, 1989 and 2000) and the push to incorporate literature in the teaching of mathematics, teachers are now able to make better connections to mathematics and students' lives (Furner, 2017b). Today there are literally thousands of children's literature books out there to teach mathematics, this paper will share several of them, advocating their use (See Appendix and A and B for an extensive list of math related literature).

USING CHILDREN'S LITERATURE TO TEACH MATHEMATICS

For about the past two or three decades now children's and adolescent literature has been recognized as a means to teaching mathematics concepts to students through the use of stories to make mathematics ideas relevant and meaningful during instruction. Children's literature may also be used as a form of therapy (bibliotherapy) to reach learners who may be frustrated with being taunted or teased for excelling in mathematics of for having math anxiety. Rozalski et al. (2010) have found that using sensibly selected thematic stories; teachers can use literature to reach young people who are experiencing difficult situations in learning and in life. Barnaby (2015) found in a qualitative case study research project that the use of children's literature in the teaching of mathematics was an effective means for teaching mathematics and helped in addressing math anxiety in students while teaching math. Muir et al. (2017) describe the groundwork for using math literature during math instructions and offers math activities and children's books in their book to use for teaching many elementary math concepts using picture books in today's classrooms. McAndrew et al. (2017) found in their quasi-experimental study that by using children's literature, specifically, Geometry-related children's literature improves the geometry success and attitudes of 2nd-Grade students. Weinstein (2017) did an all-encompassing literature review on how using children's literature is effective in covering the new Common Core State Math Standards and gives an all-inclusive list of children's literature to use to model and teach many math concepts covered today in elementary school.

In today's classrooms, teachers can use children's literature to reach a child in a non-threatening way by reading literature that can help to teach math concepts and really connect to the mathematical understanding of the learner and at the same time not intimidate, threaten or turn-off a child to mathematics like some traditional approaches may have in the past. Children's and adolescent literature can be a beneficial way of teaching mathematics (See Appendix A and B).

Some Benefits of Using Literature in Mathematics Instruction Include:

- Math ideas are taught in the context of a story
- Combines integrated studies with reading, writing, speaking, listening, etc.
- Advances mathematical thinking
- Thwarts math anxiety and creates a less math anxious classroom milieu
- Permits for a variety of responses
- Allows for historical, cultural, and practical applications and connections
- May promote the use of certain math manipulatives as it relates to the story
- A teacher can evaluate a child's understanding by reading/questioning
- Currently there is a wide range of books to use in teaching most math concepts K-8
- Lends itself to problem solving and active involvement from the context of the story
- Affords for a shared experience for both students and the teacher (Furner, 2017a and b; Furner and Kenney, 2011; Furner and Duffy, 2002)

Math teachers can address the NCTM's "Communication Standard" by incorporating literature in the teaching of mathematics as well as by having students discuss math from the stories and write about such concepts in mathematics to demonstrate their understanding of math concepts as well as their feelings toward math (NCTM, 1989). Griffiths and Clyne (1991) in their book, *Books you can Count on: Linking Mathematics and Literature,* wonderfully illustrates countless examples of how to connect children's literature into a math lesson. Included below is a sample of some suggested activities tying literature into the teaching of mathematics. It is important to mention a distinction between using literature in the teaching of mathematics. Math teachers may use literature to introduce, teach, reinforce, and to make connections to many math concepts through the use of story books that have mathematics uses. There are also books that may be used to assist students with helping them come to terms with things like fear of mathematics for example, the book, *Math Curse* (Scieszka and Smith, 1995) or the book, *Counting on Frank* (Clement, 1991), which can be used to help gifted math students to accept and respect their giftedness with mathematics (Furner and Kenney, 2011).

USING BIBLIOTHERAPY WHILE TEACHING MATHEMATICS

Today affective factors play such an important role in learning mathematics (McLeod, 1992) and teachers need classroom approaches that are practical so to address the feelings of their students suffering from mathematics anxiety. Teachers need to create supportive environments in which their students feel at ease expressing how they are feeling about their current and past mathematical experiences. A psychological method to assist people to feel more at ease with an issue or situation is by using bibliotherapy. Bibliotherapy is the reading of pre-selected books in order to create change in attitude so to improve character development and growth progress toward an issue or concern of the individual (Abdullah, 2002; Betzalel and Shechtman, 2010; Doll and Doll, 1997; Forgan, 2002, 2003; Furner, 2004; Jeon, 1992; Heath et al., 2005; Jack and Ronan, 2008; Lenkowsky, 1987; Reis and Renzulli, 2004; Rozalski et al., 2010; Sridhar and Vaughn, 2000; Sullivan and Strang, 2003). Bibliotherapy may be used as an endeavor to help students better understand themselves and deal with problems by sharing pertinent literature to their personal circumstances and evolving needs (Betzalel and Shechtman, 2010). Hébert and Kent (2000) strongly believe teachers need to use literature geared toward young gifted teens so to address societal and emotional apprehensions. Teachers using this approach hold a fundamental belief that reading will impact thinking and comportment, and that through guided discussions designated readings may be concentrated on the exact needs of students as well. Reading children's literature, fairy tales, and stories while teaching math concepts can allow students to invoke more creativity and employ their imaginations further while making important mathematical connections to their understanding (Furner, 2017a).

The bibliotherapy process is fairly easy to understand and implement. The therapeutic experience while reading a book happens to us each time we pick up a good book and say, 'This character is very much like me. I can relate to this person.' This interaction is known as identification, and the more we have in common with people we meet in our reading, the closer will be the identification process. That identification produces a sense of tension relief, or 'catharsis,' an emotional feeling that tells us we are not alone in facing our problems. As the learner enjoys the book and story and is able to identify with the character, they learn vicariously through the person in the storybook. We gain new ways of looking at troublesome issues we face and insight evolves. With this new insight, changed behavior may occur as real life situations similar to those experienced in the books are challenged and experienced (Furner, 2004). The three widely recognized stages of bibliotherapy are identifications, catharsis, and insight

(Forgan, 2002; Halsted, 1994; Jack and Ronan, 2008); conversely, another less cited in the literature yet particularly enthralling for math teachers working with students anxious with math, is the concept of universalization (Slavson, 1950), or the acknowledgement that each person's problems are not unique. When teachers use universalization they realize and emphasize to their sensitive individuals that they are in this together and not alone. Thatcher and Fletcher (2008) discovered that most teachers do not realize or see the importance in using books and literature or bibliotherapy approach for neither addressing students' problems nor how to use such a practice in a school setting. The author hopes this paper helps to address some of these issues and advocates for more literature use during mathematics instruction (Furner, 2017b).

Children's books can help teachers guide the emotional development of their students' far more than intellectual discussion because stories directly affect human feelings (Forgan, 2002, 2003; Furner, 2004; Rozalski et al., 2010). Sometimes a skillful author can help young people connect with others who have similar problems. If books or short stories can touch young people emotionally, they may be much more receptive to ideas presented by the author than if they are presented to them in a lecture by a concerned teacher. Students who are unable to talk about their anxieties often can identify with characters in books strongly enough to experience the catharsis and acquire some significant discernments (Halsted, 1994; Heath et al., 2011).

In order for bibliotherapy to be successful, a meaningful follow-up discussion is required by the instructor (Forgan, 2002; Furner, 2004). Teachers also must recognize that to read a respectable book with a whole class is not automatically bibliotherapy, as there is a process one needs to follow as they put bibliotherapy into practice. It is very important that young people not only read books, but also become involved in discussions, counseling and follow-up procedures such as play-acting/role-play, innovative problem solving, and relaxation with artistic and musical activities and even some journal writing (Furner, 2004; Forgan, 2002, 2003; Hébert, 1991, 1995; Hébert and Furner, 1997). Bibliotherapy can be gratifying and also provide a time for firm self-analysis for the learner to better deal with possible obstacles that may be holding them back.

It is important that sensitive mathematics teachers' help students recognize that their abilities may vary from their peers and acknowledge that they may also have areas of weakness and assist them in developing self-esteem by becoming satisfied with who they are as individuals (Ableser, 2008). Teachers using bibliotherapy may be successful in doing so by making relations to the students' attitudes and feelings with the characters in storybooks (Regan and Page, 2008). Leininger et al. (2010), Burke (2009), and Kurtts and Gavigan (2008) have all established that there are a wide range of literature and picture books useful in shepherding bibliotherapy to address a wide range of conditions and societal concerns impacting young people today. The bottom line here is that using fairy tales or literature to teach mathematics can be beneficial for student in learning mathematics concepts in a more meaningful way, making important connections while allowing our young people to employ some creativity and imagination to the learning situation. In addition, the use of bibliotherapy is beneficial in that it can help some students in class who might struggle with either fears or unease about math or even the peer-pressure of being mathematically talented and considered a geek or nerd (Furner and Kenney, 2011).

POSSIBLE MATH ACTIVITIES FOR TEACHERS TO TRY USING CHILDREN'S LITERATURE

1. "Alphabet Snoop" is an activity used at Math Fairs in schools in Palm Beach County. In the activity using books and letters, the children predict which letter of the alphabet would occur most frequently in their reading books. The activity involves tallying with tally marks, individual graphing, class graphing, the use of calculators, and working together in groups or with families. It was very exciting and rewarding for the class as it incorporates children's literature and actual mathematics in a non-threatening way.
   At the intermediate grade levels, students can also connect math and language concepts in a similar fashion. There are a series of books on the parts of speech by Ruth Heller that could be used to stimulate student interest as they relate to different parts of speech. These books could be used to identify different types of words and understanding their use, an important approach for English Language Learners (ELL) students. Some math skills that can be applied are:
   - Assembling information and choosing an appropriate way to record and display.
   - Averaging the usage of words and finding percentages of kinds of words used in different types of writing.
   - Finding patterns in various forms of writing and expressing them in mathematical terms.
   - Develop calculator skills when analyzing information.

   These are a few of many ideas that you can develop as math teachers (Furner, 2018; Furner et al., 2005).
2. Another great idea to connect math and literature in the classroom is by using the book, *The Grandfather Tang's Story*, a Chinese folktale; this book uses tangrams to tell a whimsical story of meeting many creatures

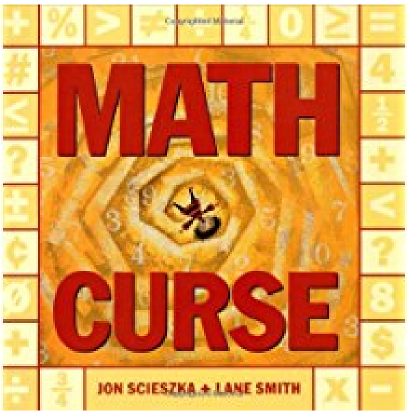

Figure 2. Math Curse

during the character's odyssey. This story can be read and used with transparencies and student activity pages geared to the appropriate grade levels to make this a participatory activity. The younger children can use pictures with outlined pieces in the drawing, while the older ones had only the basic outline and had to fill it in with the tangrams to make the animal mentioned on each page of the story. Children can also come up to the projector to work with the tangram pieces. It can be a very successful lesson at all grade levels. The use of literature to develop math concepts can go a long way in relieving children's math anxiety.

3. Teachers may like to use Shel Silverstien's poem, *Smart,* while teaching a unit on money. The poem starts out with a young boy receiving a one-dollar bill from his dad because he is "his smartest son" and he goes through a series of trades and transactions to receive other coins. He feels that each time he trades and receives more coins he has more than one. For example, swapping the one-dollar bill for two shiny quarters "cause two is more than one." After reading this poem to children, a teacher may use a journal writing prompt activity from the book, *Write Starts: 101 Writing prompts for math*, by McIntosh and Draper (1997), to have the students write about and then discuss what the error is in the story. Teachers may use many of the prompts in this book for follow-up of different children's literature. How is math used in your favorite sport? Maybe be a great writing prompt after students read the book, *Sports Math Mania*, by Hopping and Egan (1996). Teachers could use the prompt: One sign of a good problem solver is.… After reading the book B*etcha!,* by Murphy and Schindler (1997).
4. The practice of employing bibliotherapy within instruction has been a accepted means for reducing/overcoming math anxiety (Furner, 2017a). Teachers can read stories to their students, such as the book, *Math Curse* (See **Figure 2**) and/or *A Gebra Named Al* (Isdell, 2017), and then have student share how the characters relate to them and their own bad experiences with math for example. This can be a catharsis or therapeutic for children who may feel as the character did and help them see they are not the only ones that feel this way. Teachers may also encourage students to discuss and write about their own experiences with math and perhaps direct them to write their very own math autobiography or history with taking math courses over the years (Kitchens, 1995). Math teachers can just use literature to introduce, teach, or reinforce math concepts and then extend their students understanding allowing the students to discuss and write about their understanding through various activities (Furner, 2017b). It is critical in this day and age that we get through to all students and if literature can be a means to reach children and turn them on to mathematics then teachers need to integrate this best practice.
5. *A Cloak for the Dreamer*, by Friedman and Howard (1994) is a wonderful story to read to students to teach about two-dimensional geometry, spatial sense, and tessellations. Today there is almost an endless array of children's literature for teaching mathematics concepts to cover almost any NCTM and Sunshine State Standard Strand in mathematics from Number Sense, Measurement, Geometry, Algebraic Thinking, and Data Analysis, etc. *A Cloak for the Dreamer* (See **Figure 3**) tells a story of a tailor being hired by the Archduke to design and sew three new cloaks for himself and three dresses for his wife. The Archduke require the cloaks to be very colorful and also use shapes so that there are no gaps or overlaps so that he will not be cold and that no material will be wasted. The tailor has his three sons help him out with this task. This book explores tessellations. It can lead to a nice activity with manipulatives like pattern blocks where children can discover which shapes tessellate. Children's literature books like this are wonderful to read as a shared experience with children as they teach mathematical concepts within the context of a story making the learning of mathematics more meaningful to the learner.

Geist (2010) feels that an undesirable outlook related to mathematics and what has now been defined as "math anxiety" are somber impediments for young people PreK-College. In his paper, the literature is reviewed and critically evaluated in regards to the reasons of math phobias and its especially harmful

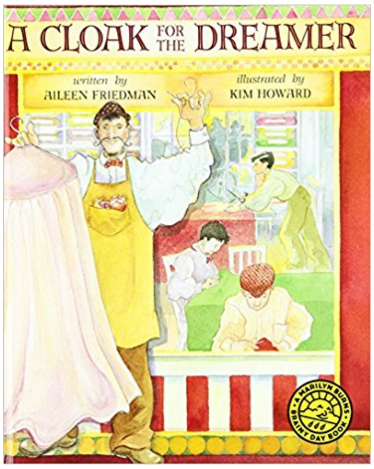

Figure 3. A Cloak for the Dreamer

influence on learners who may be part of the "at-risk" population like, girls, special needs and particularly low socioeconomic status; Geist contends that an anti-anxiety curriculum is very important in improving students' confidence when working with the subject. Furner (2017b) hence feels that the use of best practices like incorporating children's literature in the teaching of mathematics to be sure to turn students on to the subject and assist in such an anti-anxiety curriculum.

SUMMARY

It was believed but unconfirmed that Albert Einstein said, "Everybody is a genius. But if you judge a fish by its ability to climb a tree, it will live its whole life believing that it is stupid" (Pettigrew, 2013). As educators we need to seek every which way to reach all types of students, turning them on to math and making them feel confident to do math and solve any problem, and also to have them use their creativity and imagination in the learning process. In today's times of increasing technology and with more of a push to better, prepare more young people for the STEM fields, children need be confident in their ability to do mathematics. With recent statistics showing students poor attitudes or declining scores in math as they increase in age for example from the Third International Mathematics and Science Study (TIMSS) (Schmidt, 1998) and other researchers like Burns (1998) and Jackson and Leffingwell (1999). Today, teachers can address the issue of math anxiety in their students by using children's literature and writing to help in reducing such anxiety by using books as a form of what is known as bibliotherapy. Teachers can also incorporate children's literature to help in preventing math anxiety from occurring by using such books in a shared setting with students making such connections to mathematics in more meaningful ways along with incorporating writing, discussion, and the use of manipulatives as they relate to the story in a children's literature book.

Teachers can do many things mentioned in this article in their own classrooms to help prevent and reduce math anxiety and better prepare young people for a STEM world. As a society, we must work together to extinguish the discomfort that our youth are having toward mathematics. It is important that our students feel confident in their ability to do mathematics in an age that relies so heavily on problem solving, technology, science, and mathematics. It really is a teachers' obligation to see that their students value and feel confident in their ability to do math, because ultimately a child's life: all decisions they will make and careers choices may be determined based on their disposition toward mathematics. As teachers, we must make the difference in our students' attitudes toward math! Using children's literature can help make better connections in math to the real world. Today it is important that we hear more students say, "Math is my favorite subject," "I am a good problem solver," "I am great at math!" or "I want to be and inventor or scientist!" Einstein said, "I am enough of an artist to draw freely upon my imagination. Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world" (Quote Investigator, n.d.). When teachers use fairy tales and children's literature in their classroom to teach math, they are allowing for creativity, imagination, and making connections for students better preparing them for a world that is ever advancing mathematically and technologically. We need to prepare our students for this new world of STEM where all young people are confident in their ability to do mathematics. The consensus of most of the research on this topic believe then that using children's literature is a great vehicle for teaching mathematics and better reaching young learners to then be able to better understand mathematics.

