AN EXPLORATION OF THE NATURE OF SOCIAL INTERACTIONS BETWEEN PRESCHOOL STUDENTS WITH DIVERSE SOCIAL-EMOTIONAL SKILLS DURING ENGINEERING ACTIVITIES

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DEDICATION

I dedicate this dissertation to the memory of my grandmother, Meenakshi Balakrishnan, who instilled in me a love of lifelong learning.

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ABSTRACT

Peer interactions are a significant part of school experiences and influence children's adjustment to school, however preschool students with and at-risk for disabilities are found to display a unique trajectory of social development, often requiring intentional instruction in social skills. A variety of interventions have been designed to support these students; however, they target foundational skills such as inviting peers to play and taking turns with materials, leaving a gap in the research on more complex social skills such as collaboration and joint problem-solving. The engineering design process (EDP) is a cyclical method that students follow to collectively build a solution to a problem. Engineering encompasses hands-on activity, inquiry, teamwork, and other instructional practices that develop students' collaboration and problem-solving skills. Given that preschool students with or at-risk for disabilities require further support in social skills such as collaboration and problem-solving, and engineering activities provide naturally embedded opportunities for collaboration, students' engagement in the EDP working along with peers is a gap in the research that needs to be explored. The purpose of this study was to explore the nature of social interactions that take place between preschool students with diverse social-emotional skills when engaging in engineering activities using a qualitative single case study design. Thirteen preschool students and one preschool teacher participated in this study wherein four engineering activities were implemented in the classroom over a four-week period. Analysis of video clips of student participation in the four activities as well as teacher interviews revealed two distinct patterns of social interactions among students: a) collaboration: wherein students assigned responsibilities to each other and completed the activities in small groups; and b) "baby steps" towards collaboration: wherein students needing teacher support worked intermittently with peers. A third emergent finding concerns the nature of materials provided during these activities and the possibilities those provided for students to work together. The importance of these engineering activities in providing the platform for students with diverse needs to work together and engage in authentic peer interactions is discussed. Implications of these findings and recommendations for future research including how students with disabilities can access and meaningfully participate in similar inquiry-driven activities as well as the teacher's role in supporting their participation is discussed.

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LIST OF ABBREVIATIONS

NAEYC	National Association for the Education of Young Children
NRC	National Research Council
NSTA	National Science Teaching Association
DAP	Developmentally Appropriate Practices
EDP	Engineering Design Process
EiE	Engineering is Elementary program
EC	Engineering Challenge
TI	Teacher Interview

CHAPTER ONE: INTRODUCTION

Social competence and skills are critical in early childhood and early childhood is a key period for setting the foundation for developing social competence (National Association for the Education of Young Children [NAEYC], 2009). However, many children with developmental disabilities and children who are at-risk need support in developing these skills. For children with disabilities, the impact of their disability can lead to difficulties in social communication and interaction (Canney & Byrne, 2006).

Challenges in social competence, which falls under the realm of social-emotional development, have the potential to inhibit opportunities for children with or at risk for disabilities to form connections with their peers, therefore, making intentional instruction in social skills necessary. As young children with or at risk for disabilities are educated in more inclusive settings, they are often presented with increased opportunities to practice and polish their social skills (Myles et al., 2008). Although research-based strategies are available to teach students with or at risk for disabilities foundational peer-related social skills (such as greeting a peer, initiation an interaction, and sharing toys), a gap remains in the research on more complex peer-related social skills (such as collaboration, problem-solving with peers, negotiation, and conflict resolution) for preschool-aged students with or at risk for disabilities. These are critical social communication skills typically already learned by children upon entry into kindergarten or early elementary (Lillard et al., 2013). Yet, the question remains how students with or at risk for disabilities can develop these peer-related social skills in classroom settings.

The engineering design process is a method that students follow to collectively come up with a solution to a problem. This process at an early childhood level includes asking a question, brainstorming possible solutions, planning and creating a solution, testing the solution, and evaluating it in order to improve it (Gruber-Hine, 2018). Early engineering encompasses hands-on activity, teamwork, and other instructional practices that develop children's "twenty-first century skills" including critical thinking, communication, collaboration, and creativity (Lachapelle & Cunningham, 2014). The National Science Teaching Association (NSTA), in its position statement on quality science education and twenty-first century skills (2011), acknowledged the need for and importance of twenty-first century skills within the context of science education and advocates for the science education community to support twenty-first century skills consistent with best practices across a prekindergarten-16 science education system.

Twenty-first century educational goals encourage classroom discourse that focus on creativity, collaboration, distributed expertise, innovation, and life-long learning (Scardamalia, 2002). The benefits of student interactions during collaboration include strengthening students' interpersonal skills while also advancing knowledge construction (Wiedmann, 2015). Engineering is defined by a number of qualities including exploration, brainstorming, and demonstrating. It requires students to ask and answer questions, consider each other's ideas, and negotiate shared solutions (Cunningham & Kelly, 2017). It therefore contains embedded opportunities for collaboration.

Given that young students with or at risk for disabilities require further support in peer-related social skills such as collaboration and problem-solving and given emerging evidence of their interest in and preference for activities with a construction component (such as LEGO construction), there is a need to study how and when students can collaborate during engineering activities. Specifically, considering the naturally embedded opportunities for collaboration during engineering, there is a need to explore what preschool students' (with and without disabilities) engagement with the engineering design process looks like; and how they interact and work together while engaging in the steps of the engineering design process.

To that end, the purpose of this study was to explore the nature of social interactions that take place between preschool students with diverse social-emotional skills when engaging in engineering activities in order to study how they interact and work together while solving a design problem. Within the scope of social interactions, specific attention was paid to collaboration and joint problem-solving. The research question is as follows: what is the nature of social interactions that take place between preschool students with diverse social-emotional skills when engaging in engineering activities?