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APPENDICES

Appendix A

Dear Teacher Website: Children's Books with Mathematics Themes Website at: http://www.dearteacher.com/math-books

Appendix B

A List of Children's Literature Books to use to Teach Math by Math Strand

Primary Grade Level Children's Literature for Teaching Mathematics Concepts

STRAND	TITLE OF BOOK	AUTHOR
Number Sense, Concepts and Operations	*Ten, Nine, Eight*	Molly Bang
	How Many Bugs in a Box	David Carter
	Six Brave Explorers	Kees Moerbeek and Carla Dijs
	There were Ten in the Bed	By Child's Play
	What Comes in 2's, 3's & 4's.	Suzanne Aker
	The Right Number of Elephants	Jeff Sheppard
	Every Buddy Counts	Stuart J. Murphy
	Anno's Counting Book	Mitsumasa Anno
	Who Wants One?	Mary Serfozo
	Twelve Ways to Get to Eleven	Eve Merriam
	Rooster's Off to See the World	Eric Carle
	Fish Eyes: A Book You Can Count On	Lois Ehlert
	The Twelve Circus Rings	Seymour Chwast
	Picking Peas for a Penny	Angela Shelf Medearis
	One Hunter	Pat Hutchins
	One Gorilla: A Counting Book	Atsuko Morozumi
	The Line Up Book	Marisaoina Russo
	Ten Black Dots	Donald Crews
	Frog Counting Books	John Liebler
	Animal Numbers	Bert Kitchen
	One Fine Day	Nonny Hogragian
	The Fox Went Out on a Chilly Day	Peter Spier
	More, More, More, Said the Baby	Vera B. Williams
	Fish Eyes	Lois Ehlert
	Frog and Toad Together	Arnold Lobel
	Tuesday	David Wiesner
	The April Rabbits	David Cleveland
	Two Ways to Count to Ten	Ruby Dee
	Seven Little Rabbits	John Becker
	The Icky Bug Counting Book	Jerry Palotta
	How Many How Many How Many	Rick Walton
	From One to One Hundred	Teri Sloat
	Domino Addition	Lynette Long
	The Crayon Counting Book	Pam M. Ryan and Jerry Pallotta
	Ten Beads Tall	By Child's Play
	One Crow: A Counting Rhyme	Jim Aylesworth
	Counting on Calico	Phyllis L. Tildes
	Ready, Set, Hop	Stuart J. Murphy
	Leap Into Math	Jane Keegan
	The Napping House	Audrey Wood
	Two of Everything	Lilly Toy Hong
	Eating Fractions	Bruce McMillan
	Gator Pie	Louise Mathews

Measurement	*Mouse's Birthday*	Jane Yolen and Bruce Degen
	The Best Bug Parade	Stuart Murphy
	Inch by Inch	Leo Lionni
	Is It Larger? Is It Smaller?	Tana Hoban
	The Grouchy Ladybug	Eric Carle
	Mice Twice	Joseph Law
	"Smart" from Where the Sidewalk Ends	Shel Silverstein
	Alexander, Who Used to Be Rich Last Sunday	Judith Viorst
	Rude Giants	Audrey Wood
	Much Bigger than Martin	Steven Kellogg
	The Very Hungry Caterpillar	Eric Carle
	Who Sank the Boat	Pamela Allen
	Temperature and You	Betsy and Guilio Maestro
	Reading the Numbers: A Survival Guide to the Measurements, Numbers and Sizes Encountered in Everyday Life	Mary Blocksma
	A Giraffe and a Half	Shel Silverstein
	26 Letters and 99 Cents	Tana Hoban
	How Many Feet in the Bed?	Diane Johnston Hamm
	How Big is a Foot?	Rolfe Myller
	Picking Peas for a Penny	Angela Shelf Medearis
	The Tortoise and the Hare	Janet Stevens
	Measuring	David Kirkby
	Mr. Archimedes' Bath	Pamela Allen
	King Bidgood's in the Bathtub	Audrey Wood

Geometry and Spatial Sense	*Seeing Shapes*	By Playschool
	Changes, Changes	Pat Hutchings
	The Shape of Me and Other Stuff	Dr. Seuss
	Color Zoo	Lois Ehlert
	The Adventures of Terry Tangram	By Learning Resources
	Shapes	David Kirky
	The Shapes Game	Paul Rogers
	The Very Hungry Caterpillar	Eric Carle
	The Greedy Triangle	Marilyn Burns
	My Very First Book of Shapes	Eric Carle
	Shapes, Shapes, Shapes	Tana Hobin
	Circles, Triangles, and Squares	Tana Hobin
	What is Symmetry	Mindel and Harry Sitomer

STRAND	TITLE	AUTHOR
Algebraic Thinking	*The Button Box*	Margarette S. Reid
	The Very Hungry Caterpillar	Eric Carle
	Somethings Go Together	Charlotte Zolotow
	The Grey Lady and the Strawberry Snatcher	Molly Bang
	Patterns	David Kirkby
	The Three Billy Goats Gruff	Marcia Brown
	Caps for Sale	Esphyr Slobodkina
	The Doorbell Rang	Pat Hutchins
	Number Ideas Through Pictures	Mannis Charosh
	Sam Johnson and the Blue Ribbon Quilt	Lisa Campbell Ernst
	Too Much Noise	Ann McGovern
	Eight Hands Round	Ann Whitford Paul
	A My Name is Alice	Jane Bayer
	Why Mosquitoes Buzz in People's Ears	Verna Aardema

STRAND	TITLE	AUTHOR
Analysis and Probability	*The Button Box*	Margarette S. Reid
	Moira's Birthday	Robert Munsch
	Sorting	David Kirkby
	Anno's Magic Seeds	Mitsumasa Anno
	Don't Forget the Bacon	Pat Hutchins
	Eating the Alphabet: Fruits and Vegetables from A to Z	Lois Ehlert
	The Best Vacation Ever	Stuart J. Murphy
	Probability	Charles F. Linn
	Happy Birthday, Sam	Pat Hutchins

Intermediate Grade Level Children's Literature for Teaching Mathematics Concepts

STRAND	TITLE	AUTHOR
Number Sense, Concepts and Operations	*Seven Blind Mice*	Ed Young
	Goldilocks and the Three Bears	James Marshall
	Always Room for One More	Sorche Nie Leodhas
	A Chair for my Mother	Vera B. Williams
	Sylvester and the Magic Pebble	William Steig
	Each Orange has Eight Slices: A Counting Book	Paul Giganti
	Clocks and More Clocks	Pat Hutchins
	Henry's Important Date	Robert Quackenbush
	How Much is a Million	David M. Schwartz
	The King's Chessboard	David Birch
	Fraction Fun	David A. Adler
	Each Orange has 8 Slices	Paul Giganti
	One Grain of Rice	Demi
	The 500 Hats of Bartholomew Cubbins	Dr. Seuss
	Palindromes and Anagrams	Howard Bergerson
	Henry Huggins	Beverly Cleary
	A Million Fish…More or Less	Patricia McKissack
	Too Hot to Hoot	Marvin Terban
	Think About Shape	Henry Pluckrose
	Sea Squares	Joy Hulme
	Bunches and Bunches of Bunnies	Louise Mathews
	Math Curse	Jon Scieszka and Lane Smith
	Anno's Mysterious Multiplying Jar	Masaichiro and Misumasa Anno
	Charlie and the Chocolate Factory	Roald Dahl
	Sideways Stories from Wayside School	Louis Sachar
	Counting on Frank	Rod Clement
	Pizza for Breakfast	Mayann Kovalski
	Moja Means One Swahili Counting Book	Muriel Feelings
	If You Made a Million	David Schwartz
	Today I Was Ten (From Don't Ever Cross a Crocodile)	Kaye Starbird
	Our Solar System	Isaac Asimov
	The Magic Schoolbus Lost in the Solar System	Joanna Cole
	On an Average Day	Thomas Heymann
	Our Solar System	Seymour Simon
	The Phantom Tollbooth	Norton Juster

STRAND	TITLE	AUTHOR
Measurement	*Frog and Toad are Friends*	Arnold Lobel
	Time Flies	Eric Rothman
	The Whipping Boy	Sid Fleischman
	The Boy of the Three-Year Nap	Dianne Snyder
	Paul Bunyan	Steven Kellogg
	Patterns	David Kirkby
	The Relative Came	Cynthia Rylant
	The Crow and the Pitcher	Mary Hill Arbuthot
	There Were Monkeys in My Kitchen	Sheree Fitch
	Math Curse	Jon Scieszka and Lane Smith
	George's Marvelous Medicine	Roald Dahl
	Tuesday	David Wiesner
	Sideways Stories from Wayside School	Louis Sachar
	If You Made a Million	David M. Schwartz
	Pigs will be Pigs	Amy Axelrod
	Measures and Space	David Kirkby

STRAND	TITLE	AUTHOR
Geometry and Spatial Sense	*How a House Happens*	Jan Adkins
	Arrow to the Sun	Gerald McDermott
	Flat Stanley	Jeff Brown
	Anno's Math Games	Mitsumasa Anno
	Anno's Math Games II	Mitsumasa Anno
	Anno's Math Games III	Mitsumasa Anno
	Sideways Stories from Wayside School	Louis Sachar
	Grandfather Tang's Story	Ann Tompert
	M is for Mirror Book	Duncan Birmingham

	The Mirror Puzzle Book	Marion Walter
	The Phantom Tollbooth	Norton Juster
	Jungle Gym (from Roomrimes)	Sylvia Cassedy
	Math Curse	Jon Scieszka and Lane Smith
	Opt	Arlene and Joseph Baum
	Round Trip	Ann Jonas
	The Straight Line Wonder	Mem Fox
	Patterns	David Kirkby
	Measures and Space	David Kirkby
	Shapes	David Kirkby

STRAND	**TITLE**	**AUTHOR**
Algebraic Thinking	*Max Found Two Sticks*	Brian Pinkney
	Ox-Cart Man	Donald Hall
	Nine-in-One, Grrl, Grrl	Blis Xiong
	Grandfather Tang's Story	Ann Tempert
	Sea Witches	By Robertson and Gal
	Loads of Codes and Secret Ciphers	Paul B. Janeszko
	The King's Chessboard	David Birch
	Too Hot to Hoot	Marvin Terban
	The Case of the Stolen Code Book	Barbara Rinkoff
	Secret Codes	Helen Fletcher
	Math Curse	Jon Scieszka and Lane Smith
	Visual Magic	Dr. David Thomson
	Codes for Kids	Burton Albert
	How to Write Codes and Send Secret Messages	John Peterson
	Solomon Grundy Born on Oneday	Malcolm E. Weiss
	A Clue in Code	Marilyn Singer

STRAND	**TITLE**	**AUTHOR**
Analysis and Probability	*Jumanji*	Chris Van Allsburg
	Ramona Quimby	Beverly Cleary
	Tikki Tikki Tembo	Arlene Mosel
	Clocks and More	Pat Hutchins
	Socrates and the Three Little Pigs	Tuyosi Mori
	The King's Chessboard	David Birch
	Henry's Important Date	Robert Quackenbush
	Fleet-footed Florence	Marilyn Sachs
	Averages	Jane Jonas Srivastava
	Math Curse	Jon Scieszka and Lane Smith
	Sideways Stories from Wayside School	Louis Sachar
	Statistics	Jane Jonas Srivastava
	What do you Mean by Average	James and Barkin
	Miss Pickerel and the Weather Satellite	MacGregora and Pantell
	Casey at the Bat	Ernest Lawrence Thayer
	Do You Want to Bet	Jean Cushman

AUTHOR BIO

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Fostering Inquiry and Creativity in Early Years STEM Education: Policy Recommendations from the *Creative Little Scientists* Project

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ABSTRACT

Creative Little Scientists was a 30-month (2011-2014) EU/FP7-funded research project focusing on the synergies between early years science and mathematics education and the development of children's creativity, in response to increasing interest in these areas in European educational policy. Using a variety of methods, including desk research, a teacher survey and classroom-based fieldwork, the research provided insights into whether and how children's creativity is fostered and appropriate learning outcomes, including children's interest, emerge. Based on these and ongoing collaboration and dialogue with participants and other stakeholders the project proposed recommendations for policy and teacher education. This paper presents these recommendations and the research on which they were based. Throughout the study, mixed methods were employed, combining quantitative approaches used in surveys of policy and teachers' views based on a list of factors, alongside qualitative approaches employed in case studies of classroom practice. A strong conceptual framework developed at the start of the project guided data collection and analysis, as well as the presentation of findings and the development of policy recommendations, thus ensuring the latter's strong and consistent relationship with the relevant theoretical knowledge, the comparative research, analysis of classroom practices and the production of guidelines for teacher education.

Keywords: science, mathematics, education, policy, creativity, inquiry, early years

INTRODUCTION

Creative Little Scientists (CLS) project was a 30-month EU funded comparative study working across nine participating countries: Belgium, Finland, France, Germany, Greece, Malta, Portugal, Romania and the UK. The project sought to build a picture of policy and practice in science and mathematics education for children aged 3-8 and their potential to foster creativity and inquiry learning and teaching.

The project aimed to add to previous EU reports in science and mathematics education in its focus on the nature of science and mathematics education in the *early years* and in seeking to characterise and investigate opportunities for *creativity in learning and teaching*. It aimed to mainstream good practices by proposing changes in teacher education and classrooms encompassing curriculum, pedagogy and assessment. A significant strand of the project was therefore the development of recommendations for policy and teacher education building on findings from the study and ongoing collaboration and dialogue with participants and other stakeholders. This paper presents these recommendations and the research on which they were based.

BACKGROUND, OBJECTIVES AND FRAMEWORK

Core Drivers for Creative Little Scientists

The project was informed by four key drivers for an increased research focus on science and mathematics education and creativity in early years education:

- *The role of an economic imperative within education*, demanding capable scientists and creative thinkers in an increasingly knowledge-based globalised economy (European Commission, 2011), requiring capabilities such as reasoning skills, innovative thinking and positive attitudes.
- *The role played by science, mathematics and creativity in the development of children and of citizens*, demanding early understanding and interaction with phenomena in nature and technology, which empower students (and therefore future adults) to take part in societal discussions and decision-making processes (Gago et al., 2004; Harlen, 2008).
- *The role of early years education in building on children's early experiences and in promoting positive skills and dispositions* (Sylva, 2009), informed by increased awareness of the child as an active and competent meaning-maker, who can take ownership of their own learning and take part in decision making in matters that affect their lives in the present (Goswami, 2015).
- *The role of a digital or technological imperative within education*, enabling but also demanding the development of children's capabilities in science, mathematics and creativity (Wang et al., 2010).

Objectives for Creative Little Scientists

In the light of the above, the *Creative Little Scientists* project set the following objectives:

- **To define a clear and detailed Conceptual Framework** comprising the issues at stake and parameters that needed to be addressed in all stages of the research.
- **To map and comparatively assess existing approaches** to science and mathematics education in pre-school and first years of primary school (up to the age of eight) in the nine partner countries, highlighting instances of, or recording the absence of, practices marrying science and mathematics learning, teaching and assessment with creativity.
- **To provide a deeper analysis of the implications of the mapped and compared approaches,** which would reveal details of current practice and provide insights into whether and how children's creativity is fostered and the emergence of appropriate learning outcomes in science and mathematics achieved.
- **To propose a set of curriculum design principles as concrete guidelines for European initial teacher training and continuous professional development programmes**, which would foster creativity-based approaches to science and mathematics learning in preschool and the first years of primary education. The proposed principles would be accompanied by **illustrative teacher training materials** examining their applicability in complex and varied European educational contexts, thus facilitating implementation, evaluation and further development across Europe.
- **To exploit the results of the research at European, national and institutional levels**, making them easily available to educational policy makers and other stakeholders, through synthesis of research outputs and their transformation into a 'Final Report on Creativity and Science and Mathematics Education for Young Children' (Creative Little Scientists, 2014a) and also a 'Set of Recommendations to Policy Makers and Stakeholders' (Creative Little Scientists, 2014b).

Conceptual Framework for *Creative Little Scientists*

The first of these project objectives was achieved through extensive reviews of policy-related and research-based literature at the beginning of the project covering diverse areas including science and mathematics education in the early years, creativity in education, creativity as a lifelong skill, teaching and teacher training approaches, as well as cognitive psychology and comparative education. The resulting Conceptual Framework (Creative Little Scientists, 2012a) provided a strong theoretical framework for the study. Two particular features of the Conceptual Framework played key roles in fostering coherence and consistency in approach across the project and in themselves have the potential to contribute to future work in the field, the *definition of creativity* in early science and mathematics employed across the project and the *synergies* identified between inquiry based and creative approaches to learning and teaching (see Cremin et al., 2015).

The definition of creativity in early science and mathematics, which was developed from the Conceptual Framework and subsequently refined through discussion with stakeholders, is: *Generating ideas and strategies as an individual or community, reasoning critically between these and producing plausible explanations and strategies consistent with the available evidence.* This needs to be understood alongside the 'Little c creativity' definition (Craft, 2001) - *"Purposive, imaginative activity generating outcomes that are original and valuable in relation to the learner"* - insofar as this effort toward originality and value through imaginative activity drives creativity in early science and mathematics.

An influencial factor cutting across the existing traditions or paradigms for understanding and researching creativity is *the location of creativity in early childhood* at the 'everyday' end of the spectrum from 'little c' or everyday creativity (Beghetto and Plucker, 2006; Craft, 2003; Runco, 2003) to 'big c' or paradigm-changing creativity (e.g. Gardner, 1993; Csikszentmihalyi, 1996; Simonton, 1994). According to Craft (2001), *"Little c creativity' [ ] focuses on the resourcefulness and agency of ordinary people, rather than the extraordinary contributions and insights of the few"* (p49). For early years education this is important as *"most creative children do not make major contributions to a field; rather, they produce useful or good products that are novel and good 'for their age group'"* (Russ and Fiorelli, 2010: 234). Another way in which this contrast has been described is as 'personal' creativity rather than 'historical' creativity (Boden, 2001, 2004). Creativity is characterised as at the heart of what it is to be human by Robinson (2001), who emphasised the need for finding one's own passion (Robinson, 2009) so as to make something of one's life. This notion of creativity as self-creating also underpins Craft's (2001, 2010) perspective on the guiding force of 'little c' creativity in learners' lives.

The Conceptual Framework for *Creative Little Scientists* also explored synergies and differences between inquiry-based (IBSE) and creative approaches (CA) to science and mathematics. Although definitions of IBSE vary, there is considerable agreement internationally, reflected in both policy and research, about the value of inquiry-based approaches to science education (Minner et al., 2010). CA, on the other hand, does not refer to a recognised set of approaches to education and learning, but nonetheless characteristics of such approaches have gained considerable attention in research and policy contexts in recent years (Chappell et al., 2008). Both IBSE and CA are pedagogically associated with a range of child-centred philosophies from European and North American thinkers, which situate the child as an active and curious thinker and meaning maker and highlight the role of experiential learning. Common synergies identified are:

- **Play and exploration**, recognising that playful experimentation/exploration is inherent in all young children's activity, such exploration is at the core of IBSE and CA in the Early Years (see e.g. Goswami, 2015; Cremin et al., 2006; Poddiakov, 2011).
- **Motivation and affect**, highlighting the role of aesthetic engagement in promoting children's affective and emotional responses to science and mathematics activities (see e.g. Craft et al., 2012; Koballa and Glynn, 2008).
- **Dialogue and collaboration**, accepting that dialogic engagement is inherent in everyday creativity in the classroom, plays a crucial role in learning in science and mathematics and is a critical feature of IBSE and CA, enabling children to externalise, share and develop their thinking (see e.g. John-Steiner, 2000; Mercer and Littleton, 2007).
- **Problem solving and agency**, recognising that through scaffolding the learning environment children can be provided with shared, meaningful, physical experiences and opportunities to develop their creativity as well as their own questions and ideas about relevant concepts (see e.g. Cindy et al., 2007; Craft et al., 2013).
- **Questioning and curiosity**, which is central to IBSE and CA, recognising across the three domains of science, mathematics and creativity that creative teachers often employ open ended questions, and promote speculation by modelling their own curiosity (see e.g. Chappell et al., 2008).
- **Reflection and reasoning**, emphasising the importance of metacognitive processes, reflective awareness and deliberate control of cognitive activities, which may be still developing in young children but are incorporated into early years scientific and mathematical learning and IBSE (see e.g. Kuhn, 1989; Bancroft et al., 2008).
- **Teacher scaffolding and involvement**, which emphasises the importance of teachers mediating the learning to meet the children's needs, rather than feel pressured to meet a given curriculum (see e.g. Rittle-Johnson and Koedinger, 2005; Bonawitz et al., 2011).
- **Assessment for learning**, emphasising the importance of formative assessment in identifying and building on the skills attitudes, knowledge and understandings children bring to school; supporting and encouraging children's active engagement in learning and fostering their awareness of their own thinking and progress (see e.g. Harrison and Howard, 2011; Feldhusen and Ban, 1995).