CHAPTER TWO: LITERATURE REVIEW

The literature review begins by summarizing the knowledge base on social competence for young children and its longitudinal implications. A definition of social skills and social competence in early childhood, for the purpose of this review, is included in this section. It will then discuss social delays in young children with or at risk for disabilities. With this as a foundation, behavioral interventions designed to enhance peer competence will be examined. While an exhaustive list of behavioral interventions falls outside the scope of this literature review, major interventions that have been the focus of recent research and have been used prominently will be discussed. The review will then transition to early engineering and a description of preschool engineering education. The engineering design process as appropriate to preschool will be outlined, along with teacher strategies to implement collaborative engineering activities in preschool. To conclude the review, a rationale for studying the engagement of young students with or at risk for disabilities in collaborative engineering activities will be provided.

Social Competence in Young Children

Building relationships, including with one's peers, is at the core of a child's development (Guralnick, 2010). As young children expand their social world and begin to interact with other children of similar ages, they are faced with additional social demands and begin to learn skills such as initiating and maintaining interactions, sharing toys and materials, and playing appropriately with peers (Koyama, 2011). The dynamic give-and-take features of social exchanges that occur between peers in early childhood typically result in creative and increasingly sophisticated forms of social play (Guralnick, 2010). Interactions with peers at school and childcare settings provide young children with the experiential foundation for developing an array of social skills generally referred to as "peer-related social competence" (Guralnick, 1999).

NAEYC in its position statement on developmentally appropriate practice (NAEYC, 2009) outlined the importance of social experiences:

> Children's early experiences, whether positive or negative, are cumulative. For example, a child's social experiences with other children in the preschool years may help him/her develop social skills and confidence that enable him/her to make friends in subsequent years, and these experiences further enhance the child's social competence and academic achievement. (p 12).

While social skills and social competence in young children can refer to an array or sub-set of skills necessary to enact social exchanges and build relationships with peers, for the purpose of this literature review, a brief definition of social skills and social competence is provided here. *Social skills* refer to specific behaviors that a child uses to perform particular social tasks (e.g. joining a peer's play, initiating a conversation) successfully (Gresham et al., 2001). Social skills that are important and necessary for a child depend on his/her personal situations and develop through each developmental phase. For instance, the ability to share toys and play cooperatively with peers may be key in preschool, whereas the ability to join and maintain a conversation with peers and establish and maintain reciprocal friendships becomes key in elementary grades (Koyama, 2011).

Social skills may be divided into two strands: *learning-related* and *peer-related* skills (Brown et al., 2008; McClelland & Morrison, 2003; Walker & McConnell, 1995). *Learning-related social skills* refer to social behaviors that are necessary for engaging in and completing academic tasks. The ability to listen to the teacher, follow directions, participate in a group, and organize materials are considered critical skills by teachers, especially when children begin formal schooling (Koyama, 2011). In comparison, *peer-related social skills* are interpersonal skills that allow children to make friends, initiate and maintain interactions, share materials, and play appropriately with peers. Peer interactions are a significant part of school experiences and influence adjustment to school (Koyama, 2011). They provide the foundation for developing an array of social skills that children use to expand their social world and build relationships through life. To be successful in school, children need both skill sets. However, many children with developmental disabilities and children who are at-risk need support in developing peer-related social skills. Challenges in this area have the potential to inhibit opportunities for children with disabilities to form connections with their peers. Therefore, the focus of this literature review is on young children's peer-related skills.

Compared to social skills which refer to specific social behaviors, *social competence* implies an evaluative term based on the performance of a child as judged by his/her significant social agents (Brown et al., 2008). Brown et al.'s definition of social competence suggests that socially competent children select and use effective strategies in a socially appropriate manner (i.e., well accepted by teachers, parents, and peers) to achieve a desired goal. To be socially successful, young children need to coordinate their cognitive, linguistic, social-emotional, and behavioral skills. Thus, whether a child is socially competent is manifested in the perceptions of significant social agents (such as teachers, peers, and parents) instead of the demonstration of specific social behaviors.

The Importance of Social Skills in Early Childhood

In early childhood, childcare centers and preschool settings provide rich opportunities for social learning. Without access to these opportunities, and when these opportunities are impeded by delays in social communication and interaction, young children miss out on the opportunity to learn about social norms and practice social behaviors (Mccollow & Hoffman, 2019). The absence of these social relations results in missing important aspects of being an individual and participating in community and social activities (Mccollow & Hoffman, 2019). Challenges or delays in social skill development have the potential to inhibit opportunities for children with disabilities to form connections with their peers, making intentional instruction in social skills necessary. Many studies have been dedicated to examining the effects of a variety of social skills interventions to improve outcomes for students with autism (Camargo et al., 2014; Rumney & MacMahon, 2017; Wong et al., 2014) as well as students with a variety of other disabilities such as emotional-behavioral disorders (Chen, 2006; Gresham, 2015), attention deficit hyperactivity disorder (Evans et al., 2014), and intellectual disability (Brooks et al., 2015; Crnic et al., 2017). In sum, the emphasis on social-emotional development appears to be of particular interest and appears to have direct connections to improving the quality of life and access.

Influence on Developmental Domains

Social skills development interacts with other developmental domains in ways that influence early learning. Appropriate social behaviors such as listening to a teacher and cooperating with peers support learning by increasing a child's engagement on tasks and promoting appropriate interactions with classroom materials. Raver and Knitzer (2002) suggest that social competence may be more predictive of academic success in the early grades than cognitive skills or family backgrounds.

Friendships

Socially competent children particularly ones with positive peer relations are more likely to establish and maintain mutual friendships. Friends/peer buddies provide skill development opportunities as well as emotional support and security. Friendships in early childhood are characterized by reciprocal, positive, and enduring interactions between children, which serve as the foundation for developing language, cognitive, and social skills (Ladd & Kochenderfer, 1996). Buysse et al. (2008) noted that friendship is different from other peer relations in that friendships are: a) dyadic in nature, b) represent bi-directional and voluntary relationships, c) are characterized by mutual liking and attachment, d) maintain physical proximity, e) engage in shared activities, routines, and rituals, and f) share positive affect. In comparison with other peer relations, friendships may make unique contributions to the development of social and emotional skills and positive self-image.