RESEARCH APPROACH AND DESIGN

Research Questions and Approach for Creative Little Scientists

The *Creative Little Scientists* project aimed to identify and characterise evidence of creativity in early science and mathematics (in relation to policy, teachers' pedagogy and children's learning) and to outline implications for policy, practice and teacher education. Its research questions were:

- **RQ 1**. How are the teaching, learning and assessment of science and mathematics in Early Years in the partner countries **conceptualised** by teachers and in policy? What role if any does creativity play in these?
- **RQ 2**. What **approaches** are used in the teaching, learning and assessment of science and mathematics in Early Years in the partner countries? What role if any does creativity play in these?
- **RQ 3**. In what ways do these approaches seek to **foster young children's learning and motivation in science and mathematics**? How do teachers perceive their role in doing so?
- **RQ 4**. How can findings emerging from analysis in relation to questions 1-3 inform the development of policy and practice in the classroom and in teacher education (Initial Teacher Education and Continuing Professional Development)?

The project's Conceptual Framework recognized three broad strands running across all these research questions that probe:

- **Aims/purpose**, aims and purposes of creativity in science and mathematics education; how science and mathematics are taught and learned in relation to other domains of knowledge; how these relate to inquiry-based science education (IBSE); views of creativity in relation to perceived purpose.
- **Teaching, learning and assessment**, including inquiry learning activities, pedagogy and resourcing, also how children develop creative dispositions and how teachers assess them in early science and mathematics education.
- **Contextual factors**, including classroom, teacher and institutional factors.

These three strands were broken down into more narrowly-defined dimensions drawing on the framework of curriculum components 'the vulnerable spider web' (van den Akker, 2007, p.39), which focus on key questions about aspects of learning in schools: Rationale or Vision; Aims and Objectives; Learning Activities; Pedagogy (or Teacher Role); Assessment; Materials and Resources; Location; Grouping; Time; Content. These were complemented by dimensions focusing on aspects of teachers and teacher education.

Within these strands and dimensions a list of creativity enabling factors (List of Factors) were identified (Creative Little Scientists, 2012b), drawing on the Conceptual Framework and highlighting the common conceptual ground between creativity and inquiry based science and mathematics education. These factors were employed across the project to provide the scope and parameters for mapping and comparing existing conceptualisations in policy and practice, and to code current approaches observed in teacher pedagogy and children's learning.

Finally, the three strands, van den Akker's (2007) curriculum dimensions and the list of factors were also used as a basis for the development of the curriculum design principles for teacher education and recommendations for education policy makers and stakeholders ensuring strong and consistent relationships amongst theoretical knowledge established though the literature review, the comparative research, analysis of classroom practices and the production of the curriculum design principles and guidelines for teacher education.

Research Phases and Methodology

To meet the project's objectives and research questions, mixed methods were employed, combining quantitative approaches used in surveys, alongside qualitative approaches employed in fieldwork.

The **First** phase of the research focused on the comparative assessment of how early years science and mathematics is **conceptualised** by teachers and in policy in the nine partner countries, highlighting instances of, or recording the absence of, practices marrying science and mathematics learning, teaching and assessment with creativity. It thus addressed RQ1 and part of RQ4 above. The research used the methodology of comparative education employing common frameworks to inform instrument design and data analysis in making comparisons, drawing on data collected via two routes:

1. A **desk survey of policy** to examine how teaching, learning and assessment of science and mathematics in the early years are conceptualised in 134 national policy documents, including curricula, reports and assessments of school practice.
2. A **teacher survey**, which gathered data through a teacher questionnaire addressed to a sample of 815 teachers from 605 schools (238 preschools and 367 primary schools) across all partner countries, aimed towards gaining insights into practicing teachers' conceptualisations of science, mathematics and creativity in early years education.

The planning of the two pieces of research commenced at the same time to achieve maximum coherence between the studies. In addition, as research instrument, they both used a similar 4-point Likert Scale questionnaire based on the curriculum components of Van den Akker (2007) and on the creativity and inquiry approaches identified in the List of Factors. In the case of the **policy** survey, the questionnaire aimed to assess the extent to which these approaches were emphasised in policy documents and how far the role of creativity was emphasised. In the case of the **teacher** survey, it aimed to assess the extent to and frequency with which teachers use these approaches in their classrooms. Aligning the two surveys facilitated subsequent comparison of their results.

The **Second** phase of the research focused on mapping the **approaches** used in teaching, learning and assessment of early years science and mathematics in partner countries and describing the subsequent development of young children's creativity and learning. It thus addressed RQ2, RQ3 and part of RQ4 above. Undertaken across four months, the project fieldwork focused on sites potentially offering 'exemplary practices' (defined in relation to insights derived from the project's literature reviews, Conceptual Framework and policy surveys) in fostering creativity and inquiry in early science and mathematics, covering preschool and early primary education provision in each country. The sampling, which was purposive, was informed by information gathered from the teacher surveys, school inspection reports, attainment records, local authorities and teacher education institutions.

The fieldwork was qualitative in nature, and conducted in 48 different sites across partner countries resulting in 71 case studies of practices in early science and mathematics. Each partner worked in at least four sites (i.e. preschools/schools), gathering data from at least six cases (i.e. one teacher/practitioner and the children they work with). Partners identified three episodes of activity per case encapsulating creativity in these domains which resulted in 218 narrative episodes for analysis. In order to capture rich data, the fieldwork encompassed multiple methods of data collection (including documents, observations, interviews, drawings, photos) designed to take account of different aspects of pedagogy and be sensitive to young children's learning.

As mentioned above, throughout both phases of the research, concepts from the project's Conceptual Framework (e.g. the definitions of creativity, children's creative dispositions, inquiry learning activities and the identified synergies between IBSE and CA), as well as the three broad strands (Aims/purpose; Teaching, Learning and Assessment; Contextual Factors), van den Akker's curriculum dimensions and the List of Factors were employed consistently to provide the scope and parameters for data collection and analysis, as well as for the development and presentation of the related teacher education guidelines and education policy recommendations building on research findings.

It was also recognized that policy and practice needed to be interpreted within partners' particular national contexts, especially when making comparative judgments. As a result, all phases of research were first reported in separate national reports, which were then synthesized to produce overall accounts and comparisons of policy and practice at European level, all available on the project's website (www.creative-little-scientists.eu). Consequently, policy recommendations were developed at both national and European levels, drawing on the corresponding research findings and informed by consultation with communities of stakeholders – teachers, student teachers, school staff members, teacher educators, researchers, policy makers and experts in the fields of inquiry, creativity or science/mathematics – in online and face-to-face national focus groups, as well as in discussion sessions set up for this purpose during the final international conference of the project.

The sections that follow summarise research findings and present these recommendations for policy development in early years science and mathematics education across Europe.

SUMMARY OF RESEARCH FINDINGS

Conceptualisations of Teaching, Learning and Assessment of Science and Mathematics in Early Years – the Role of Creativity

This section presents summary of research findings in relation to RQ1, concerning conceptualisations of teaching, learning and assessment in early years science and mathematics (and creativity in these), held by teachers and in education policy in the project countries (see Stylianidou et al., 2016).

Aims and Purposes

The explicit curriculum **rationale** in policy for science education in nearly all partner countries focused on children's role as citizens and highlighted science and environmental awareness as a part of their life in general; this was also reflected in teachers' views. However research findings revealed that teachers' viewpoints regarding the rationale for science learning was in practice more holistic than that found in the policy documents in partner countries. Learning **aims and objectives** were conceptualised by teachers as primarily contributing towards affective and social aspects of learning, such as increasing interest and positive attitudes towards science and science learning. These views contrasted with the emphasis in policy (especially in early primary education) on the development of knowledge and understanding of science and mathematics ideas and on process skills associated with scientific inquiry.

Teaching, Learning and Assessment

In terms of **learning activities**, specific features of inquiry were reflected in both teachers' views and policy guidance. Teachers in both preschool and early primary science and mathematics classroom made reference to inquiry based learning, a key part of the policy framing in all countries, in particular through learning activities associated with observation, questioning, communication and the use of simple tools. Yet, despite this general reference to inquiry based learning, teachers' responses rarely referred to inquiry activities related to practical investigations and using data to construct explanations.

In terms of conceptualisations about **pedagogy** teachers across the partner countries held a great appreciation for pedagogical approaches that promote *dialogue and collaboration* amongst children, although teachers often failed to see the potential of these approaches for the development of children's creativity. This was consistent with policy which put some emphasis on their importance, but included very limited reference to features of creativity that might be fostered through dialogue and collaboration and very limited guidance to support teachers in enabling creativity using classroom discussions and collaborative work.

There was an uneven treatment in both policy and teachers' reported practice of the approaches associated with the synergy *motivation and affect*. Learning approaches based on *building on children's prior experiences* or *relating science and mathematics to everyday life* were amongst those reported as most frequently used by teachers and referenced in policy, although they were not highlighted as 'creativity enabling' either by teachers or in policy documents. In contrast cross curricular approaches for example, making use of *drama* or *history to teach science and mathematics* were rarely promoted both by teachers and in curricula, which also failed to make reference to their potential for creativity.

There was a similarly uneven treatment of approaches with reference to the synergy *play and exploration*. Preschool teachers reported using open forms of *play* and *role play* significantly more than early primary school teachers, and a greater proportion of preschool teachers also conceptualised these as 'creativity enabling'. This was also reflected in preschool curricula across the partner countries, with policy in the majority promoting *playful exploration* in preschool considerably more than in primary education. On the other hand teachers and policies from both phases were in agreement in fostering children's *physical exploration of materials*, an approach also conceptualised as 'creativity enabling' by teachers and in policy, and especially for primary education.

Teachers, as well as policy guidance, emphasised teaching approaches linked to *problem solving and agency* across both phases of early years education. These approaches were also often suggested to foster children's creativity, particularly in preschool.

Learning approaches associated with *questioning and curiosity* and their importance in fostering creativity were similarly conceptualised by teachers and in policy guidance. Practices that encourage children to ask questions and foster their imagination were reported as frequently used by teachers, were emphasised in policy and were perceived by both as 'creativity enabling'. In contrast, the role of teacher questioning in supporting creative learning were given more limited recognition.

Learning approaches linked to fostering *reflection and reasoning* were perceived to have limited scope in promoting children's creativity by both teachers and in policy documents, though teachers reported using them quite or very frequently.

In terms of teachers' conceptualisations about *scaffolding,* teachers saw themselves as facilitators of children's own inquiry, delaying instruction until the learner had had a chance to investigate and inquire on their own or with others. They were a little more reticent to allow children to find solutions on their own, although they strongly rejected the suggestion that they should first act as demonstrators of the correct solution before children investigate for themselves.

Assessment, especially formative assessment, was widely highlighted as an important area for development in both policy and practice in both preschool and primary phases. Policy guidance in terms of both methods of assessment and criteria for assessing on-going progress was often found lacking, which is reflected in considerable variability in assessment approaches found across partner countries. A common tendency to focus on *product* instead of *process* in assessment, allied with the pressures of statutory summative assessment processes in a number of partner countries revealed a number of challenges related to assessment of inquiry and creativity. Whilst the *assessment* of science and mathematics was widely emphasised in policy, more limited attention was given to assessment of inquiry processes and procedural understanding, and even less to social and affective dimensions of learning across the majority of partner countries, even though these dimensions were often highlighted in the *rationale* and *aims* set out for early science and mathematics education. Teachers' responses to the survey regarding their priorities for science *assessment* on the other hand were consistent with the frequency with which they indicated pursuing the corresponding *aims and objectives* in their science teaching.

Finally, there was very limited evidence in policy of a role for creativity either in the priorities or methods for assessment advocated. In particular, little attention was paid to multimodal forms of assessment or the involvement of children in assessment processes often associated with creative approaches to learning and teaching in the early years. Again here a contrast was noted between findings from the policy and teacher surveys as teachers reported taking account of children's multimodal expressions for assessment purposes, especially in preschool.

Contextual Factors

In general, limited advice was given in policy in terms of the physical and social environment for learning. Where advice on materials was provided, it mostly related to the provision of equipment for inquiry and use of digital technologies. There was very little emphasis on a budget for teaching or technical support for science. In terms of ways of grouping children for learning, common themes included the recommendation of a variety of approaches to suit particular tasks and learning needs and the benefits of collaborative learning.

Finally, fieldwork highlighted the important influence of wider contextual factors on the opportunities for inquiry and creativity. Episodes illustrated the positive impact of whole school philosophy in for example:

- provision of support for experiential and child-centred approaches to learning and teaching; attention to provision for learning in the whole school environment, both indoors and out;
- support for team working and for further professional development and scope for trying out new ideas.

In interviews with researchers, teachers made reference to a number of barriers in fostering inquiry and creativity in mathematics and science. Restrictions of *space, time and curriculum requirements* were often highlighted. Teachers in primary settings also noted that *levels of staffing* limited their use of the outdoor environment and their employment of a wider range of assessment strategies.

Approaches Used in the Teaching, Learning and Assessment of Science and Mathematics in Early Years: Opportunities for Inquiry and Creativity

This section presents summary of the findings in relation to RQ2.

Aims and Purposes

Finding from fieldwork indicated that in both preschool and primary settings there was a strong focus on social and affective factors of learning and the development of scientific and mathematical concepts and process skills was a common feature of episodes observed.

The aims of activities were often implicit. Where aims were made explicit, they rarely included a focus on creativity although the promotion of creative dispositions was evident in the majority of classroom episodes observed. Explicit focus on the nature of science was also limited.

Teaching, Learning and Assessment

Overall, in both preschool and primary settings considerable potential was found for inquiry and creativity in the opportunities teachers provided for the *generation and evaluation of ideas and strategies*. Opportunities for the generation of ideas, for example, were fostered by rich motivating contexts for play and exploration, whilst purposes for inquiry were linked to children's everyday experiences and there was considerable scope for children's decision making.

Dialogue and collaboration, promoted by widespread use of group work and teacher questioning, played important roles in encouraging the processes of reflection and explanation associated with the *evaluation of ideas and strategies*.

The potential of sensitive and responsive *teacher scaffolding* both to support independence and extend inquiry was underlined, particularly in relation to when to intervene and when to stand back in order to listen to and build upon children's creative engagement and the development of their ideas and questions.

Opportunities for play were limited in primary settings. The value of *play and exploration* in the primary age phase could be more widely appreciated, for example in generating ideas and questions and fostering a feel for phenomena.

Findings suggested that the roles of varied forms of representation and the processes of representation (not just the product) in developing children's thinking needed greater recognition; this included the role of ICT, particularly in preschool settings.

There were few examples of episodes involving the use of outdoor resources or non-formal settings for learning in museums or the wider community. Here differences were noted between preschool and primary settings. In a number of preschool settings, children had free access to outdoor areas, and the overall provision of space and staffing levels were more generous, providing greater scope for practical exploration.

Assessment approaches observed were generally informal and formative and were based on observation and teacher questioning. There was limited evidence of the involvement of children in assessment, although interviews with children during fieldwork did indicate their capabilities to reflect on their learning and gave new insights into learning processes.

Contextual Factors

Findings underlined the important influence of teachers' wider perspectives on learning and teaching, and their views of the nature of science and mathematics and understanding of creativity on the aims and approaches explicit or implicit in the activities observed. Teachers in most settings designed their own learning experiences with only a small proportion of episodes relying on textbooks or published schemes, where this was observed it was most common in the teaching of mathematics.

Project partners commented on the greater scope for child-initiated activity and creative engagement in preschool settings, although this was not always recognised by teachers, and on the tendency for pressures of time and curriculum requirements to limit opportunities for children's creativity and inquiry in primary settings.

Fostering Young Children's Learning, Interest and Motivation in Science and Mathematics

This section presents summary of the findings in relation to RQ3 that is concerning the outcomes of the approaches described above in terms of children's inquiry skills and creative dispositions; and how teachers perceived their role in fostering these outcomes.

Across the episodes there were many examples of children *observing* and *making connections,* for example drawing on prior learning or between experiences. Opportunities for children's *questioning* were also present but not always recognised or built upon.

There was greater evidence of children's engagement in the social dimensions of inquiry, *explaining evidence* and communicating *explanations* than might have been expected from the findings of policy and teacher surveys; this was often prompted by dialogue with peers and adults.

Explicit examples of children's developing *understanding of the nature of science* were limited however starting points were indicated in a number of episodes, in children's reflections on learning in classroom discussion, or in interviews with researchers.

Children's inquiry skills and understandings noted in episodes were interconnected with evidence of a number of creative attributes. For example children's *motivation, curiosity* and *abilities to come up with something new* were evidenced in raising questions and in their active pursuit of explorations and investigations. The episodes reported offered many examples of children's *sense of initiative* and *growing abilities to collaborate* in deciding what to do in carrying out investigations. Children showed *imagination, ability to make connections and thinking skills* in offering explanations.

How Did Teachers Perceive their Role in Doing So?

Teachers involved in the case studies often indicated that they had not previously thought about the approaches they adopted in terms of opportunities for inquiry and creativity. Fieldwork processes had prompted reflection on the nature of inquiry and creativity in early science and mathematics and how this might be fostered.

Most teachers made reference to the importance of encouraging and supporting young children's engagement in early years science and mathematics as an important starting point for learning. Many emphasised the need to foster motivation and collaboration and provide a rich environment with space and time for exploration and problem-based learning, underlining key roles for teachers in encouraging reflection and making connections to promote children's conceptual understanding and the application of ideas in varied settings.

In sharing their approaches limited explicit reference was made to the role of creativity or to features of inquiry in science and mathematics.

Future Development of Practice in the Classroom and in Teacher Education (ITE and CPD)?

This section addresses RQ4, which suggested –based on the research findings above– the areas for attention in teacher education to support inquiry and creativity in early science and mathematics education. They included:

Aims and Purposes

- Perspectives on the nature of science and mathematics and the purposes of science and mathematics education in the early years.
- The characteristics and roles of creativity in learning and teaching in early science and mathematics.

Teaching, Learning and Assessment

- Approaches to planning at whole school and class levels to maximize scope and flexibility to foster children's inquiries and to provide opportunities for play and exploration (across both preschool and primary phases of education).
- Ways in which everyday learning activities can be opened up to allow space for children's agency and creativity.
- The roles of questioning in supporting inquiry and creativity; different forms of teacher questioning; ways of supporting children's questioning; recognising questions implicit in children's explorations.

- Importance and roles of varied forms of representation, including the use of ICT, in supporting children's learning processes.
- Use of the outdoor and wider school environment for learning in science and mathematics.
- Assessment strategies and forms of evidence that can be used to support learning and teaching in early science and mathematics, the roles of peer and self-assessment.

KEY RECOMMENDATIONS FOR POLICY DEVELOPMENT ACROSS EUROPE IN EARLY YEARS SCIENCE AND MATHEMATICS EDUCATION

The recommendations for policy development are drawn from key findings from across the different phases of research summarised in the previous section. They are presented in relation to the key strands of importance in relation to opportunities afforded for inquiry, problem solving and creativity in early years science and mathematics: aims, teaching learning and assessment and contextual factors.

Aims and Purposes

The aims of the curriculum should:

1. Give greater recognition to **young children's capabilities** to engage with processes associated with evaluation as well as the generation of ideas in science and mathematics.

The review of policy noted a lack of coherence in policy in this aspect, for example a mismatch between rationale or aims that might emphasise the promotion of inquiry skills and creative dispositions, and assessment methods and criteria that allow limited opportunities for children to show their capabilities. Having said this, teachers needed help to recognise more fully young children's capabilities to engage with processes associated with the evaluation as well as generation of ideas in science and mathematics.

2. Foster the role of **social and affective dimensions of learning** and their connection with cognitive dimensions of learning such as engagement, evaluation skills and understandings related to the nature of science.

Across project countries social and affective dimensions of learning were given more limited attention in policy compared to cognitive dimensions. More particularly, the majority of policy documentation inspected lacked emphasis on promoting positive attitudes to learning and interest in early years science education.

Teaching, Learning and Assessment

Curriculum content and policy guidance should:

3. Emphasise the important **roles of play-based approaches**, child–initiated activity and practical investigation in both preschool and early primary school.

The project's Conceptual Framework considers playful experimentation and exploration is inherent in all young children's activity; such exploration is at the core of IBSE and CA in early years settings. Policy in the majority of project countries promoted playful exploration in preschool considerably more than in primary education, with guidance that suggests a recognition of its value in promoting creative skills and dispositions. It would be valuable to exemplify ways of creating such opportunities in the primary age phase within the greater constraints of time and curriculum requirements.

4. Give detailed attention to **key features of problem solving and inquiry based learning and teaching** particularly with regards to providing sufficient space and time in the curriculum for problem solving and inquiry to study areas in depth. Emphasise also the need for **space and time for teachers** to develop inquiry approaches and explore opportunities for creativity in learning and teaching in early science and mathematics.

Curriculum and assessment requirements, and space and time at school level can constrain teaching approaches, particularly in primary settings. Findings from fieldwork revealed pressures of time and curriculum requirements that drastically limit opportunities for children's creativity and inquiry in both settings. They also indicated that more flexible timetabling and the more holistic approaches to learning and teaching commonly associated with preschool settings allowed teachers greater flexibility to follow children's interests over time and to revisit experiences, making provision for children to encounter ideas in a range of contexts. The challenge here was often less one of time but of recognising and building on children's emerging interests, skills and creative ideas.

5. Include more explicit and detailed focus on the **role of creativity in early science and mathematics**. Provide explanation and illustration of the nature of creativity in learning and teaching in early years science and mathematics.

Findings from all research phases of the project suggest that a more *explicit* and detailed focus in policy on the role of creativity in early science and mathematics would be helpful. Where explicit references were made to creativity in policy they were often in very general terms without provision of guidance about what this might mean in the context of early science and mathematics. These need to be drawn out and exemplified to support teachers in translating policy priorities concerning creativity into specific classroom practices. Furthermore, while certain teaching approaches were often signaled as associated with creativity, such as problem solving and the use of digital technologies, there was limited indication of how such approaches might be used to foster creativity or inquiry.

6. Promote the role of inquiry activities in supporting the children's **understanding of science ideas** and **nature of science**. Give more attention to reflection and consideration of alternative ideas building on the social and collaborative features of learning and inquiry.

Approaches to teaching and learning associated with inquiry and creativity were widely included in policy guidance in partner countries. Connections to creativity were largely associated with the generation, rather than the evaluation of ideas. In seeking to foster opportunities for inquiry and a role for creativity, greater recognition could be given in policy to the roles of imagination, reflection and consideration of alternative ideas in supporting children's understanding of scientific ideas and procedures. Consideration of alternative ideas is also connected to social factors in learning and the provision of opportunities for development of understandings associated with the nature of science, on which explicit focus was found limited.

7. Recognise the importance and roles of **varied forms of representation**, including the use of ICT, in supporting children's learning processes.

The research indicates that the role of varied forms of representation in learning could be more widely recognised. While there were examples of children's employment of diverse forms of expression across the episodes, findings suggested that the range of approaches might be extended, in particular to incorporate children's greater use of ICT. They also indicated the value of dialogue with children about their recordings, and the potential of representation and expression, not just for recording outcomes, but for fostering reflection and reasoning processes.

8. Encourage **meaningful and authentic contexts** for inquiry, linked for example, to: events and experiences in everyday life; children's interests and concerns; questions emerging from cross-curricular projects or explorations; and issues in the wider environment beyond school.

Findings from the review of policy suggest that limited attention was given in policy to contexts for learning such as drama, stories, historical projects or everyday experiences in the environment. Exemplification would be valuable of the kinds of contexts teachers can provide, and ways of capitalising upon them to foster inquiry and creativity. Fieldwork findings indicated the important contribution of rich, motivating contexts in generating ideas, questions and interests, but also the need for teacher sensitivity to features of inquiry and emerging ideas implicit in young children's explorations, as well as for time and teacher flexibility to build on these.

9. Create **coherence in assessment** between the aims and objectives of learning and priorities in assessment. More attention should be given to social and affective and inquiry related issues in assessment guidelines.

A common theme to emerge across the research was the limited policy guidance for science assessment and inconsistencies in emphasis across different elements in curriculum policy, resulting in considerable variability in approaches adopted among project countries. For example while assessment of science ideas was widely emphasised in policy, limited attention was given to social and affective dimensions of learning, although these dimensions were often highlighted in the rationale and learning aims set out for early science and mathematics education and were greatly valued by teachers.

10. Foster the development of **on-going assessment strategies and criteria for assessment** to better reflect the emphasis on inquiry and creativity in the aims for science and mathematics in the early years.

Findings reflected lack of policy guidance in terms of both methods of assessment and criteria for assessing on-going progress. They also revealed particular challenges in assessment related to inquiry and creativity, linked to a common tendency to focus on product rather than process in assessment requirements, allied with pressures of statutory summative assessment processes. There was very limited evidence in policy of a role for creativity either in the priorities or methods for assessment advocated across project countries. Greatest emphasis was given to the assessment of science ideas. Understandings and competencies in relation to scientific inquiry were emphasised in assessment policy in a minority of countries and in only a few instances were attitudes a priority for assessment in science.

11. Provide further guidance on **formative assessment approaches** to support classroom practices. **Assessment methods** should be clearly linked to the multimodal approaches used in classroom practices. Policy statements should foster the use of **children's involvement in assessment** and provide increased opportunities to mirror the children's various strengths and opportunities in their learning.

While the importance of formative assessment has been increasingly recognised in policy, findings indicated that further guidance would be valuable to support classroom practices in assessment. Areas highlighted include: the use of multimodal forms of assessment to give young children opportunities to show best what they understand

and can do; ways of involving children in peer and self-assessment to support children's reflection on inquiry processes and outcomes; and criteria to assess progression in learning, particularly in relation to inquiry and the development of dispositions associated with creativity.

Contextual Factors

Findings from across the project also identified a number of contextual factors of importance in fostering creativity and inquiry in early science and mathematics. Findings from the teacher survey and fieldwork in schools indicated there is a need to:

12. Ensure **sufficient resources and facilities** in schools to support practical inquiry and problem solving in early science and mathematics.

Across the research findings the project identified the influence of resources on the opportunities provided for inquiry and creativity in early science and mathematics. In some countries lack of resources was acknowledged as presenting an important challenge in implementing inquiry and problem-based approaches to learning and teaching. Need for further funding was found for example to support the *use of ICT* to extend children's problem solving and inquiry processes and the development of the whole school environment, in particular *the outdoor environment* to support learning.

13. Extend opportunities for **ongoing professional development** in early science and mathematics.

Access to Continuing Professional Development (CPD) was very varied across the project countries. Further recognition is needed of the value and importance of continued training and qualifications. Findings highlighted the need for knowledge and understanding of child development and early learning in science and mathematics to be included in teacher education programmes to support teachers in recognising and building on children's interests, ideas and explorations. The need for further training for teachers was identified in the use of the environment to support learning and teaching in science and mathematics, both the school environment indoors and out, and the wider environment and community beyond the school.

14. Encourage **dialogue with parents and the wider community** concerning the aims of science and mathematics education in the early years including the development of skills, processes and attitudes associated with inquiry and their roles in developing not just factual knowledge but long term understanding of concepts.

The different phases of the project have indicated opportunities provided in policy for promoting inquiry and creativity in early science and mathematics. However common challenges have also been identified associated with the demands of curriculum content and a focus on summative assessment in primary schools. Both can result in a focus on factual knowledge rather than deeper understanding and attention to outcomes at the expense of the development of skills, attitudes and processes associated with inquiry and creativity. In addition, a number of teachers across project countries have commented on the pressures they felt from parents to focus on factual knowledge and grades.

Future Work

Erasmus+ funding enabled members of the consortium to take forwards the CLS project's curriculum design principles and guidelines for teacher education and create a teacher development course and accompanying teaching materials to be used in European teachers' professional development to promote the use of creative approaches in teaching science in preschool and early primary education, in the frame of inquiry-based educational environments (*Creativity in Early Years Science Education* project, www.ceys-project.eu).

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Teachers' Roles in Preschool Children's Collective Mathematical Reasoning

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ABSTRACT

The aim of this paper is to study teachers' roles in preschool children's mathematical reasoning using analysis of epistemological moves. Three moves were identified: instructional moves, confirming move and a new move, concluding move. There were no generative moves encouraging the children to produce different arguments for choice of strategy or conclusion. Both the confirming move and the concluding move functioned as an end of the reasoning and thereby limited the opportunities for the children to learn creative mathematical reasoning. This although that several encounters were created by the preschool teachers, both as formal planned situations and unformal such as free play.

Keywords: epistemological moves, mathematical reasoning, preschool education

INTRODUCTION

Young children's mathematical reasoning is receiving increasing attention (Sumpter and Hedefalk, 2015), such as studies that indicate that young children are more competent to develop and demonstrate processes regarding mathematical thinking than previously reported (e.g. Mulligan and Vergnaud, 2006). The focus on mathematical reasoning is indeed relevant for younger children as well: mathematical reasoning is, alongside problem solving, the core of what it means to think mathematically (Niss, 2003). They create what is called mathematical proficiency (Abrantes, 2001; Kilpatrick et al., 2001), which is here understood to mean the actions adopted by an individual who identifies a situation as problematic and is favourably disposed to solve the problem and proceeds to do so. The solution is done by deploying a strategy in a series of not necessarily linear steps. This deployment and creation of steps is what characterises mathematical reasoning, where the non-linearity is related to creativity. These are competencies relevant for all and not just a mathematical elite (OECD, 2013).

Recent studies show that children use different competencies in their reasoning (Sumpter and Hedefalk, 2015). However, when looking at the development of mathematical thinking, there is evidence that these competencies are not developed without the provision of a learning opportunity (Bergqvist and Lithner, 2012; Bobis et al, 2005). Also, it has been indicated that if children have access to a guide, they are more likely to go further in their mathematical thinking especially if that person asks key questions (Laine et al., 2017; van Oers, 1996). The importance of the teacher has been stressed in mathematical reasoning teaching (e.g., Bergqvist and Lithner, 2012; Kilpatrick et al, 2001; Shimizu, 1999). This is in line with previous studies on active learning environment (e.g. Derry and Lesgold, 1996; Marks, 2000). This implies that to avoid rote thinking, teachers need to know what to do, when to do it and the implications of their actions (Laine et al., 2017; Lester and Cai, 2016; Liljedahl, 2016).

However, when analysing Swedish secondary school teachers' presentations, we see that most task solutions that are presented to the students are based on algorithms with only rare opportunities to see aspects of creative mathematical reasoning (Bergqvist and Lithner, 2012). We don't know how such results are translated to the preschool level, especially with informal settings as an important learning opportunity: although the competence mathematical reasoning is the same and education in Swedish preschools should strive for children to "develop their mathematical skill in putting forward and following reasoning" (School Agency, 2011, p. 10), teaching should be play-based (Sumpter and Hedefalk, 2015). The way the education differs at preschool invites a different set of problems:

Finding ways to educate such a teacher for young children, with a deep understanding of the psychological characteristics of young children's playful learning, with valid mathematical understandings, with abilities to demonstrate the relevance of mathematical creativity and the attitude to improvise in her pedagogical practice within a strongly structured field (see, for example, Sawyer, 2011) may be the biggest challenge that we face in our attempts to improve mathematics education for young children (van Oers, 2013, p. 271-272).

In order to understand what it means to understand mathematical reasoning, in an informal setting as well, we need to look at preschool teachers' roles in collective mathematical reasoning. This is the aim of this paper: to study the opportunities for participation in mathematical reasoning that are presented to children at the preschool level. The research questions posed are: (1) what different arguments can be found in collective mathematical reasoning in a preschool setting?; and, (2) what are the different roles of the teacher connected to these arguments?

THEORETICAL BACKGROUND

Reasoning in mathematics education is often denoted as some type of 'high-quality thinking' but with little explanation of what it could encompass (Lithner, 2008). This is true for research focusing on the preschool level as well where few studies define what it means to perform mathematical reasoning independent of mathematical area (Sumpter, 2016). The starting point is to separate creative mathematical reasoning and imitative reasoning, where the former is based on mathematics and the latter on other arguments often non-mathematical, and reasoning is defined as the line of thought adopted to generate assertions and conclusions when solving mathematical tasks (Lithner, 2008). This is a product and we see it as a sequence or several sequences that begin with the tasks and ends with an answer, where the answer could be no conclusion at all. Reasoning is a chain of arguments where arguments can be defined as a collection of statements where some are offered in support of another (Toulmin, 2003). It should be stressed that creative mathematical thinking is not restricted to people with an exceptional ability in mathematics since it includes rather elementary reasoning (Lithner, 2008). However, it could be difficult to produce without sufficient key competencies and a supporting environment. Also, teaching mathematical problem solving doesn't automatically mean that students become mathematically proficient, meaning that there is something more that is required in order to teach 'mathematical thinking' (Lester and Cai, 2016). Previous research has shown that creative mathematical reasoning can be difficult for students, both at the secondary level (e.g., Bergqvist, Lithner and Sumpter, 2008) and at the primary level (Pehkonen, 2000). Research also indicates that it is not the implementation of a strategy, the deployment of a strategy that provides the main difficulty for students, but more finding the right arguments for the choice of strategy (e.g. Kester et al., 2004).

Following the idea of learning opportunity and the importance of the teachers when creating them with regard to mathematical reasoning, teachers need to be able to pick up children's mathematical ideas (Bergqvist and Lithner, 2012; van Oers, 1996; Shimizu, 1999). Also, since the key component of Swedish preschool education (children age 1-5) is the emphasis on play and whereby education should not be formal schooling, this should happen independently of whether the activity is planned or informal (School Agency, 2011). One could argue that, at least in such a system as the Swedish one, the role of the teacher at the preschool level is particularly important since the format and context is much more varied and less predictable. Such an argument is supported by Sawyer (2011) when discussing the balance between structure and improvisations regarding what it is that makes good teachers great: that relying on improvisation requires skills. However, these skills are on a general level and when giving examples that are mathematics-specific, the analysis doesn't focus on the teachers' roles (Martin and Towers, 2011).

Continuing to focus on mathematics, van Oers (1996) concluded that teachers at preschool level can promote mathematical reasoning although in his study there is no definition of reasoning and there is no further suggestion of how to do it besides asking the question 'are you sure?' There is also no explanation of why this question works beyond the notion that it should be related to the solutions suggested by the children and not when the problem is initiated. Time then seems to be a factor but no further discussion why is provided. Another study raising the importance of asking the right questions at the right time, although focusing on teacher education, is Shimizu (1999). There is a separation between the initiation of the task and other key questions, but also the instructions a teacher should give at the students' desk. One of the things required is the ability to scan and assess students' problem solving progression, but there are no explanations of what or of how this scanning should be done, of what makes a key question or of what to assess when deciding what to ask, meaning it is hard to distinguish what is generating and promoting mathematical reasoning and what is not. The teachers' role is stressed by Liljedahl (2016), who focuses more on how questions are answered when students are working on a task. His conclusion was that the questions of the types 'proximity questions' and 'stop thinking questions' should not be answered, although acknowledged, in order to create a 'building thinking classroom'. The teacher should only answer 'keep thinking questions' to avoid leading questions and scaffolding, but there are no details of how to answer them and when.

Another study takes the opposite perspective and instead looks at the importance of specific leading questions, with the aim to promote mathematical reasoning (Davydov and Tsvetkovich, 1999). A clear structure is presented about what to say and what mathematical properties to emphasise, but no justifications are presented and there is no analysis of why the structure works. The idea of certain questions being constructive is supported by Laine et al. (2017). In the conclusion, they state that a "teacher who is accustomed to guiding problem-solving knows certain types of good questions that will help the pupils to move forward" (Laine et al., 2017, p.16). Considering the close relationships between problem solving and mathematical reasoning (Niss, 2003) both being part of mathematical proficiency (Abrantes, 2001; Kilpatrick et al, 2001), it is plausible to make the inference that the same questions could function for mathematical reasoning. Nonetheless, no examples are given illustrating what is a 'good question' or whether the quality of the question is dependent on the time and situation.