Early School Adjustment

Moreover, early social competence is an indicator of how well a child adjusts to school. Although early school adjustment is influenced by cognitive, emotional, and social development, social competence is also essential to school success, especially as children enter Kindergarten (Missal & Hojnoski, 2008). Ladd and Price (1987) examined children's social and school adjustment during the transition from preschool to kindergarten.

Children's cooperative play behaviors in the preschool years were found to predict teachers' positive perception and higher levels of peer acceptance in Kindergarten. In contrast, children with a negative pattern of peer relations were less liked by peers and perceived as more problematic by Kindergarten teachers. Ladd and Kochenderfer (1996) developed a measure of Kindergarten students' perceptions of classroom friendships and analyzed its predictive power on subsequent school adjustment during the transition to grade school. Their results indicated that problems with friendships were associated with indicators of school maladjustment such as higher levels of loneliness and avoidance at school, and less academic engagement for boys. For both boys and girls, perceived validation and aid from friends predicted positive school attitudes.

Longitudinal Implications

The development of social competence in early childhood is also important due to its longitudinal influence on social and school adjustment in later life (Brown et al., 2008). Problematic peer relationships in early childhood predict adjustment problems in adolescence and adulthood. Parker and Asher (1987) reviewed studies that examined the relationship between peer-related social competencies (acceptance, aggression, and shyness/withdrawal) and later maladjustment (dropping out of school, criminality, and psychopathology). The aggregate data from these studies suggested that lower levels of peer acceptance and higher levels of aggression were predictive of social maladjustment in later life and that dropping out of school and criminality are the most likely consequences of problematic peer relationships in childhood. In a longitudinal study covering a longer time span, Pihlakoski et al. (2004) found an association between higher scores of externalizing behavior problems on the Child Behavior Checklist (CBCL) at age 3 and the use of mental health services at age 12, again pointing to the importance of and need for developing social competence from an early age in children.

Social Validity

Echoing these studies, developing social competence in early childhood is a need that has been identified and expressed among researchers, practitioners, and parents (Koyama, 2011). Researchers have identified the development of peer-related social competencies as a central goal of early intervention (Brown et al., 2008; Guralnick, 1999; Strain, 1990), stressing the importance of socialization opportunities for all young children. Parents and practitioners too believe that social skills interventions are a particularly important part of early childhood special education (Baumgart et al., 1991). A survey of teachers and parents of preschool-age children showed agreement on the importance of cooperation skills for school success. Their expectations of preschool students' behavior diverged in that teachers tended to emphasize self-control skills while parents tended to value assertion skills more (Lane et al., 2007).

Given that patterns of social behaviors are fairly persistent from early childhood to elementary grades, and the impact that social competence has on overall development and well-being, the need for developing effective early interventions that address social competence in young children is clear.

Social Delays in Young Children with Disabilities

Children with developmental delays may display a unique trajectory of social development (Koyama, 2011). There is accumulating evidence of peer-related social difficulties in young children with developmental delays which continue over time. In a series of studies, Guralnick and Weinhouse (1984) found unique patterns of peer-related social behaviors in young children with developmental delays. Specifically, preschool children with developmental delays engaged in interactive social play with peers less frequently than children who are chronologically younger but have similar cognitive skills (Guralnick & Weinhouse, 1984). Although typically developing three-year old children may spend 25% of their time playing with peers, preschool children with developmental delays spent 10% of their time in associative play (i.e. two or more children play side by side, in identical activities but not interacting) and no time in cooperative play (i.e. two or more children interact in a common play venture). Similarly, Guralnick et al. (1996) found that preschool children with developmental delays formed fewer reciprocal relationships with their peers. These studies indicate that advanced social play involving reciprocal interactions and cooperation may be particularly hard for children with developmental delays.

Preschool children with communication disorders may demonstrate a slightly different pattern of peer interactions (Guralnick et al., 2006). They tend to engage in fewer social interactions, converse with peers less frequently during non-play activities, are less successful at getting peers' attention, and are less directive in play. However, preschool children with communication disorders tend to have an equal likelihood of sustaining social play, minimizing conflict with peers, joining others in ongoing activities, and responding to peers' social bids appropriately.

Delays in the development of reciprocal social relationships may be more serious among children with autism spectrum disorder. Young children with autism rarely initiate or respond to social interactions with peers (Strain & Hoyson, 2000). Libby et al. (1998) and other studies have found that play behaviors of young children with autism tend to be repetitive, non-symbolic, and object-oriented. Deficits in advanced social play skills are characteristic of children with autism and may further deprive them of socialization opportunities. Lee et al. (2007) revealed an inverse relationship between social engagement with peers and stereotypic behavior of preschool children with autism. The children in their study demonstrated a high rate of stereotypic behavior initially, but stereotypic behavior decreased as the rate of social engagement increased.

Odom et al. (2006) examined social acceptance and rejection of children with disabilities in inclusive preschool programs. Social withdrawal and aggression were behavioral traits of children who were more likely to be rejected by their peers, while awareness and interest in others, communication and play skills, and friendship and social skills were associated with social acceptance. In addition, children whose disabilities affected social problem solving and emotional regulation were more likely to be rejected than children whose disabilities did not impact those skill areas.

Lack of reciprocal play as observed in children with developmental delays during the early childhood years is likely to continue to be an issue in elementary and middle school years. Guralnick et al. (2007) investigated continuity and change of peer-related social competence of children with developmental delays during the early childhood and elementary years. Over the two-year period, children with developmental delays became less likely to engage in solitary play, became more responsive to a peer, became more successful at gaining a peer’s attention, increased their level of positive interactions, and conversed with a peer more often. However, children with developmental delays were unable to translate these behaviors into an increase in cooperative play. Not only did the amount of interactive play remain the same, but their level of group play was also far lower than that of typically developing children of similar age or even developmentally matched younger children, accounting for only 12% of all interactions. Despite the development of various prosocial behaviors, children with disabilities continue to lack reciprocal play skills.

Sigman and Ruskin (1999) followed children with autism, Down syndrome, and developmental delays from early childhood to middle school to assess continuity and change in their social competence. Lack of spontaneous initiations and unresponsiveness to peers' social bids were characteristic of children with autism. Consequently, children with autism, regardless of their level of functioning, were less socially engaged than children with other developmental disabilities. Early nonverbal communication and play skills predicted frequency of peer play initiations for children with Down syndrome and levels of peer engagement for children with autism in middle school. These results suggest that delays in early communication and play skills may have long-term consequences on later language and social development.

Social Skills Interventions for Young Children with Disabilities

There are many conceptual models for understanding and classifying different types of social skills interventions for young children with disabilities (Brown et al., 2001; Hemmeter et al., 2006; Odom et al., 1999). Brown et al. (2001) and Hemmeter et al. (2006) propose a tiered approach. At the base of their social skills intervention framework is the provision of universal quality practice and nurturing social environments (tier 1) which stress the importance of offering developmentally appropriate practices (DAP) (Brown et al., 2001) or high-quality supportive environments (Hemmeter et al., 2006) that serve as foundations for promoting social competencies of every child. DAP are delineated in the field of both early childhood education and early intervention (NAEYC, 2009; Sandall & Council for Exceptional Children, 2005).

Conceptual Models for Social Skills Interventions

When children need a more systematic approach, Brown et al. (2001) recommend that educators consider specific intervention strategies (tier 2) which include *incidental teaching of social behaviors, friendship activities, social integration activities, and explicit social skills training*. *Incidental teaching of social behaviors*, and *friendship activities* also known as “group affection activities” (McEvoy et al., 1988) are targeted but naturalistic social interventions that facilitate young children’s social interactions. *Social integration activities* (such as “environmental arrangements” (Odom et al., 1999) and PALS Group (“Play, Arrange, Limit materials, Structure activity”, Chandler, 1998)), and *explicit social skills training* are additional approaches that requires further planning and expertise in specialized instruction.

Similarly, Hemmeter et al. (2006) suggest systematic approaches (tier 2) to support social skills of children who are at risk for social delays. When children do not learn prosocial behaviors naturally through highly supportive social environments, they need targeted social skills instruction that may include explicit instruction of social skills, role play, skill practice in free play, and feedback. Hemmeter et al. (2006) refer to interventions appropriate for some children as targeted social support. This may include the use of a social-emotional curriculum to enhance an early childhood curriculum that may already be in use. Such curricula are developed for preschool children and have varying levels of research support (Joseph & Strain, 2003). For children who do not respond to targeted social support or need further support than is usually provided in tier 2, Hemmeter et al.

(2006) propose the use of individualized intensive interventions (tier 3). Such interventions assess each child's social skills and areas needing further support and tailor instruction to meet those needs.

Brown et al. (2001) argue that early childhood practitioners should use approaches that are as least restrictive as possible. However, young children with disabilities and children at risk for social delays often receive systematic instruction (tier 2) tied to specific peer-related social skills that they need support with, while opportunities to generalize these skills are overlooked. These skills enable young children to initiate and respond to peer interactions, form connections with their peers, and expand their social world. However, the systematic instruction that children receive to develop these social skills, while explicit, are limited to the setting, skill, and individual present, and therefore in contrast with the dynamic give-and-take features of social interactions that typically occur in early childhood. Given the features of social interactions that occur in naturalistic contexts in early education settings, children need more nurturing social environments (tier 1) that support the generalization of peer-related social skills learned during tier 2 interventions and that serve as the foundation for promoting social competence.

Review of Literature on Social Skills Interventions

A series of studies have been conducted to investigate the effectiveness of tier 2 peer-related social skills programs for young children with developmental delays (Hundert & Houghton, 1992; Leblanc & Matson, 1995; Matson et al., 1991). For instance, Leblanc and Matson (1995) and Matson et al. (1991) implemented a puppet modeling intervention in which 4- and 5-year old preschool children with mild to moderate developmental delays received 1-hour of social skills training twice weekly for a total of 12 sessions. The intervention consisted of 15 minutes of puppet modeling of target social behaviors (greeting, requesting toy, showing toy, and play initiations) and role playing, followed by 45 minutes of free play activities in which teachers modeled and prompted target social behaviors and children received reinforcement for demonstrating those behaviors. While findings from both studies showed increased instances of target social behaviors following the intervention, the researchers reported difficulty generalizing these target social skills to other settings.

Odom et al. (1999) compared the effects of four tier 2 social skills interventions (environmental arrangements, child-specific, peer-mediated, and comprehensive) for young children with disabilities. They classified interventions on the basis of the medium of delivery. Environmental arrangements here are equivalent to social integration activities as described by Brown et al. (2001). In peer-mediated interventions, teachers group children with and without disabilities together and select activities that are likely to facilitate peer interactions and guide children through the activities with some prompting. Here, socially competent peers are seen as the 'teacher', are taught ways of interacting with children with disabilities and are grouped together in an effort to model social skills to children with disabilities. Since peer-mediated interventions closely resemble daily activities in natural contexts, this type of intervention is particularly well suited for inclusive classrooms and has the potential for maintenance and generalization of acquired social skills: an important goal of social skills interventions (Hemmeter, 2000; Trembath et al., 2009). On the other hand, in the child-specific approach, specific social behaviors are targeted and explicit instruction is provided to a small group of children with disabilities. This is sometimes followed by role play and/or play activities in which children practice enacting targeted prosocial behaviors. The comprehensive approach combines all of the above approaches. After empirically examining the impact of the four types of interventions, Odom et al. (1999) concluded that peer-mediated interventions had the biggest and longest-term impact on improving both quantity and quality of children's interactions. However, it should be noted that peer-mediated interventions also pose potential challenges in implementation: the lack of treatment fidelity is the primary concern due to the fact that this approach relies on the ability of young children to implement the intervention rather than practitioners (Horner et al., 2005). In addition, it may overlook emotional experiences or motivation of the target student and his/her peers (Koegel et al., 2012, 2013). Both parties here are required to participate and behave in activities or scenarios prescribed by the researcher/practitioner rather than engaging in activities of their interest or preference. Therefore, while it is more naturalistic than other approaches, children are still prescribed particular activities and observed interacting in those rather than allowed to choose an activity that is engaging to them (which could give an opportunity to observe interactions as they occur spontaneously and provide better chances of generalizing skills to other scenarios).