Therefore, we argue that, with respect to mathematical reasoning, it is not clear what makes a question from a teacher function as a key question and if and how this differs dependent on content or time. Also, we anticipate that the ability to pick up ideas and ask the right question, hence providing the right stimuli, is a challenge (c.f. Bergqvist and Lithner, 2012) especially for preschool teachers since they often do not know about the mathematical topic beforehand and what mathematical competencies that could be involved due to the centrality of free play (c.f. Laine et al., 2017; Sawyer, 2011). Such a study has been done in research looking at preschool teachers in play-based situations who have different educational content in focus (Hedefalk, 2014; Klaar and Öhman, 2014). As theoretical tools to study teachers' roles, Practical Epistemological Analysis (PEA) and Epistemological Move Analysis (EMA) were used. Practical epistemology is used as a tool for describing the route that meaning making takes, and the meaning-making processes involved (Wickman and Östman, 2002). It is in this meaning-making process that the teacher takes on different roles in order to direct children/students in different directions suggesting that learning and teaching are understood as "ongoing changes in human conduct" (Caiman and Lundegård, 2017, p. 6). Previous research in science and technology education in primary school and secondary school (e.g., Lidar et al., 2006; Lundqvist and Östman, 2009) and in preschool in general education (Hedefalk, 2014; Klaar and Öhman, 2014) has identified the following moves: confirming, reconstructing, instructional, generative, and reorienting moves. In the confirming move, the teacher confirms that the children are recognizing the correct phenomenon, or confirms that the children are undertaking a valid process, by agreeing with what the children say or do. The reconstructing move makes the children pay attention to the 'facts' they have already noticed but have not yet perceived as valid. The instructional move gives the child a direct and concrete instruction for how to act, to discover what is worth noticing. In the generative move, the teacher enables the children to generate explanations by summarizing the important facts in the context of the activity. This is similar to the Lithner and Bergqvist (2012) theoretical framework regarding stimulation argumentation, both predictive and verifying, including reflections. In their study of such argumentation, creative reflection, was sparse.

Finally, the reorienting move indicates that other properties may be worth investigating and encourages the children to take another, alternative direction (Hedefalk, 2014; Lidar et al., 2006; Klaar and Öhman, 2014). Hence, some comments or questions from the teacher will generate different moves depending on the context and interaction with the students. Therefore, van Oers' (1996) suggestion "Are you sure?" could be a key question and create meaning, but it could also not generate an epistemological move. By studying the interaction between the content, here with a focus on different arguments in mathematical reasoning, and the participants and their interplay, there is a possibility to offer such explanations.

METHODS

Method of Data Collection

The data was collected via video filming at a preschool in Sweden during 17 visits over a period of two months. The researcher (second author) had access to three groups of children, the groups are here named Dundret, Kebnekaise, and Skanderna with the ages 1-2, 3-4 and 5 respectively (more information about the data collection can be found in paper masked). The names of the children and teachers have been altered in the transcripts: the children that belong to Dundret have names beginning with D, to Kebnekaise with K, and to Skanderna with S. Out of 24 hours and 10 minutes of film, 13 hours and 30 minutes were transcribed since we were interested in interactions between actors. Hence, episodes where children sat quietly, not interacting with peers or teachers, were not transcribed. The interactions we choose to analyse were restricted to mathematical reasoning both planned and informal. A first analysis resulted in 21 episodes consisting of collective mathematical reasoning in different mathematical areas such as measurement (e.g., height, weight and time) using both informal and formal units, counting and basic arithmetic (e.g., adding) and geometry (e.g., shapes).

Method of Analysis

In order to answer the two research questions, we perform two different analyses. The first analysis is a modification of Lithner's (2008) framework to focus on collective mathematical reasoning. It focuses on the content in the mathematical reasoning, the different arguments (Sumpter and Hedefalk, 2015). The second analysis focuses instead on the different roles of the teachers. What these two analyses share is the structuring of data, a step-by-step transcription stating actors and actions and utterances. In addition to the data structure, the first analysis requires an organization of the data, a four-step structure (Lithner, 2008): (1) A task situation is met (TS); (2) A strategy choice is made (SC); (3) The strategy is implemented (SI); and, (4) A conclusion is obtained (C). In Lithner's (2008) framework, there are two types of arguments attached to two of these steps. The strategy choice can be supported with predictive arguments that aim to answer the question 'Why will the strategy solve the task?'. The implementation of the strategy can be supported with verifying arguments. Their function to answer the question 'Why did the strategy solve the task?'. This categorisation of arguments was used in Bergqvist and Lithner (2012) when studying upper secondary school teachers and mathematical reasoning. However, a first test of the present analysis showed that this categorisation did not cover arguments focusing on the conclusion and the evaluation of it. Therefore, the choice was, just as Sumpter and Hedefalk (2017), to add evaluative arguments. Such arguments focus on the conclusion and how and in what way the conclusion is an answer to the initial question.

In the second step of the analysis of the arguments, we use the notion of anchoring. It is important to note that anchoring does not refer to the logical value of the argument, since it allows us to talk about reasoning that is incorrect (Lithner, 2008). This helps us to look at the foundation and how it is used. Anchoring is seen as the fastening of the relevant mathematical properties, or alternatively, of the components reasoned about. These components are objects, transformations, and concepts (Lithner, 2008). Certain mathematical properties will be surface and other intrinsic depending on the task, e.g., when comparing fractions, the size of the numerator and denominator is a surface property, whereas the quotient is the intrinsic property. In Lithner's (2008) framework, different types of reasoning can be classified. Here, we will only focus on the different types of arguments and their foundation.

For the second analysis, we need analytical tools focusing on the teachers' roles. Here, the choice was Practical Epistemological Analysis (PEA) and Epistemological Move Analysis (EMA). By using PEA, we can understand why a conversation takes a certain path and why it stays on the same path. There are four concepts in focus in PEA: encounter, stand fast, gap and relations (Wickman and Östman, 2002). An encounter is a specific situation in terms of what the participators interact with and here we will focus on encounters between children and teachers where mathematical discussions take place. What stands fast for the participator is identified in their actual use of words within the practice. When the participator uses a word without hesitation or questioning, such words are said to stand fast in the particular situation. Standing fast is a situational description of the meaning that words have in action. When the participator hesitates, when what is happening cannot be taken for granted, there is a gap. When a gap is noticed it can, according to Wickman and Östman (2002), be filled by establishing relations to what stands fast in the encounter. Then it is possible for the participators to proceed in their meaning making again.

PEA is then combined with analysis of Epistemological Move Analysis (EMA). EMA is an analytical method that aims to generates knowledge about the role a teacher plays in children's meaning making (Wickman and Östman, 2002). The focus of the analysis is how the teacher directs children's meaning making in different ways (Lidar et al., 2006). When the children respond, verbally or non-verbally, to the teacher's direction, we call it an epistemological move. The epistemological moves of the teacher show the children both what counts as knowledge and appropriate means of obtaining knowledge.

For each of the selected episodes, the task situations (TS) were identified with an appropriately chosen grain size. Then the central decisions for each TS were identified alongside the argumentation for these decisions. The mathematical content was analysed using the notion of anchoring and mathematical properties. Then, we applied PEA and EMA. First, we analyse how the actors move forward during the mathematical discussions, i.e., an analysis of the children's practical epistemology. Then we analyse what stands fast, i.e., what they all agree on, what is understandable and reasonable for the children. In order to get to the direction of meaning making, we also look for a gap, i.e., where there is doubt in the interaction between the actors. Here we can see that the actors do not agree on what is said to be reasonable, and in particular how the gaps are filled. These are situations that could indicate learning opportunities.

Table 1. Instructional and confirming move

Line	Person	Data	Argument	EMA
2705	Solveig [T]:	Then we should not forget to say how much we have. How much was it? One litre. [Walks to the table with a colander, then pours the content into the colander]	Initiating a TS: How much is the volume? SC: measuring with a standard unit, reading the scale. SI: Straightforward. C: 1l.	Instructional move. Concluding move.
2706	Sandor:	Here is some more. [reaching for the measure putting some bits of rhubarb in it]		
2707	Sam:	One litre.	Repeating the conclusion.	
2708	Solveig [T]:	That was, one litre is what we have now. Uhm. [goes back to the place where she puts the dough into a pie dish].	Repeating the conclusion.	Confirming move.
2709	Sandor	It is special when you take long [ones]. I take these [holding up a stalk of a certain length]	Indirect measure of lengths. Comparing magnitudes.	
2710	Solveig [T]:	Maybe we can have a whole extra litre [of rhubarb].	Beginning of a new TS.	Instructional move.
2711	Sandor and Sam [at the same time]:	Yes.		
[…]				
2783	Solveig [T]:	Hey you, it is time for you to empty your bits into the measure. And how much do we have then? [pointing at the measure, Svante pours the content from the measure into the colander]	TS: How much is the total content?	
2784	Svante:	Two litres. [using the measure]	SC: No explicit arguments is given. First measure using standard unit l, then adding result to previous result: 1+1 = 2. SI is straightforward with no hesitation. C: Two litres.	
2785	Solveig [T]:	Two litres, correctly! These that are a bit long, could you cut them please? You have got the… [referring to the ability to use a sharp knife] remember which is the straight side. Look at the knife. Yes, you must look. This one you have to work a bit more with [picking up a stalk and putting it on Samuel's tray]		Confirming move.

The next step in the analysis involves EMA, the teacher's role in meaning making. The teacher's epistemological positions are examined using moves identified in earlier research, but also allowing for new moves to be identified. Finally, the different moves were compared to the different arguments (supportive, verifying, or evaluative) using the structuring of the data, thus enabling us to focus on the teachers' roles in collective mathematical reasoning.

RESULTS

The analysis showed that three different types of epistemological moves reoccurred and that these had three different roles in mathematical reasoning. These three were instructional, confirming and a new move, a concluding move. We will here present three episodes to illustrate these moves and their different functions in the reasoning. The numbered lines indicate position in transcriptions, *T* stands for 'teacher' and explanations and further information is provided in square brackets. Pauses not relevant to the task situation are marked with […].

Repeating instructional and confirming epistemological move

The most common situation in the data was teachers initiating a task situation (TS) using an instructional move and then, with a confirming move, establish a conclusion with no further arguments. In this episode, four boys (Sandor, Samuel, Sam and Svante) from Skanderna are going to bake a rhubarb pie with their teacher Solveig. The transcript begins when they have been cutting rhubarb for approximately 30 minutes, see Table 1.

The teacher instructs the children to measure the amount of rhubarb using a measure with standard unit litre (row 2705). However, since she herself provides the strategy choice including implementation of the strategy and conclusion without any arguments, this means that the children are not participating in this particular part of the sequence. However, there are some indications of what stands fast, such as what the unit is and how to operate the measure as nobody shows any hesitation when asked about it or using it. Also, the confirmation of the conclusion ("one litre") is repeated by Sam (line 2707), thus making it an epistemological move, a concluding move. The teacher makes the children focus on the measure and how much rhubarb they have cut up by repeatedly commenting on the amount of rhubarb in the liter measure (lines 2710 and 2783). The TS is initiated (line 2783), and a conclusion is given when Svante states "Two litres" (line 2784). There are no arguments provided besides the film showing Svante operating with the measurement. The conclusion is confirmed by the teacher as a

Table 2. Confirming and concluding move as part of conclusion

Line	Person	Data	Argument	EMA
2501	Kasper:	Yes, but the house is bigger than the rock.	Final C. New TS and C. Argument not provided. House's height > rock's height.	
2502	Kristina [T]:	Where?		
2503	Kasper:	The house is bigger than the rock.	House's height > rock's height.	
2504	Kristina [T]:	The house? Yes, definitely. Because the house, I can step in [the house], right?	Agreeing to C: provides argument using transitivity: Since House > Teacher, and Teacher > Rock, therefore House > Rock.	Confirming move. Concluding move.
2505	Kasper:	Uhm.	Confirming C.	

reasonable conclusion (line 2785), but there is no encouragement to produce any supporting, verifying, or evaluating arguments.

Confirming Move and Concluding Move

Another situation that occurred in the data was the combination of a confirming move and a new move, here called a concluding move. It appeared in the conclusion in relation to evaluative arguments: why is this conclusion an answer to the TS? It is here illustrated with this encounter where two children from Kebnekaise playing in the woods and who have found a rock. When they start trying to climb the rocks, a teacher sees this and interacts with the children. The main TS for this encounter is: what is rock's height in relation to other objects/people? In this part of the reasoning, the teacher (Kristina) and one of the children (Kasper) have disagreed about the height of the rock in relation to the teacher creating a gap (see **Table 2**).

There is one incident where a gap occurs. It starts when Kasper says that the house is bigger than the rock (line 2501). This is a statement that is confirmed by the teacher as a valid statement (line 2502). However, she doesn't encourage Kasper to give any arguments for this conclusion but provides them herself. The arguments are related to the TS and not to the SC or the SI meaning that they are evaluative arguments functioning as control. The gap is not filled in this chain of interactions. What stands fast is that the rock is smaller than the house, which turns out to be the final C to the TS. The encounter ends with Kasper's recognition of the conclusion, (line 2505). According to PEA and EMA. Kasper's 'uhm' is seen as recognition, an affirmative statement, and not an objection or contradiction. Therefore, the conclusion is an epistemological move.

However, since the conclusion is not a confirmation of something the children have discussed or evaluated, but instead it is the teacher who provides the conclusion, the move is a concluding move. This is a new move that has not has been previously described. Due to its content, we call it a concluding move. It is the teacher who makes the conclusion which is recognised by Kasper. If the conclusion was made by the children using evaluative arguments, it would have become a generative move.

Initiating Evaluative Arguments

In this episode, there is also the same repetition of instructional move when initiating a TS and confirming move regarding the conclusion as in the first episode, but in this particular encounter, there is a variation. As part of a first initiation of evaluative arguments in relation to the conclusion to the main TS, the teacher instead breaks down the TS into a sub-task. Saga (teacher) and some children from Kebnekaise are outdoors playing in the sand pit and an activity is initiated: a leopard (played by Kalle) has a birthday and he is five years old. The sand in the bucket is the cake and the sticks are the candles. When the episode starts, three sticks are already in the bucket and now they need to determine how many more candles should be lit (see **Table 3**).

The teacher initiates the main TS by asking about how many candles are left to light, which then becomes an instructional move (line 1256) when the children show in action that they are now focusing on the amount of lights. One child confirms the instructional move, but also give a conclusion to the TS. (line 1257). The teacher responds to the conclusion with a confirming move, but the difference here compared to the second episode is the teacher doesn't end the reasoning with a concluding move. The teacher tries to engage the children with a question that would focus on evaluative arguments (line 1258), but since there is no change in the children's epistemology, it doesn't become an instructional move or a generative move. The teacher asks again, and this time a sub-task is initiated (line 1260). However, since the question doesn't encourage the children to produce their own arguments or further explain their thinking, it becomes an instructional move instead of a generative move. The sub-TS is solved by counting ending in a conclusion (line 1265). During this part of reasoning, we have one gap: when Kalle disagrees with Kasper's statement about the leopard's age (line 1263). The teacher states that the leopard is five (line 1265) and no further discussion takes place. We see by Karolina's actions, when she counts five candles, (line 1265) that the statement from the teacher is an epistemological move. The teacher then confirms Karolina's actions (SC and SI) and conclusion as reasonable (line 1266).

Table 3. Initiation of evaluative arguments

Line	Person	Data	Argument	EMA
1255	Kasper:	Light [it]. Light [it]. [takes a stick and pulls it towards the three other sticks that are already pushed down in the sand in the bucket.]		
1256	Saga [T]:	How many candles are left to light now?	TS: What is the difference between two amounts, a=5 and the amount of sticks in the bucket, b?	Instructional move
1257	Kasper:	We need more candles! [gets up]	C: b<5, no arguments are given.	
1258	Saga [T]:	More candles? Yes, because how many years do we celebrate? [Kalle push one more stick down into the bucket]	Confirms conclusion. Evaluative argument: what is a?	Confirming move.
1259	Kasper:	I bought one more candle. [comes running with a stick]	SC to previous TS: 1 more is needed, $a-b$ = 1. SI straight forward. C: 1.	
1260	Saga [T]:	Yes. How many years is it that you are celebrating, Kalle?	Confirms C. Initiates sub-TS as part of main TS: what is a?	Confirming move. Instructional move.
1261	Kasper:	Uhm. Five! [working with the bucket]	Sub-C: a=5. No arguments are given.	
1262	Saga [T]:	Five. And how many candles do you have now?	Confirms Sub-C: a=5. TS: How many candles? Implicit TS: is the amount of candles the same as the amount of years?	Confirming move. Instructional move.
1263	Kalle:	No, I'm turning six years. [Kalle walks away a few steps]		
1264	Saga [T]:	We have agreed upon five now.	Implicit re-establishment of sub-TS.	Instructional move.
1265	Karolina:	1,2,3,4,5 [points to each stick and counts them]	SC: count sticks, one-to-one, cardinal. SI: Straight forward. C: 5 candles.	
1266	Saga [T]:	Five candles. Now birthday child, it is time to sit down.	Repeating conclusion: 5.	Confirming move.

DISCUSSION

In the present paper, the aim was to study preschool children's participation in collective mathematical reasoning, and the teachers' roles in the reasoning. The empirics show that the teachers did help the children to pay attention to mathematics in their everyday lives at the preschool, both during planned activities and free play. As a learning environment, it was interactive and in many ways meaningful context often with a specific content in focus (c.f. Derry and Lesgold, 1996; Marks, 2000), but regarding the results concerning the construction of mathematical reasoning and different arguments, a different image emerges.

Regarding mathematical arguments, there were no supportive or verifying arguments concerning the choice of strategy or the implementation of such in the data. It should be noted that the lack of arguments is not because of the preschool teachers not being able to create learning opportunities; 21 episodes were identified with interactions between children and teachers with mathematical content. The conclusion is that preschool teachers are able to initiate different types of task situations in different mathematical areas. However, the lack of engaging children in mathematical reasoning is similar to what has been reported by Bergqvist and Lithner (2012) regarding the 'opportunity to learn' mathematical reasoning at the upper secondary school level. It appears to be difficult to encourage students to express arguments about different choices at different stages in mathematical reasoning (c.f. Kester et al, 2004). Here, initiations of arguments are replaced by the teacher instead confirming the strategy choice or the conclusion, meaning that the role is about confirming moves instead of generative moves.