There are further examples in the literature of tier 2 social skills interventions for preschool students with disabilities, however the focus of these interventions is on modifying deficiencies rather than building on strengths to develop peer-related social skills (LeGoff, 2004; Reichow & Volkmar, 2010). These include direct teaching of specific social skills (for example, greeting, sharing, complimenting, assisting, and inviting peers to play) by way of modeling and prompting during interactive social routines (Antia et al., 1993); use of commercially available social skills training programs (such as 'Taking Part, Introducing Social Skills to Children' (Guglielmo & Tryon, 2001); or Skillstreaming in Early Childhood curriculum (Hyatt & Filler, 2007); and puppet modeling (Hundert & Houghton, 1992).

Such direct teaching interventions made use of strategies such as teacher reinforcement (Guglielmo & Tryon, 2001), immediate feedback, prompts, and praise (Hundert & Houghton, 1992) in activities prescribed by the practitioner rather than following children's interests and observing their interactions in an activity that is of interest to them and which does not contain a set of prescribed actions. Although the use of these strategies showed an immediate increase in children's peer-related social skills during free play, these could not be maintained when supports were gradually faded. Furthermore, difficulty generalizing these social skills to other settings was reported across a majority of these studies. Considering that preschool children are observed to have more social interactions when they are engaged in preferred activities (Koegel et al., 1987) and the naturally occurring opportunities for peer interactions in activities of shared interest to the students, researching peer interactions during activities of mutual interest to students, where rather than following a set of prescribed actions they can instead steer the direction the activity takes, is worth considering. When considering the high number of studies that investigate systematic direct instruction (tier 2 supports) for students with disabilities while overlooking provision of nurturing social environments (tier 1) to support generalization of a variety of peer-related social skills (i.e. not limited to specific skills such as greeting a peer or sharing a toy), this becomes an important next step in the research on social skills for young children.

Taken together, the literature has reported mixed results on the effectiveness of direct social skills instructions for young children with developmental delays. A majority of studies compared students' social behaviors pre- and post-treatment as a way to measure effectiveness. The most common outcome measure was direct observation of target social behaviors during free play. Overall, it appears that direct teaching of specific social behaviors, when implemented with some intensity and combined with skill practice and systematic reinforcement, has a positive impact for children with mild to moderate developmental delays. However, the literature also indicates that prosocial behaviors (i.e. positive social interactions with peers) may not be maintained when reinforcement is faded and are unlikely to be generalized to other settings. While direct teaching showed an increase in prosocial behaviors in free-play periods immediately following the intervention, these behaviors did not generalize well to other settings especially when considering that a narrow set of skills were taught in activities chosen by the practitioner rather than activities that the students themselves may find interesting or engaging. This coupled with the direct social skills interventions that students with disabilities receive point to an absence of high-quality nurturing social environments (tier 1 supports) for students with disabilities to practice and generalize skills learned. In addition, results may differ depending on the nature of the student's disability. A majority of preschool children in the reviewed literature had mild to moderate developmental delays and the severity of their social delays was not reported.

Nevertheless, although research-based direct teaching strategies are available to teach students with disabilities targeted peer-related social skills, the focus of these strategies often remains limited to specific foundational skills such as turn taking, greeting, and play initiations, while more complex peer-related social skills such as collaboration, problem solving, and negotiation are often overlooked. These social skills, typically already learned by children upon entry into kindergarten or early elementary (Lillard et al., 2013), are also a part of critical peer-related social skills that children use in interacting with their peers, particularly as they begin to engage in creative and increasingly sophisticated forms of social play in preschool. Interactions with peers in preschool and childcare settings provide young children with the experiential foundation for developing their social competence, therefore, research on such complex peer-related social skills such as collaboration is a gap in the research that needs to be explored.

In addition to its impact on early school adjustment, friendships, and longitudinal implications, such peer-related social skills encourage classroom discourse that focus on creativity, collaboration, distributed expertise, innovation, and life-long learning (Scardamalia, 2002). The benefits of student interactions during collaboration include strengthening students' peer-related social skills while advancing individual knowledge construction (Wiedmann, 2015). Additionally, research suggests that children with intact functioning in these domains have better overall outcomes across skills (academic skills; Montroy et al., 2014). Therefore, a focus on such skills is the natural next step in the established body of social communication interventions.

LEGO Play Intervention

Although there are several guidelines for social skills interventions as highlighted above, they show varied evidence of effectiveness (Orsmond et al., 2013; Ozonoff & Miller, 1995; Swaggart et al., 1995), and the focus is on modifying deficiencies rather than building on strengths (LeGoff, 2004; Reichow & Volkmar, 2010). Furthermore, these interventions have targeted a narrow set of peer-related social skills such as greeting a peer or sharing toys during play in specific settings such as a classroom or clinical setting and are unlikely to be generalized to other settings.

LEGO therapy is a social skills intervention that focuses on developing children's strengths and interests (Bianco et al., 2009; LeGoff, 2004) while also addressing some of the limitations in other social skills programs. It is more naturalistic and can be implemented within school settings (Boyne, 2014). LEGO therapy draws on children's natural interest in play to help motivate behavioral change and can be used as an effective teaching tool to increase social competency and communication (Baron-Cohen et al., 2014). Target skills include verbal and nonverbal communication (self-initiated interactions), turn-taking, sharing, and collaboration. Among typically developing children, LEGO has been used to help increase social skills and promote positive moods (Kato et al., 2012).