The most common epistemological moves, the instructional move and the confirming move, could be considered effective as they make the children pay attention to mathematics (c.f. Bobis et al., 2005). However, it is the generative move that creates the condition for reasoning as it generates different arguments that could include reflection (c.f. Bergqvist and Lithner, 2012). Here, the analysis found no generative moves in the data although there were several situations where mathematics was in focus (e.g., second episode, line 2503). Laine et al. (2017) concluded that guidance without preparation requires an open attitude and good mathematical knowledge. The teachers in our study show both mathematical knowledge and an open attitude, and as such as they both encouraged and engaged in mathematical activities although they were not planned, but still there was something more needed to create a generative move. We suggest, as a possible development in this research area, is to further explore the ability to scan mathematical reasoning (see Shimizu, 1999), if this could possibly be what is missing in order to voice good questions (c.f. Laine et al., 2017). This could include an exploration of what scanning could encompass and how it can be used to create key questions based on the results of the understanding of mathematical ideas.

Looking closer at the confirming moves, when combining EMA and the analysis of the reasoning, we see that the latter one means that the teacher guides and draws conclusions for the children, i.e., a kind of scaffolding. This could be related to Liljedahl's (2016) distinction between three types of questions. When confirming a strategy choice or a conclusion, it is related to the 'stop thinking questions', which could be illustrated with "is this right?". Such a question is about external validation removing the need for the student to think for themselves. Here it is represented by the confirming moves which are mainly found in the conclusions. The teachers act as external validators, almost as an answering section, pointing out what is right and what is wrong. As a comparison with the 'are you sure?' question suggested by van Oers (1996), our results cannot confirm such a conclusion: that a specific question would result in a certain epistemological move. This is here illustrated by the third episode, when the teacher poses the same question twice (line 1258 and line 1260) but with two different reactions from the children. Hence, all that a teacher says does not automatically result in epistemological moves which could be contrasted with previous research aiming to describe key questions (e.g., van Oers, 1996; Shimzu, 1999).

Another result is the discovery that the epistemological moves from research in science teaching were insufficient to describe the teacher's influence on the meaning of the mathematical reasoning (c.f. Hedefalk, 2014; Lidar et al., 2006), as we had to add a new move, a concluding epistemological move. The concluding move differs from the confirming move as it establishes a conclusion in relation to the task situation. If arguments were given, i.e., evaluative arguments, they were provided by the teacher. What concluding moves and confirming moves have in common is that both end the reasoning: the children do not spontaneously continue with the reasoning. A possible explanation could be the difference between mathematics education and science education: that in the former there is often *one* right answer, whereas in the latter there could be several. This requires further investigation.

What we can see in the empirics is a need for the teacher to take the discussions further. The implication then is that this should be addressed by teacher education and in-service education since this is difficult. Shimizu (1999) talks about the need for prospective and beginning teachers to learn key roles. The results from the present study indicate a similar conclusion. If teachers need to know what to do and also when to do it (c.f. Lester and Cai, 2016), especially when taking free play into account (van Oers, 2013; Sawyer, 2011), they need the tools and practice to do it, but they should also be given the explanation of why a certain question could become a generative move in one situation but a confirming move or a concluding move in another situation. Such analysis is needed to understand what makes a key question.

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STEM Media in the Family Context: The Effect of STEM Career and Media Use on Preschoolers' Science and Math Skills

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ABSTRACT

Children's learning of science, technology, engineering, and mathematics (STEM) is important for their achievement in related fields. Before formal schooling, families can expose children to STEM by sharing knowledge and influencing children's use of learning tools, including media. We investigated whether parent attitudes towards STEM media and having a family member with a STEM career is related to children's science and math media use, and whether these factors predict children's science and math skills. We surveyed 296 American parents of children 3- to 5.5-years old on their attitudes toward STEM and their children's use of STEM television, computer games, and apps. Regression analyses showed that positive attitudes toward science and math media positively predicted children's science and math media use. Having a STEM-career family member was a negative predictor. Children's science and math media use was negatively related to their reported science and math skills. However, there was an interaction: children from non-STEM career families who consumed the most science and math media reportedly had worse science and math skills. Our findings have implications for how families can support science and math learning. These results can direct research on the role of media in early STEM education.

Keywords: informal learning, family environment, children's media, parent survey, STEM career

INTRODUCTION

In the United States, educators, researchers, and government agencies have been increasingly focused on promoting children's engagement with science, technology, engineering, and mathematics (STEM) in order to prepare youth for the needs of the global market. Before children enter formal schooling, the family environment may play an especially important role in exposing children to STEM concepts. For example, family members, such as parents, can share STEM knowledge, expose children to learning experiences like science museums, and encourage children's use of science and math learning tools and participation in STEM activities. Despite a plethora of research showing that the family context plays an important role in child development (e.g., Bronfenbrenner, 1986; Jant et al., 2014; Maloney et al., 2015; McCarthy et al., 2015), little research has investigated how family factors are related to practices around children's informal learning of science and math early in life, before they begin schooling. In the United States, children who have not begun compulsory primary education have the option of enrolling in preschool programs, which typically includes children between the ages of 3 to 5 years of age. Using data from a survey of American parents with preschool-aged children (between 3- to 5.5-years old), we investigated whether parent attitudes toward science and math media and having a family member in a STEM career are related to young children's reported science and math media use, and if these factors and children's science and math media use predict children's reported science and math skills. By investigating whether children's family environment is related to their science and math skills, researchers and educators can better understand how to promote opportunities for family members to directly (e.g., sharing expertise) and indirectly (e.g., encouraging media use) support children's informal STEM learning.

Early Exposure to STEM Learning

Exposure to STEM learning opportunities early in life is important because the development of STEM skills can further students' interest and educational attainment in STEM, as well as expand their career choices later in life (Bybee and Fuchs, 2006; DeJarnette, 2012; Nugent et al., 2010; Wai et al., 2009; Watts et al., 2014). For example, research shows that children who received science instruction for longer periods of time and more regularly in kindergarten performed better than peers on a science assessment in third grade (Saçkes et al., 2011). Considering math, much research suggests that math learning that occurs prior to a child entering formal schooling has long-term benefits on their math achievement (Duncan et al., 2007; Nguyen et al., 2016; Watts et al., 2017; Watts et al., 2014). For example, Watts and colleagues (2014) found that children's math ability in preschool predicted their achievement in math at age 15. Research also shows that high school students with strong spatial abilities – an important STEM skill – are more likely to pursue advanced degrees and careers in STEM fields (Wai et al., 2009). Thus, promoting early STEM learning may have long-term implications on STEM achievement in school and on children's pursuit of a future STEM career.

One potential way of supplementing children's early STEM learning is through educational media (e.g., television, videos, computer games, apps), which can be a powerful learning opportunity through which children are exposed to STEM concepts before they enter formal schooling (Pasnik and Hupert, 2016). Much research shows that preschool-aged children can learn from educational television (e.g., Anderson et al., 2001; Fisch et al., 1999; Kirkorian et al., 2008) including science and math concepts. For example, there has been a plethora of research on *Sesame Street*, a media property that debuted in the United States in 1969 and has expanded into many different productions globally. Research shows that long-term viewing of *Sesame Street* at young ages can impact later student achievement in many subject areas. Specifically, children who watched *Sesame Street* at age 5 had higher academic grades, including science and math, 10 years later during secondary school (Huston et al., 2001).

A number of evaluative studies also show that children can learn important STEM concepts from media. For example, exposure to the *Sid the Science Kid* and *Peep and the Big Wide World* programs and interactive games significantly increased preschoolers' science talk at home (Penuel et al., 2010). Additionally, children's exposure to *Peg + Cat* programs and interactive games, along with parents' exposure to material that support parent engagement, promoted preschoolers' learning of ordinal numbers and spatial relationships (Pasnik et al., 2015). These properties are all available via public-access television stations in the United States, and therefore are widely accessible to preschool-aged children.

Recent research also suggests children can learn foundational STEM concepts from interactive media, which has been defined as "technology that invites the child to physically manipulate the platform and is contingent to the child's manipulations" (Aladé et al., 2016, p. 434). Several studies have explored children's STEM learning from touchscreen devices in short, lab-based experiments. For example, Aladé and colleagues (2016) found that playing an interactive game or watching a non-interactive video on a touchscreen device both supported 4- to 6-year-olds' learning to measure. Additionally, Huber and colleagues (2016) found that children aged between 4 to 6 years could learn to solve a spatial problem on a touchscreen and then transfer that learning to a 3-dimensional context. Furthermore, evidence from a longitudinal study indicates that using a math app, *Bedtime Math*, at home with a parent over the course of a year leads to significant improvements in primary school children's math skills compared to children who played a reading app (Berkowitz et al., 2015). Children's learning from interactive media does however seem to depend on age. For example, Schroeder and Kirkorian (2016) found that older preschool-aged children could learn STEM concepts (i.e., quantity and growth) from a touchscreen app regardless of whether they watched or played the game, whereas younger children only learned if they watched rather than played the game. Although research on interactive STEM media is emerging, the existing evidence along with the longstanding research on children's learning from STEM television programming suggests STEM media can be an important learning tool for young children.

Effects of Family Environment on Children's Media Use and Learning

The family system is an important context for children's STEM learning, both because the family environment is a space where children are exposed to STEM concepts during family interactions, and because families monitor whether and how children are exposed to STEM learning opportunities. Bronfenbrenner (1986) posited that children's development can only be fully understood by acknowledging the distal and proximal ecological systems that promote or deter children's development and viewed family functioning as an important context for human development. According to this theoretical perspective, children are directly affected by entities in their microcosm, such as their family, school, and activities. Importantly, these entities can also interact with each other, such as family members monitoring what activities their children do. Therefore, families themselves provide a context for directly influencing children, but also interact with other entities that can indirectly affect children's development.

We adopt Bronfenbrenner's theory by considering the proximal (i.e., family context) and distal (i.e., media context) and their relation to children's development. Specifically, we consider how family involvement in STEM careers and children's use of STEM media may affect children's learning of STEM skills. Firstly, families may directly affect children's short- and long-term learning by sharing their STEM knowledge and teaching their children how to engage in STEM activities. Adults can help develop children's curiosity toward STEM (Early Childhood STEM Working Group, 2017). For example, one intervention study showed that supporting family engagement around their preschool-aged children's math learning helped improve preschoolers' mathematical knowledge (McCarthy et al., 2015). Moreover, research shows that parental beliefs and attitudes toward math affect first and second graders' own beliefs and attitudes toward math (Maloney et al., 2015).

Another research study asked doctoral students in the physical sciences what factors encouraged their early interest in science and found that family involvement in science facilitated early interest, with parent occupation being one primary source of early interest (Dabney et al., 2013). Although the specific impact of parent occupation on children's interest was not specified, other researchers have posited that having a parent in a STEM career has a positive influence on children's involvement and subsequent learning of STEM (Sonnert, 2009; Tai et al., 2006). One possibility is that parents or other caregivers who have a STEM career may share their STEM knowledge and interest with their children, promoting learning and engagement with STEM concepts. Research shows that providing parents with science information via cue cards at a science exhibit facilitated parent talk with their children, which promoted children's learning compared to children whose parents did not receive cue cards (Jant et al., 2014). In this vein, immediate family members who already have STEM knowledge from their career may be primed to subsequently engage children in more STEM learning compared to children who do not have an immediate family member with a STEM career.

Secondly, families may also indirectly affect children's STEM learning by influencing children's use of STEM learning tools, particularly their media use. One research study showed that family demographics predicted 3- to 7-year-old children's exposure to *Sesame Street* (Pinon et al., 1989). These researchers found that children with a younger sibling were more likely to watch *Sesame Street*, and parental encouragement of watching *Sesame Street* was positively related to children's viewing. This finding is complemented by more recent research showing that parent attitudes toward media predicts their children's media use (Cingel and Krcmar, 2013; Lauricella et al., 2015; Rideout and Hamel, 2006). Cingel and Krcmar (2013) surveyed parents of children between the ages of 6 months and 5 years and found that while parents reported agreement with the statement "I believe educational [television/DVDs/computers] are helpful to my child's cognitive development," parents also reported high agreement with the statement "I worry that electronic media will have a negative effect on my child's cognitive development" (p. 383). In turn, Cingel and Krcmar (2013) found that their measure of positive parent attitude toward screen media was positively related to children's overall media use. Moreover, Lauricella, Wartella, and Rideout (2015) found that positive parent attitudes toward television, smartphones, and computers were associated with more child use of these devices. Therefore family structure and attitudes toward media can influence children's exposure to educational media, thereby impacting their potential opportunity to learn.

The Current Study

Previous research suggests families influence children's exposure to STEM, but little research has investigated specific family factors, their relation to STEM exposure, and children's informal learning. We surveyed American parents of 3- to 5.5-year-old children to investigate the relation between media use, family context, and children's science and math skills. Specifically, we investigated whether parent attitudes toward the educational value of media and having a family member with a STEM career predict parent report of children's science and math media use (Research Question 1). Additionally, we were interested in whether there may be differences in media use for families with and without a member in a STEM career, and whether these differences affect children's STEM skills. Therefore, our second research question asked whether children's science and math media use, having a family member in a STEM career, and their interaction were related to parent report of children's science and math skills. The research questions addressed in this paper are important given the global efforts to teach STEM to students (Kennedy and Odell, 2014) including the efforts to teach STEM to young children during the influential time before they enter formal schooling (Clements and Sarama, 2011). Importantly, this research was also motivated by the continuing focus on utilizing media, such as television, apps, and educational games, as tools for STEM education (McClure et al., 2017). With a better understanding of the possible direct and indirect pathways through which families influence their children's exposure to STEM concepts, researchers and practitioners will be better equipped to help families support children's early STEM learning.

METHOD

Participants

A total of 296 American parents of preschool-aged children (3 to 5.5 years) completed the online survey. Most of the respondents were female (78%), 20% were male, and 2% (n = 7) did not report their sex. Our sample was 75% White, 6% Black, 8% Hispanic/Latino, 9% Asian/Pacific Islander, and 2% Other/multiracial. We also asked parents to report their highest education level: 8% of our sample had attained a high school education or less (i.e., less than 12 years of formal education), 12% completed some university (i.e., tertiary) education, 30% obtained an Associate's degree (i.e., equivalent to two years of tertiary education or certification at a vocational school), 28% obtained a Bachelor's degree, and 22% of our sample obtained a Master's degree or a professional degree. Additionally, 54% of children were male and 45% of children were female. The average age of children was 4.25-years (SD = .76 years; median = 4.5 years). Fifty-one percent of respondents indicated that they lived in Illinois, which is the U.S. state where the research team is located and where they typically recruit for studies. The remaining participants resided in various states throughout the United States.

Procedure

Informed consent was obtained from all participants included in the study in accordance with the University's ethics boards. The survey questions analyzed here were part of a larger survey, which took approximately 40 minutes to complete. Parents were recruited using a variety of methods, including via a University database of families interested in participating in studies, Facebook postings, parent group websites, and via word-of-mouth. Parents with STEM careers were not specifically recruited for the study.

All participants took the survey online via Qualtrics. Participants were directed to a page that described the survey and asked participants for their informed consent. After agreeing to participate, participants were directed to the first page of the survey. Participants received a $10 Amazon electronic gift card and were also entered into a drawing to win one of three $100 Amazon electronic gift cards upon completion of the survey.

Measures

Parents answered a series of questions about their beliefs and attitudes toward educational media, the frequency of their child's media use (i.e., television, apps, computer games) in their home, their family involvement in a science- or math-related career, and their perceptions of their child's ability to perform science and math skills.

Parent attitudes toward science and math media. To measure parents' attitudes about science and math media as educational tools, we asked parents three separate questions related to the survey questions used by Cingel and Krcmar (2013). Parents were asked three questions about how much their child has learned about science and math from television/DVDs, computer games, and apps. Specifically, parents were asked, "In your opinion, how much has [child's name] learned about the following subject areas from watching educational TV shows or DVDs?" Parents separately rated their response for science and math on a 5-point Likert scale anchored by "nothing" to "a lot" including the option to select "Not Applicable." Next, parents individually answered the same question about "educational computer games" and "educational apps on mobile devices" by rating their response for math and science on the same 5-point scale.

To investigate parents' *overall* attitudes toward educational media, we averaged parent ratings for the three statements about television/DVDs, computer games, and apps and created separate scales for science media (M = 2.96, SD =.98; α = .67) and math media (M = 3.03, SD = .96, α = .64).

Children's science and math media use. To measure children's use of science and math media, parents were asked about the frequency of their children's use of science and math media. Specifically, parents were asked, "How often does [child's name] do each of the following activities at home or outside of school?" Below, parents rated three items "Watch science-related TV shows or videos via TV, DVDs, or online; Play science games on the computer; Play science apps on a mobile device." Parents were asked the same three questions for math. Responses were measured on a 6-point Likert scale anchored by "never" to "daily." The scores were averaged for science and math to obtain a science media use score (M = 3.15, SD = 1.48, α = .73) and a math media use score (M = 3.32, SD = 1.47, α = .69).

Family involvement in a science or math career. Parents were asked "Does anyone in your immediate family have a science- or math-related career?" Participants then received an explanation of what constituted a science- or math-related career: "A science- or math-related career is one that requires studying science or math at the college or university level. Careers like an engineer, accountant, weather forecaster, economist, and doctor are all examples of science- and math-related careers." Of the 287 responses to this question, 45% reported that someone in their family worked in a science- or math-related career (n = 129), and 55% reported that no one in their family worked in a science- or math-related career (n = 158).

Children's science and math skills. We identified preschool science and math skill by referencing parent resources and school readiness standards for teachers, including the Head Start Early Learning Framework (U.S. Department of Health and Human Services, 2011), the Early Childhood Longitudinal Survey (National Center for Education Statistics, 2011) and academic research (Brenneman, 2011; Brenneman et al., 2009). We asked parents to rate how well their children performed a variety of science- and math-related activities by asking "When [child's name] does each of the following activities, how often does he/she do them correctly?" Parents rated their response on a 6-point Likert scale anchored by "does not do this activity" to "all of the time." For science, parents rated the following six items: *Describes basic life cycle concepts; Sorts object and living things based on similarities and differences; Describes cause and effect relationships between objects; Describes the physical properties of objects and living things; Makes educated guesses based on past experiences; Describes concepts of body parts and processes.* For math, parents rated the following five items: *Counts to 20 or more; Identifies basic shapes; Identified written numbers; Identifies spatial relationships; Identifies numerical relationships.*

The scores were averaged for science skill items and math skill items to obtain a science skill score (M = 3.95, SD = .78, α = .82) and a math skill score (M = 4.07, SD = .72, α = .68).

RESULTS

Children's Science and Math Media Use

Research Question 1 focused on the relationship between parent attitudes toward science and math media as being educational, family involvement in a science or math career, and their children's science and math media use. To answer this question, we ran two linear regressions predicting science media use and math media use. For science media use, we entered parent attitudes toward science media being educational and STEM career (yes or no) as predictors of children's science media use. Demographic information including child age, child gender, and parent education were entered as control variables. The regression was significant, R = .68, adjusted R^2 = .45, $F(5, 278) = 46.34$, $p < .001$. Parent education was negatively related to children's reported science media use (β = -.11, p <. 04). Parent reports of how much their child has learned from science media positively predicted children's reported science media use (β = .56, p <. 001, see **Table 1**). Additionally, having a family member with a science or math career was negatively related to children's reported science media use (β = -.18, p <. 001).

Table 1. Regression analyses for children's science and math media use

	Science			Math		
Variable	***B***	***SE B***	***β***	***B***	***SE B***	***β***
Child Age	-.01	.05	-.01	.01	.04	.01
Child Gender	-.05	.07	-.03	-.06	.06	.04
Parent Education	-.09	.04	-.11*	-.03	.38	-.04
Family STEM Career	-.54	.15	-.18***	-.41	.13	-.14**
Media as Educational	.84	.07	.56***	1.06	.07	.68***
ΔR^2		.45			.55	
ΔF		46.34**			68.89***	

Note: *indicates $p < .05$, **indicates $p < .01$, ***indicates $p < .001$

The second regression predicted math media use by entering parent attitudes toward math media being educational and STEM career (yes or no), as well as demographic variables including child's age, child gender, and parent education. The regression was significant, R = .75, adjusted R^2 = .55, $F(5, 278) = 68.89$, $p < .001$. Parental report of how much their child has learned from math media was positively related to children's reported math media use (β = .68, p <. 001, See **Table 1**). As with science, having a family member with a science or math career was negatively related to children's reported math media use (β = -.14, p <. 01).

Children's Science and Math Skills

Research Question 2 focused on the relationship between children's science and math media use, family involvement in a science or math career, and children's science and math skills. To answer this question, we ran two linear regressions predicting children's science skills and math skills. For science skills, we entered child's age, child gender, and parent education as control variables along with science media use and STEM career (yes or no). Because we were interested in the relation between media use and family factors, we also entered the interaction between STEM career and science media use into the model. The regression was significant, R = .41, adjusted R^2 = .15, $F(6, 277) = 9.25$, $p < .001$. Child age was positively related to children's reported science skills (β = .20, $p < .001$). Children's reported science media use was negatively related to their reported science skills (β = -.27, p = .001). Having a family member with a science or math career was not a predictor of children's science skills (β = -.09, p = .52). However, there was an interaction between STEM career and science media use (β=.33, p = .01). While STEM families reported high science skills regardless of science media use, non-STEM career families who consumed the most science media reported their children had significantly worse science skills (See **Table 2**).

Table 2. Regression analyses for children's science and math skills

	Science			Math		
Variable	***B***	***SE B***	***β***	***B***	***SE B***	***β***
Child Age	.10	.03	.20***	.17	.03	.36***
Child Gender	-.01	.09	.01	.14	.08	.10
Parent Education	.03	.03	.07	.07	.02	.17
Family STEM Career	-.36	.21	-.09	-.35	.20	-.24
Child Media Use	-.14	.04	-.27**	-.16	.04	-.32***
STEM Career*Media Use	-.17	.06	.33*	-.16	.06	.40**
ΔR^2		.15			.22	
ΔF		9.25***			13.87***	

Note: *indicates $p < .05$, **indicates $p < .01$, ***indicates $p < .001$

The second regression predicted math skills using child's age, child gender, parent education as control variables, along with math media use, STEM career (yes or no), and the interaction between STEM career and math media use. The regression was significant, $R = .49$, adjusted $R^2 = .22$, $F(6, 277) = 13.87$, $p < .001$. Child age was positively related to children's reported math skills (β = .36, $p < .01$). Children's math media use was negatively related to their reported math skills (β = -.32, $p < .001$). Having a family member with a science or math career was not a significant predictor of children's math skills (β = .-.24, p = .08). However, there was an interaction between STEM career and math media use (β = .40, p = .002). As with science, STEM families reported high math skills regardless of math media use, but non-STEM career families who consumed the most math media reported their children had significantly worse math skills (See **Table 2**).

DISCUSSION

The results provide insight into the relation between family factors and 1) children's reported science and math media use, and 2) children's reported science and math skills. First, the initial set of regressions provide additional support to prior research showing that parent attitudes toward media predicts children's media use (Cingel and Krcmar, 2013; Lauricella et al., 2015), including science and math media. Specifically, we found that parent attitudes toward the educational value of science and math media positively predicted their children's reported use of that media. These results add support to our hypothesis that parents may indirectly affect their child's exposure to STEM concepts by influencing how often their child is exposed to science and math television, apps, and computer games. However, more research is needed to understand the nature of children's exposure to media, including what science and math content children are exposed to and how parents interact with their children around STEM media.

Notably, our results also suggest the larger family context – outside of parents exposing their child to STEM media – may play an important role for children's learning. We found that having an immediate family member in a STEM career was negatively related to science and math media use. But importantly, variations in media use had little effect on skills for children from STEM career families. Instead, children *without* a family member in a STEM career who used the most science and math media had reportedly worse science and math skills compared to children without a family member in a STEM career who used less science and math media. In contrast, children with a family member in a STEM career had reportedly higher science and math skills regardless of their media use. As we hypothesized, there were important differences in media use for families with and without a member in a STEM career, but these differences were only related to children's skills for non-STEM career families.

STEM Learning in the Family Context

Children can potentially be exposed to multiple science and math learning opportunities within the family context (Bronfenbrenner, 1986), either from direct instruction from family members (e.g., Jant et al., 2014) or from family members indirectly exposing children to different learning opportunities, like educational media (Cingel and Krcmar, 2013; Lauricella et al., 2015; Rideout and Hamel, 2006). We found that families with a member in a STEM career have children who use *less* science and math media compared to families without a member in a STEM career. One hypothesis is that STEM career families may be more adept at identifying STEM opportunities in everyday life in comparison to non-STEM career families because of their career and educational experiences. Previous research has found that parents who engage in science talk with their children better prepare them for school science discussions (Crowley et al., 2001). Perhaps families with a STEM-career member are better able to identify opportunities to highlight STEM concepts in everyday experiences, and therefore turn to media less as a source of supplemental information.

In contrast, families *without* a member in a STEM career may be less likely to find opportunities to integrate STEM learning into their child's out of school activities, and also may be less comfortable supporting STEM learning at home. Research shows that parents and teachers often report discomfort supporting science and math learning for preschool-aged children (Berkowitz et al., 2015; Brenneman et al., 2009; Copley, 2004; Tu, 2006). As a result, families with less STEM experiences may turn to media more to supplement their perceived lack of expertise, which may be why not having a family member in a STEM career was positively related to viewing media as good sources of STEM education. Non-STEM career families may feel as if media can supplement their children's informal STEM learning in ways that they do not feel entirely comfortable supporting themselves. However, our results show that these children's reported science and math media use was negatively related to their reported science and math skills, which calls into question what media children are consuming and how families are using it to support children's learning.

Our results have implications for how the family context can be leveraged to improve preschool-aged children's exposure and potential learning of science and math, as well as where there are opportunities for future research to supplement our findings. First, our research suggests that it may be beneficial to help parents and other close family members identify science and math learning opportunities in everyday activities including media, especially families who may lack confidence in their own STEM skills. There are uplifting findings from multiple studies that indicate that with some support, parents of different backgrounds can be primed to talk about specific science curricula with their children (Haden et al., 2014; Jant et al., 2014), and that media can support parent scaffolding opportunities (Pasnik et al., 2015). More so, research shows that children who have a parent with math anxiety benefit the most from co-using a math app with their parent (Berkowitz et al., 2015). Here, the app not only helped children learn math skills, but provided resources that scaffolded parents' abilities as teachers. Incorporating tips for joint media engagement around science and math media may be especially important for parents and family members who feel uneasy about teaching their child science and math concepts.

Limitations and Future Directions

Despite the important implications of this research, this study had limitations. First, although surveys are useful for measuring parent attitudes toward media, parents may not know exactly what content their children are consuming across multiple devices. Some television programs and games certainly teach science and math concepts in well-constructed narrative contexts or game designs that are less explicitly about science or math (Mayo, 2009), and television programs that claim to teach STEM concepts vary in their actual representation of STEM subject areas (Lovato et al., 2017). Moreover, parent report of children's skills may be less accurate than direct child measures of their science and math skills (Jordan, 2001; Schmitt, 2000). However, parent perception of children's skills may be the best estimation given that our sample included young children who were not yet enrolled in formal education.

Our research raises interesting questions about the indirect role of science and math media as a tool for learning within the larger family context. For example, it is important to consider whether the interaction between STEM career and media use that we found in our analyses may be an outcome rather than the cause of children's poorer science and math skills. For non-STEM career families, it is possible that they identify that their children need to improve their science and math skills and therefore use media as a primary tool to supplement their children's learning. In this sense, media use is the outcome rather than the cause of children's poor science and math skills. In contrast, STEM career families may rely more heavily on other approaches that are not media-based. If difference in family career involvement in STEM reflect differences in how families are engaging their children in STEM, then it is necessary to better understand the nature of those differences so that early educators and practitioners will be better equipped to help families support their children's STEM learning.

Conclusion

Our research highlights the important role family context plays in children's STEM learning while also calling for more research on whether and how families promote their children's STEM learning, both through educational media and with other activities. This paper emphasizes the complex and sometimes indirect means by which family members may influence their children's STEM skills; family members with STEM careers may be less likely to use media as a tool for STEM learning, but there only seems to be a relation between STEM media and STEM skills for children from non-STEM career families. Additional research is crucial to understanding the nature of this relationship, particularly whether media indeed serves as a supplemental tool or instead as a substitute for exploration and discussion. With future research, researchers and educators can better understand how the family environment influences children's STEM learning, and how practitioners can best communicate with families on how to optimally help children engage with STEM outside of formal school environments.

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Implementing STEAM in the Early Childhood Classroom

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ABSTRACT

STEAM (Science, Technology, Engineering, Art, and Math) education has received growing attention over the past decade, primarily within the middle and high school levels. This article focuses on the need for STEAM education at the early childhood level. Preschool children have a natural disposition toward science with their sense of curiosity and creativity. This ethnographic research involved professional development for 50 in-service preschool teachers in an urban high-needs area of the northeastern United States. The researcher explored how providing hands-on professional development, consistent support, and rich resources for STEAM lesson implementation into the early childhood curriculum would impact the dispositions, self-efficacy, and rate of implementation for teachers. The study also involved observation of the reception of STEAM instruction by preschool children. Data was collected through pre and post surveys, teacher interviews, and field observations. Findings revealed an increase in positive dispositions and self-efficacy of preschool teachers, however, the rate of implementation of STEAM lessons by the teachers was initially limited. The reception of the STEAM lessons by these high-needs preschool children was phenomenal with high levels of engagement and cooperation. More research needs to be done in the area of STEAM implementation in the PK-12 classrooms to incorporate engineering education.

Keywords: STEM education, early childhood STEAM, early science education, preschool STEM, preschool STEAM

INTRODUCTION

There is a growing need in the United States to produce more skilled laborers in the areas of science, technology, engineering, and math (STEM) (Gomez and Albrecht, 2013; Nugent et al., 2010). According to the National Center for Education Statistics (2009), the United States has fallen behind other developed countries in math and science (Myers-Spencer and Huss, 2013). If the U.S. wants to support growing technological innovation, then it is important to increase the amount of positive exposures and experiences to STEM fields for PK-12 students (Aronin and Floyd, 2013). With greater attention to the need for STEM education in recent years, United States youth have shown some improvement in the areas of math and science performance, but still lag behind their international peers (Desilver, 2015).

STEAM Adds the Arts

There is a growing trend in adding the arts to STEM and making it STE**A**M (Jones, 2011). STEAM is important because it helps teachers incorporate multiple disciplines at the same time and promotes learning experiences that allow children to explore, question, research, discover, and exercise innovative building skills (Colker and Simon, 2014). Including the arts in the STEM disciplines is a natural fit because of STEAM's emphasis on creativity and design (Sharapan, 2012). STEAM concepts are second nature for children, as they like to explore and experiment within their natural environment. Adding art provides additional options for educators to present STEM concepts to children, especially at the elementary and early childhood levels. Robelen (2011) states that STEAM integration allows for intersection of the arts with the STEM fields which not only can enhance student engagement and learning, but also help unlock creative thinking and innovation. The nature of the arts and STEM both lend themselves to hands-on learning and production.

Early Exposure

Research has shown that providing meaningful hands-on STEAM experiences for early childhood and elementary age children positively impacts their perceptions and dispositions towards STEAM (Bagiati et al., 2010; Bybee and Fuchs, 2006; DeJarnette, 2012). STEAM concepts are not too difficult for preschoolers (Kropp, 2014) who are persistent and determined when building designs; they naturally try to fix them when things don't quite work out the way they wanted. Van Meeteren (2015) states,

> Engineers often define their work as design under constraint. In the block center, preschoolers work hard to build structures under many constraints or limitations. They must consider space, shapes, sizes, materials, the numbers of blocks available, and of-course gravity. Preschoolers are budding engineers! (p. 30)

Young children need time to explore, create, and innovate. They want to learn basic knowledge and gain understanding of how the world works (Koester, 2013). Preschool children have a natural disposition toward science with their sense of creativity, curiosity, and persistence (Banko et al., 2013). STEAM activities provide preschoolers with a natural environment for collaboration and communication. They are capable of discussing different strategies and suggestions for a simplistic engineering design.

The preschool age is a great age in which to introduce science literacy (Koester, 2013). Early learning librarians can utilize children's literature to design STEAM activities in the library and begin building a foundation for STEM concepts (Kropp, 2014; Myers-Spencer and Huss, 2013). Preschoolers have a natural sense to work with materials, try things out, and problem-solve. Engineers identify a problem, design and construct a solution, test their product, and work to improve it (Jackson et al., 2011). Testing products is a key aspect of the engineering design loop. In STEAM education, teachers need to question their young students and encourage critical thinking about their designs and ways in which to improve them (Ingram, 2014). This instructional strategy will easily turn play into learning.

There are many benefits for young children from early exposure to STEAM. Integrated and exciting learning experiences improve students' interests and learning in STEM and helps prepare them for the 21st Century. In Becker and Kyungsuk's (2011) research, cohesive STEAM lessons within the curriculum identified a positive impact on student achievement with students at the elementary level. When children are introduced to STEAM at an earlier age, there tends to be less gender-based stereotypes and fewer obstacles regarding STEM (Kazakoff et al., 2013; Davidson, 2011). However, little research exists regarding the impact of STEAM initiatives at the early childhood level (Moomaw, 2012).

Professional Development for Teachers

Science classrooms need to exhibit more critical thinking, inquiry and problem-solving activities that promote process skills rather than simply content knowledge (DeJarnette, 2012). Middle and high school teachers are specifically trained within their STEM disciplines, however, at the elementary and early childhood level, teachers have had little or no instruction. When faced with this new emphasis on STEAM education in the primary grades, teachers are often intimidated, lack self-efficacy, and reveal negative dispositions as a result of their lack of training (Jamil, Linder and Stegelin, 2018). When they feel inadequate with certain content areas, they tend to spend less time teaching that particular content with their students. Nugent et al. (2010) research revealed that teachers significantly increased their knowledge of engineering and developed more positive attitudes towards STEM, increasing their self-efficacy and confidence in teaching STEM lessons, after receiving effective professional development. Self-efficacy is defined as one's impression of their own proficiency on a task (Myers, 2014). It resembles one's contemplation and discernment of their own abilities on a given performance. This lack of STEM or STEAM training for elementary and early childhood teachers brings new urgency for quality professional development in light of the newly released Next Generation Science Standards (NGSS), which emphasize K-12 engineering and technology education.

Next Generation Science Standards (NGSS)

In the spring of 2013, the Next Generation Science Standards (NGSS) were officially released in the United States. States across the nation have slowly been adopting the new standards. Currently in mid-2018, 19 states and the District of Columbia have adopted the standards and have implementation schedules. These standards were developed by 26 lead state partners (Next Generation Science, 2016). The NGSS emphasize scientific inquiry, engineering design, and require K-12 students to have the ability to link broad concepts across scientific fields. The inclusion of K-12 engineering education will bring challenges and anxiety to many teachers who have not been adequately trained on this specific content and skill set, especially at elementary and early childhood levels. With the adoption of the NGSS by the states, there is a realization that adequate professional development will be required for teachers before they can fully implement the new standards, resulting in slow adoption rates as well as implementation schedules (Next Generation Science, 2016). The inclusion of K-12 engineering education reveals that science educators at the highest levels are in agreement that STEM concepts are not only appropriate for early childhood, but that young children are also capable of completing simple engineering design challenges and experience success with STEM skills (Moomaw and Davis, 2010).

Theoretical Perspective

The theoretical framework for this study was based on the sociocultural theory leading to the Constructivist theory, which is an approach to learning based upon the work of Vygotsky (1978). Sociocultural theory accentuates the importance of students' interaction with others and their environment in order to gain understanding. Constructivist theory emphasizes the importance of providing students with authentic learning experiences where they can relate real world problems and situations to the task at hand (Wilson, 1996). The unique structure of the professional development workshop (provided for the teachers in this study) reflected these learning theories through the hands-on modeling of STEAM lessons. Research has shown that when professional development for teachers focuses on specific teaching practices, it results in an increase of the use of those practices in the classroom (Desimore et al., 2002; Huffman et al., 2003).

Research Questions

The research questions for this study were as follows:

1. *What will the result of providing professional development in STEAM (Science, Technology, Engineering, Arts and Math) initiatives in high-needs schools have on the* ***dispositions*** *of early childhood teachers toward STEM as they implement?*
2. *What will the result of providing professional development in STEAM in high needs schools have on the* ***self-efficacy*** *of early childhood teachers as they implement?*
3. *What will the result of providing professional development in STEAM initiatives in high needs schools have on the* ***rate of implementation*** *of STEAM pedagogy in the early childhood classroom?*

The hypotheses for the study posits that preschool teachers in high-needs schools will show a positive increase in their dispositions, self-efficacy, and rate of implementation regarding STEAM lessons in their classrooms after receiving professional development, in-class support, and needed resources.