LEGO therapy is a successful method of social skills intervention for children with developmental delays, particularly autism, due to its "constructive application" (Yalamanchili, 2015). Previous research suggests that characteristics of activities and the number of social interactions for young children with autism are correlated. For instance, preschool children with autism are observed to have more social interactions when they are engaged in preferred activities (Koegel et al., 1987). The activities should be predictable, structured, and organized so that children know how they are expected to behave and how the activity will be sequenced (DeKlyen & Odom, 1989; Ferrara & Hill, 1980). The LEGO play intervention is designed to maximize young children's learning motivation by embedding social interactions in LEGO construction activities (LeGoff, 2004), rather than direct teaching of specific skills. Many children, including children with ASD, are interested in predictable and systematic LEGO play that results in natural reinforcement, such as the completion of a LEGO model (Legoff & Sherman, 2006). Capitalizing on a stereotyped interest of children – LEGO blocks – provides intrinsic motivation for learning social skills where other external rewards are often short-lived (Yalamanchili, 2015). LEGO blocks provide children with developmental delays a genuine shared interest, creating a naturally occurring opportunity for social interaction and reciprocity (LeGoff et al., 2012). Shaping behaviors and interactions to encourage social skill acquisition is a benefit of LEGO therapy and this can be accelerated by selecting natural reinforcers such as LEGO blocks. Ultimately, it leads to motivated participation in the LEGO group (Legoff et al., 2012). Dewey et al. (1988) reviewed the effects of dramatic play, functional play, rule-governed games, and construction materials such as LEGO blocks on social interaction skills in children with autism. They found that construction materials were the second-best supporter of social interaction skills improvement after rule-governed games.

LEGO therapy is a social skills intervention centered on collaborative play (Kato et al., 2012; Legoff et al., 2012). Groups consist of three participants, each of whom takes on a specific, designated role: “engineer”, “supplier”, or “builder”. LEGO therapy involves a “social division of labor”, and each participant must follow specific rules for creating the design (LeGoff et al., 2012). The role of the “engineer” is to interpret the instructions and describe the specific LEGO blocks needed for each step of the assembly. The “supplier” locates and retrieves the LEGO blocks as indicated by the engineer and hands them to the builder. The “builder” is responsible for assembling the blocks according to the instructions given by the engineer. During this process, verbal and nonverbal communication skills are activated. Turn taking and sharing skills are also strengthened in the group, since in each session the participants switch their roles as the engineer, supplier, and builder. The LEGO group is centered on collaborative problem solving in order to build the structure. Such collaboration requires verbal and non-verbal communication, observation of each other's work and the work of his/her own, and constant attention to the tasks, thereby creating opportunities for children to engage in meaningful social interactions (Owens et al., 2008). Trust and reliance on each other are also implicated in the LEGO group (Legoff & Sherman, 2006).

In addition to serving children with autism, LEGO therapy has been observed to be beneficial for children with anxiety, depression, and adjustment disorders (Yalamanchili, 2015). Typically, children with social and/or communication deficits are prime candidates for participation in LEGO therapy. It is a type of intervention best executed in groups of two-three (LeGoff et al., 2012). Azmitia (1988) studied the effects of group work versus individual work using LEGO blocks as a medium for problem solving and learning in five-year old children. Results showed that collaboration produced greater learning than individual work. Furthermore, participants working in a group generalized skills learned to a greater degree than participants working alone. Azmitia (1988) also considered the features of collaboration that contribute to learning in suggesting that children may spend more time problem-solving when working within a group or even with a partner than when working alone, due to the encouragement from peers.

LEGO therapy sessions, in the beginning, are structured in order to accomplish the goals of the intervention (LeGoff et al., 2012). When the group members arrive, they are prompted to greet one another while maintaining eye contact, followed by a discussion where an agenda is set. After a plan is made and goals are determined, the group assigns roles before engaging in the LEGO activity. During this task, the therapist/teacher works to facilitate social and communicative experiences among members as these naturally occur within the group. Once the goals are achieved, the participants are allowed to engage in free play and use the LEGO blocks in an unstructured manner. During this time, the therapist/teacher remains in a coaching position to maximize social skills, interactions, and communication among group members.

There are multiple states or levels throughout the course of the intervention that the children move through in order to demonstrate skill attainment and mastery (LeGoff et al., 2012). Children begin as "LEGO helpers" in order to either learn the process of building, to increase their ability to sustain attention, or to increase the motivation to develop higher skills. The next level is the "LEGO builder". If someone at this level assembles an original freestyle creation using the blocks, he/she is acknowledged as a "LEGO creator". Next, if a child decides to lead a design, including directing the project and assigning tasks to group members, he/she can become a "LEGO master". A "LEGO genius" is the next step and attainment requires creating a LEGO movie script or story to be acted out by the group members. The group members then discuss whether or not the individual has earned a "LEGO genius" based on their project. The final stage is "LEGO Legend". This is reserved for children who have attained their goals and continue participating in LEGO therapy. They take on a peer monitoring role and continue attending sessions (LeGoff et al., 2012). This progression reflects the opportunity for each child to practice and improve verbal and nonverbal communication and social competence at each level appropriate to their skill base as well as the scope for continual improvement.

Studies by Baron-Cohen and colleagues (2002, 2003, & 2006) suggest that children with high functioning autism are highly motivated by LEGO blocks due to their systematic nature. Furthermore, Golan and Baron-Cohen (2006) indicated that children with developmental delays can strengthen their ability to recognize emotion through the LEGO intervention. Owens et al., (2008) determined that LEGO therapy is most applicable to students with high functioning autism who are placed in inclusive classrooms at school. Due to students' preference for LEGO play as well as the scope for spontaneous, meaningful interactions that go beyond merely greeting one another and sharing toys during this activity unlike in systematic social skills instruction, LEGO interventions have been shown to be particularly beneficial.