METHODOLOGY

This research is based on a phenomenological approach focusing on the "lived experiences" of the participants within the professional development provided and its aftermath.

Participants & Setting

The study involved 50 in-service preschool teachers in an urban high-needs area in the northeastern United States. These teachers taught children ages three to five. Ninety percent of the teachers were female with a wide range of diversity represented, the majority being African American. Fifty percent of the teachers had ten or more years of teaching experience, forty percent had 4-9 years' experience, with the remaining ten percent having less than four years' experience.

These preschools were located in an urban center with approximately 150,000 people. The median household income in 2014 was around $43,000 per year, which is well below the state average (City-data, 2016). Ethnicities of the city population included 39% Hispanic, 34% African American, and 22% Caucasian. The crime index for this city is 449.7, which is nearly double the US average. The difficult issues surrounding this city (crime, poverty, unemployment, etc.) are similar to challenges in other urban centers around the United States.

The Study

In this phenomenological research study, the researcher provided two consecutive professional development workshops for 50 preschool teachers. The two workshops were offered three months apart with the first offered in February and the second in May, 2016. Each workshop was 90 minutes long with two back-to-back identical sessions serving 25 participants in each. The workshop content provided a brief overview of the newly adopted Next Generation Science Standards (NGSS) and the need for STEAM at the preschool level, followed by modeling a variety of hands-on age appropriate STEAM lessons appropriate for the preschool classroom. All lessons were directly related to children's literature and utilized recyclables and inexpensive everyday materials. Two different instructional formats were modeled for the teachers during these workshops. The first consisted of multiple STEAM learning centers. These learning centers included quick hands-on activities that exhibited simple engineering and science concepts appropriate for the preschool child to manipulate independently or with assistance. The second instructional format consisted of whole-class led STEAM lessons related to children's literature.

One example of a whole-class lesson utilized the children's book, *The Gingerbread Man*. After an oral reading of the story, the children are asked to design a different way for the gingerbread man to get across the river other than on the sly fox's head. The materials provided were various sizes of aluminum foil, foam board pieces, craft sticks, tape, and plastic straws. The engineering challenge was to design a boat for the gingerbread man that will hold the most weight (pennies or dominos) without sinking. Two small tubs of water were placed in different sections of the classroom to be used for testing. The participants were encouraged to follow the engineering design loop where they *ask, imagine, plan, create, and improve* their designs (Jackson et al., 2011). Upon implementation, the teachers are encouraged to discuss simple science concepts with the children as they engage in these STEAM activities.

Between the two workshop days, the researcher made herself available to provide in-class support for the implementation of STEAM lessons, however, no formal invitations were received. The researcher was however, invited to one of the preschool sites to provide STEAM demonstration lessons for the teachers within their classrooms. The school consisted of four preschool classrooms of children ages 4-5 with approximately 20 in each. While the researcher worked with the children directly on the STEAM lessons, the classroom teachers either assisted or observed. The four lessons were conducted over a two-day period with two lessons conducted each day.

Individual teacher interviews were conducted during the final professional development day. Random teachers were interviewed during the lunch that was provided. All interviews were recorded to ensure transcription accuracy with member checks. This workshop series was grant-funded and provided two STEAM lesson activity books for each teacher as a valuable resource for future implementation.

Instruments & Analysis

Identical pre- and post- surveys were given to the teachers, which asked them to rate their level of comfort regarding STEM instruction utilizing a 5-point Likert scale. The Likert scale ratings consisted of 4 = Extremely, 3 = Very, 2 = Moderately, 1 = Little, and 0 = Not at all, in reference to their personal activity and confidence levels. The survey data was analyzed using Chi-square and Wilcoxon Tests. The Chi-square test is applied when you have two categorical variables from a single population to determine if there is a significant association. Wilcoxon tests are used to compare ordinal or nominal pre- and post- data collected from the same group (teachers). An Institutional Review Board (IRB) application was submitted and accepted by the university for this research. Teachers were informed about the study and voluntarily signed a letter of consent prior to participation. The survey was validated prior to the study using two pilot groups, the first with 25 pre-service teachers, and the second with ten in-service teachers. The survey questions are displayed in **Table 1**.

Table 1. Pre and Post-Survey of Teachers' Comfort with STEM Instruction

Scale:	**0** **Not at all**	**1** **A little**	**2** **Moderately**	**3** **Very**	**4** **Extremely**
Questions:					
1. I regularly incorporate STEAM activities for my students.					
2. I am comfortable with the idea of planning and implementing STEM activities with my students.					
3. I enjoy teaching STEM topics and lessons with my students.					
4. I believe that incorporating STEM within my curriculum is within my reach at this time.					
5. I understand how STEM can be integrated into the curriculum major content areas.					
6. I am knowledgeable about strategies and resources for implementing STEM into my curriculum at this time.					
7. I am confident in my ability to plan and imbed STEM in the curriculum at this time.					
8. I am able to design strategies to assess my students' growth in STEM instruction at this time.					
9. I would need some additional professional development to effectively implement STEM content more regularly into my curriculum.					
10. I feel comfortable and knowledgeable regarding STEM content.					
11. I believe that STEM implementation within the preschool curriculum is important for preschoolers' cognitive development.					
12. I believe that Engineering concepts and activities are developmentally appropriate for my preschoolers.					

During the second professional development day, teacher interviews were conducted at random. The interview questionnaire was also validated prior to the study using the same two pilot groups as the survey. The teachers were asked a variety of questions about their current practices with STEAM instruction as well as their comfort levels with planning and delivering STEAM lessons. The teacher interview questionnaire is displayed in **Table 2**.

Table 2. Interview Questionnaire of Teachers' Experiences with STEAM Instruction

Questions:
1. Do you believe there is a need for STEAM in the preschool classroom? Why or why not?
2. Do you enjoy planning and implementing STEAM lessons with your students?
3. How often do you include STEAM lessons and activities into your current curriculum?
4. Describe, if anything, what would help you incorporate more STEAM activities in your classroom.
5. Describe, if anything, what inhibits you from incorporating more STEAM activities in your classroom.
6. How prepared do you feel you are to plan STEAM lessons for your students?
7. Were science and math classes in your past a positive experience? Why or why not?
8. How confident are you with finding STEAM resources to help you plan lessons?

Field observations were recorded as a third data point in which the researcher served as a participant observer. Participant observation is a method in phenomenological research where the researcher is directly involved in the activities of the observation environment (DeWalt and DeWalt, 2011). These field observations included two professional development hands-on workshops for teachers as well as demonstration lessons provided by the researcher in four preschool classrooms. As a result, the researcher was entrenched within the culture of the research setting and interacted with both teachers during the workshop and the preschool students during the model lessons.

FINDINGS

Surveys

Fifty preschool teachers participated in the study and attended two days of professional development on implementing STEAM lessons into their preschool curriculum. They completed a pre survey prior to engagement in the STEAM workshops and a post survey at the end of the second day of the workshop. Out of the fifty teachers, thirty agreed to participate in the study and completed both surveys. The statistical results of the Chi-square analysis at alpha < 0.05 for the pre and post surveys showed a statistically significant positive change in their confidence level regarding their ability to plan and implement STEAM lessons for their preschoolers as a result of the professional development. For the comparison of participants' answers before and after the professional development, a Wilcoxon test at the < 0.05 significance level was also performed. The Wilcoxon Test results are displayed in **Table 3** where the p values indicate a statistically significant difference between pre and post data for those questions at the < 0.05 significance level.

Table 3. Significance Found in Survey Questions

Question 2	$p < 0.032$
Question 6	$p < 0.005$
Question 8	$p < 0.008$
Question 9	$p < 0.04$
Question 10	$p = 0.00$
Question 12	$p < 0.02$

Alpha < 0.05

On question two, *I am comfortable with the idea of planning and implementing STEM activities with my students,* teachers showed the largest increase from pre to post survey with a statistical significance of $p < 0.032$. This question in particular addressed research question number two, regarding their confidence and self-efficacy to plan and implement STEAM activities with their students. Teachers' self-efficacy towards STEAM increased as a result of the professional development. Descriptive results of questions four and seven were also in agreement with this finding as teachers showed an increase in their own abilities to incorporate STEAM activities in their classrooms. Question six which states, *I am knowledgeable about strategies and resources for implementing STEM into my curriculum at this time,* had significant results with $p < 0.005$ demonstrating an increase in teachers' knowledge about strategies and resources for implementing STEM into their curriculum as a result of the professional development.

Descriptive results from question three*, I enjoy teaching STEM topics and lessons with my students,* showed a positive increase by 1.01 ratings according to the scale in teachers' dispositions towards STEAM. As a result of the workshop, teachers felt more comfortable with STEAM concepts and their own personal skills. Results of question ten, *I feel comfortable and knowledgeable regarding STEM content,* confirmed this also showing an increase in their own perceived knowledge of STEAM content with a statistical significance of $p < 0.001$.

There was a minimal increase in question 12, *I believe that Engineering concepts and activities are developmentally appropriate for my preschoolers,* as teachers rated this question fairly high to begin with. The question rated high on the pre and post survey with a significance level of $p < 0.02$, which indicates that the teachers believe that these concepts are not beyond the early childhood development stage.

Question nine, *I would need some additional professional development to effectively implement STEM content more regularly into my curriculum,* showed very little change with only a slight dip of .05 on the rating scale and significance rating of $p < 0.04$. This indicates that teachers' perception from pre to post survey remained the same of their acknowledgement of needing additional professional development in order to effectively implement STEAM content regularly into their preschool curriculum. This indicates that while their self-efficacy and dispositions towards STEAM increased as a result of the professional development, they still did not feel confident enough to regularly implement. This confirms question one, *I regularly incorporate STEAM activities for my students,* which scored the lowest of all the questions on both the pre and post survey regarding their regular current implementation of STEAM activities. Even though the data showed an increase for implementation on the survey, when asked later during the interviews, none of the teachers had actually implemented a STEAM lesson within their classroom after the first training. The descriptive bar graph results of the survey can be seen in **Figure 1**.

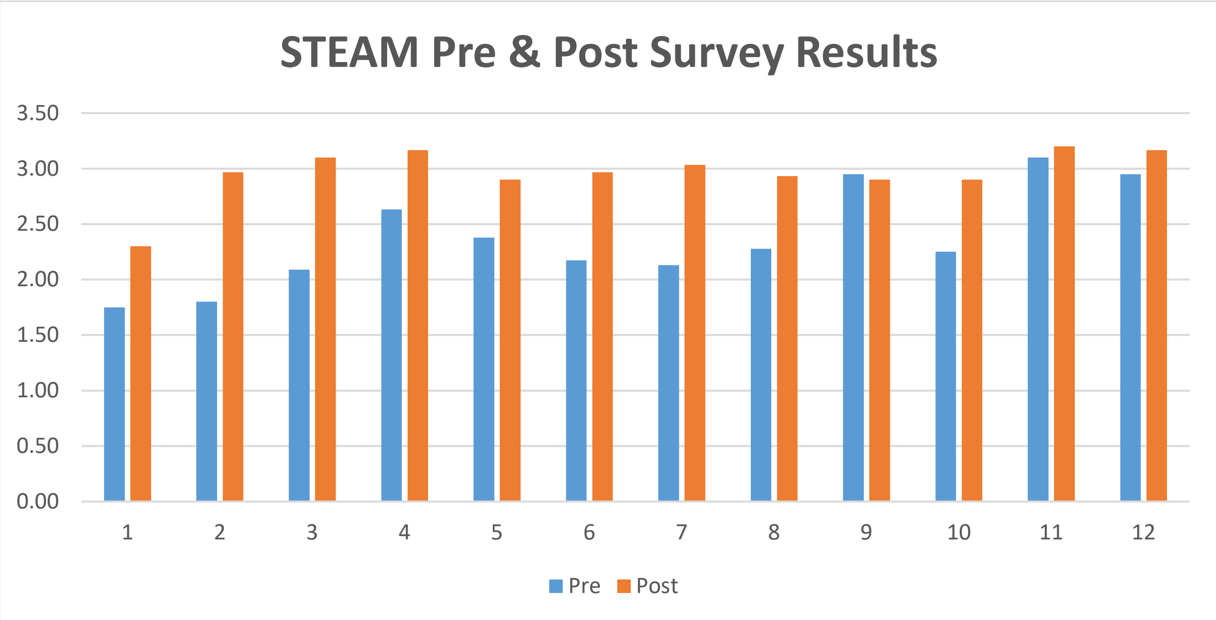

Figure 1. Preschool Teachers Pre and Post Survey Results

Interviews

After the second professional development offering, the researcher interviewed four individual teachers to seek their personal feelings towards STEAM instruction. Regarding question one, all four teachers were in agreement that there is a need for STEAM at the preschool level. One teacher stated, "*STEM is a big topic right now, and it seems to have trickled down to our level, so it is needed.*"

Question three asked them how often they include STEAM lessons into their curriculum, and all four teachers stated that they had not yet attempted a specific STEAM lesson with their young students. Question five then asked what inhibited them from implementing more STEAM activities. One teacher stated, "*It is still all too new to me, I am not sure how it would go teaching it [STEAM] to my kids.*" A second teacher stated, "*You gave us a lot of resources, however, I feel like I need more time to really look through them and get comfortable with the STEAM content before I try it in my classroom.*" A third teacher said, "*You modeled the STEAM activities with us, which was great, but I think I would need to see STEAM lessons modeled with children to help me feel more comfortable.*"

Question six asked how prepared the teachers felt to plan STEAM lessons for their students. All four teachers were in agreement that the professional development definitely helped them see what STEAM lessons looked like for the preschool classroom and that the resources provided were fantastic. They stated that they now felt more prepared as a result. However, they also reported that they still had reservations about their own abilities to implement it in their own classrooms. One teacher stated, "*I feel much better now than I did before, and you modeled some great STEAM activities that I think I could do in my classroom with my kids, but I still think I need a little more time.*" The last interview question asked about their confidence level in finding STEAM resources to help them plan lessons. All four teachers again stated that as a result of the workshop they felt more confident, since many great resources were provided by the researcher (books and websites) that will help them plan.

Field Observations

During the two professional development workshop days, the teachers were pleasant and eager to participate in the hands-on STEAM modeled lessons. The teachers were fully engaged during the workshops. They were talking and laughing as they made their designs and moving through the engineering design loop. When asked if their preschool students would be successful with these STEAM activities, they all whole-heartedly agreed. Several groups went back to the testing table three and four times trying to improve their boat designs to hold even more weight. This simple act demonstrates the engagement of the teachers and their commitment to the STEAM process. The teachers consistently asked questions of the researcher for specific implementation suggestions with their preschool students.

Between the two professional development days, the researcher was invited in to one school to conduct demonstration lessons in four different preschool classrooms containing children ages four to five. At the request of the site director, the researcher demonstrated the use of purchased STEM learning kits on magnetism, and force and motion. In one classroom, the researcher worked alongside the teachers and set up three learning centers, placing a teacher at each station, and the children rotating through each. In the other three classrooms the teachers asked that the researcher set up one learning center in the room and rotated the children through the one center. The first situation was optimal because the classroom teachers were then engaged and fully participated in the instruction, whereas in the latter situation, the teachers were removed and only observed from a distance. As a result, the teachers in the first classroom expressed how much they enjoyed the STEAM lessons and looked forward to continued use of the learning centers.

The preschool children in all four classrooms were thrilled with the STEM learning centers and did not want to leave the center. The children were fully engaged, took turns, experimented, and communicated with the researcher and one another regarding the STEM content and phenomena that they were experiencing. The children appeared to be enjoying the STEM activities in the learning centers as they were smiling and talking excitedly with active participation.

DISCUSSION AND CONCLUSIONS

This study consisted of three research questions. The first question explored the impact of STEAM professional development on preschool teachers' dispositions towards STEM content. The findings did indicate that the teachers' dispositions towards STEM content did reflect a positive increase as a result of the workshops. This finding is in agreement with Nugent, Kunz, Rilett, and Jones (2010), who also found that teachers developed more positive attitudes towards STEM and increased their self-efficacy as a result of receiving STEM professional development.

The second research question explored the impact of STEAM professional development on preschool teachers' self-efficacy regarding planning and implementing STEAM content. The findings revealed that through the workshop, supplied resources, and modeling of the STEAM activities, the teachers did experience a positive increase in their self-efficacy regarding STEAM. Although their survey results showed a rise in their confidence and dispositions, during the interview process, teachers revealed that they still would need additional professional development in order to fully implement STEAM lessons within their classrooms. This is in agreement with Ralston et al. (2013), who found that K-12 teachers would need assistance in order to successfully implement the engineering education component of STEM. They also emphasized that simply hearing or reading about STEM was not enough, but that students and teachers alike actually need to participate in hands-on STEM training to be effective. This researcher has also found this to be true, so all of the workshops offered are hands-on and model STEAM lessons for teachers.

The third research question explored the impact of the professional development workshop on the rate of STEAM implementation by the teachers in their classrooms. It was interesting to note that after the first hands-on workshop, not one teacher had conducted a STEAM lesson in their classroom as a result during the two-month span, even though they were given a complete resource book filled with lessons and complete STEM learning kits for learning centers. The teachers themselves reported how much they had enjoyed the STEAM lessons and were in agreement that their preschool students would love the lessons as well, but yet they were reluctant to implement them in their classrooms. This gap between effectively educating PK-12 teachers and supporting them as they attempt to integrate their curriculum with STEM subject matter for students continues to exist even after major emphasis has been placed on STEM in recent years (Gomez and Albrecht, 2013).

These research findings showed a statistically significant change in how preschool teachers' confidence levels positively increased regarding their ability to plan and implement STEAM lessons for their preschoolers as a result of their engagement in the professional development sessions. However, even as the preschool teachers were actively engaged and experienced an increase in their knowledge, skills and dispositions regarding STEAM implementation, they were still reluctant to implement, as none of them implemented a STEAM lesson independently during the course of this study (self-reporting).

More research needs to be done in the area of STEAM implementation in the PK-3 classrooms as more and more states adopt the NGSS, which formally incorporates engineering education and STEM across all grade levels. Suggested research may involve investigating professional development strategies that increase the likelihood of actual classroom implementation, such as offering in-class support for teachers when implementing STEAM lessons with their children for the first time.

Ethical Approval

"All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards."

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