LEGO therapy studies have so far evaluated the intervention for elementary school children with disabilities. Hu et al., (2018) used peer-mediated LEGO therapy to investigate social interactions for preschool students with autism in an inclusive setting. Specifically, they addressed whether the number of social interactions (social initiations and social responses) among group members increased as a result of the peer-mediated LEGO intervention and whether teachers perceived the intervention as feasible, acceptable, and effective. Previously no formal attempt had been made to combine peer-mediated intervention with LEGO play to improve children's social interactions in inclusive settings.

The researchers conducted pre-intervention peer training sessions where two children were paired to receive one 25-30-minute training session. The training included basic rules in LEGO play, opportunities to initiate and respond to an interaction, and how to provide visual or physical prompts, modeling, and reinforcement to the target child with autism. Results showed a strong functional relationship between the peer-mediated LEGO intervention and the children's social initiations and responses in group play, with an increase in both initiations and responses. The results of the study were consistent with previous studies that have shown that peer-mediated interventions improve social interactions for children with autism in inclusive settings (Katz & Girolametto, 2013; Lee & Lee, 2015). The LEGO intervention attempted here within a peer-mediated framework not only introduced a variety of LEGO models to increase the diversity of social skills used, but also expanded LEGO play as a cooperative and engaging activity in a group with peers sharing the same interest rather than as a teacher-directed activity with prescribed actions as typically seen in systematic social skills interventions.

Benefits of Participation in a LEGO group

Effectiveness of LEGO therapy can be observed in social communication and trust. Trust in others has increased following participation in collaborative LEGO play (Kato et al., 2012). This is especially important considering that developing trust in peers may contribute to an increase in sharing behaviors, a behavior that is implicated in cooperative play (Yalamanchili, 2015). Participation in a LEGO group may facilitate group communication, increase social skills, and positively affect the mood of each participant involved.

LeGoff (2004) found that social competence increased after 12 or 24 weeks of a LEGO play intervention. Participants demonstrated a significant increase in their social competence after participating in the LEGO intervention than they had previously experienced. Furthermore, results indicated that the longer the duration of LEGO therapy (24 weeks versus 12), the greater the increase in social competence (LeGoff et al., 2012).

Participants demonstrated more social interactions during play time at school post-intervention and these occurrences were observed lasting a longer period of time.

Students who participate in LEGO therapy can make academic, social, behavioral, and emotional gains as well (Yalamanchili, 2015). However, it should also be noted that despite the literature on social skills interventions, many are limited in their ability to provide empirical evidence especially with regard to generalizability of findings. LEGO therapy programs vary greatly in length, duration, number of sessions, and delivery format (Lindsay et al., 2017). The duration can range from 20 to 90 minutes, weekly sessions for a period of four weeks to three years. The person delivering the intervention has also varied across studies. Some have been led by clinicians (Barakova et al., 2015; LeGoff, 2004; Owens et al., 2008), some by educators (Andrews et al., 2012; Boyne, 2014; Brett, 2013; Tuonen et al., 2014), one by a joint team consisting of a teacher and clinicians (Pang, 2010), one by parents (Peckett et al., 2016), one by a community coordinator with volunteers (MacCormack et al., 2015), and one was even run by a robot (Huskens et al., 2015). The interventions run by clinicians and educators have shown improvement in social, communication, and play skills. Interventions led by clinicians alone showed significant improvements in autism-specific behaviors. Most importantly, LEGO interventions run by educators in a classroom setting found significant differences in interpersonal skills (Lindsay et al., 2017).

Nevertheless, LEGO therapy is an approach that has potential to improve outcomes for children with disabilities, particularly given that it embeds social interactions in LEGO construction activities rather than using a direct teaching approach as seen in social skills interventions highlighted earlier. Results generally report at least one improvement in peer-related social skills (e.g. improved social interactions, social competence, building friendships), autism-specific behaviors, belonging, family relationships, or reductions in playing alone (Lindsay et al., 2017). Although children with high functioning autism tend to demonstrate greater gains, the LEGO intervention provides all children with social skill advancement. The collaborative problem-solving component of this approach encourages group members to work together to steer the direction of the activity and achieve the desired result rather than to follow a set of prescribed actions. When taken in consideration along with findings that students who work in groups generalize skills learned to a greater degree than students working alone (Azmitia, 1988), these overall findings are especially important considering that students with disabilities often lag behind typically developing peers in complex peer-related social skills such as collaboration and problem-solving.

Given the naturally occurring opportunities for peer interactions during such activities of shared interest, LEGO construction activities provide a nurturing social environment in which students can learn and practice complex peer-related social skills such as collaboration. As a collaborative activity, such an approach may be an important way to address the development of students' complex peer-related social skills often overlooked in systematic instruction, particularly given students' preference for construction-type activities, a genuine shared interest in LEGOs that creates naturally occurring opportunities for collaboration, and most importantly, the scope to go beyond a narrow set of foundational peer-related social skills.

Preschool Children and Engineering

Although research-based strategies are available to teach students with disabilities targeted peer-related social skills (foundational skills such as turn taking, greeting, and play initiations), a gap remains in the research on more complex peer-related social skills for preschool-aged students with disabilities such as collaboration and problem-solving. The LEGO play intervention attempts to address this issue by embedding opportunities for collaboration and communication between students. While it is more naturalistic than previous interventions described earlier and provides scope for spontaneous and meaningful interactions that go beyond initial greetings and sharing toys with peers, it is limited in its ability to generalize findings. LEGO play interventions, the focus of which is the social interactions that occur during the building of a LEGO model by group members, can vary greatly in length, duration, number of sessions, and delivery format. Yet, the key issue standing out here is that the intervention is limited to the specific plan made within the group to build a LEGO structure.

Previous research suggests that characteristics of activities and the number of social interactions for young children with disabilities are correlated. Given emerging evidence of preschool students' interest in and preference for activities with a construction component (such as LEGO construction), the next step in addressing their social skills is to provide further naturalistic settings in which they can practice collaboration and communication in activities that go beyond the completion of a specific, short-term target such as building a LEGO model.

The *engineering design process* (hereon referred to as EDP) is a cyclical method that students follow to collectively build a solution to a problem (Gruber-Hine, 2018). Engineering encompasses hands-on activity, inquiry, teamwork, and other instructional practices that develop children's twenty-first century skills, including critical thinking, communication, collaboration, and creativity (Lachapelle & Cunningham, 2014). The

Framework for K-12 Science Education (National Research Council [NRC], 2012), while noting that engineering is an essential dimension to science education, supports the development of such skills, recognizing that advances in knowledge occur through collaboration and established social norms, with many minds working together to communicate and share ideas over time. The benefits of student interactions during collaboration include strengthening students' interpersonal skills while also advancing knowledge construction (Wiedmann, 2015). Considering the support students with disabilities require in peer-related social skills such as collaboration, and the limited opportunities they receive to engage in activities that promote collaboration in nurturing social environments as opposed to the emphasis on systematic direct social skills instruction, their engagement in the EDP working along with peers is a gap in the research that needs to be explored.

While considered an essential aspect of science education, engineering is different from science in that students are expected to define a problem, generate and evaluate multiple solutions, build and test prototypes, and optimize a solution (NRC, 2012). The *Framework* also projects a vision of engineering design and what students can accomplish from early school years onward:

> In some ways, children are natural engineers. They spontaneously build sandcastles, dollhouses, and hamster enclosures, and they use a variety of tools and materials for their own playful purposes. Children's capabilities to design structures can then be enhanced by having them pay attention to points of failure and asking them to create and test redesigns of the bridge so that it is stronger. (NRC, 2012, p. 70)

As children try to understand and influence the world around them, they develop ideas about their role in that world, and how it works (Inagaki & Hatano, 2002; 2006; Keil, 2003; as cited in NRC, 2012). Although they may lack deep knowledge and extensive experience, they often engage in a wide range of subtle and complex reasoning about the world (Metz, 1995; Gelman & Kalish, 2005; as cited in NRC, 2012). Therefore, by listening to these ideas, the *Framework* suggests that educators can use them as a foundation to introduce engineering practices in the early grades.

Cunningham and Kelly (2017) articulate eight critical components of the EDP, of which one is of particular interest in this review: collaboration. They state "…collaboration is valued and cultivated in engineering. Students are required to brainstorm, consider each other's ideas, and negotiate shared solutions." (p. 9). Cunningham and Kelly (2017) state that collaboration is an epistemic practice of engineering. The researchers assert that collaboration is an essential intrinsic construct of engineering. "Studies of engineering practice note the importance of collaboration and the need to bring together expertise across types of knowledge" (Cunningham & Kelly, 2017, p. 7). When students work together in groups and take on certain roles and responsibilities, they simulate the actions of engineers who work collectively to solve problems or create novel solutions (Gruber-Hine, 2018). Therefore, engineering activities contain embedded opportunities for collaboration.

However, while researchers argue for the necessity of collaboration within engineering, little information is provided about how this manifests itself in the EDP, what preschool students' engagement with the EDP looks like, and how they interact and work together while following the steps of the EDP. Given that young students with disabilities require further support in peer-related social skills such as collaboration and problem-solving and given emerging evidence of their interest in and preference for activities with a construction component (such as LEGO construction), there is a need to study how and when students collaborate during engineering activities. Specifically, considering the naturally embedded opportunities for collaboration during engineering, there is a need to explore what preschool students' (with and without disabilities) engagement with the EDP looks like; and how they interact and work together while engaging in the steps of the EDP.

This section of the literature review will explain engineering and precursors to engineering knowledge and behaviors, such as working collaboratively, that preschool students exhibit. The EDP as appropriate to preschool will be outlined, along with teacher strategies to implement collaborative engineering activities in preschool. To conclude the review, a rationale for studying the engagement of young students with disabilities in engineering activities will be provided.

What is Engineering?

Engineering is defined here as goal-oriented thinking that addresses problems and decisions within given constraints by drawing on available resources, both materials and human capital. Twenty-first century educational goals encourage classroom discourse that focus on creativity, collaboration, distributed expertise, innovation, higher-order thinking, and life-long learning (Scardamalia, 2002). Engineering encompasses hands-on activity, inquiry, teamwork, and other instructional practices that develop children's twenty-first century skills, including critical thinking, communication, collaboration, and creativity (Lachapelle & Cunningham, 2014). Based on these discussions, the features that need to be taught appear to include scientific content and methods knowledge, process knowledge, critical thinking and problem-solving skills, organization and management skills, and communication skills. These perspectives and approaches to engineering design thinking and learning seem to constitute the core of engineering (Adams, 2011).

Engineering Habits of Mind

To further visualize engineering education, the engineering habits of mind (NRC, 2009) are discussed here. These are a set of ways of thinking and acting that are important both for engineering and school readiness. Specifically, the six habits of mind are systems thinking, optimism, communication, collaboration, creativity, and ethical considerations. Each of these occurs within the wider context of engineering within a given set of constraints. This context distinguishes some of the engineering habits of mind from general preschool behavior. Lippard et al. (2019) give the example of two of the engineering habits of mind to illustrate this. Collaboration and creativity must occur in the context of solving a problem or making a decision as opposed to communicating daily experience or general engagement with art or dramatic play. Further, engineering habits of mind focus on solving materials-based problems, which is distinct from social problem-solving. For example, both types of problem solving may address the concern that one child used up all the purple paint, but if a teacher's goal is to facilitate engineering design thinking, the teacher will help children to identify the problem that the preferred material is no longer available and guide them in generating solutions together such as mixing colors to make purple. This contrasts with social problem solving where the teacher may guide the children to talk about how they feel about not having the material they want or sharing the paint.

Of the six habits of mind, the focus of this review is on collaboration and communication. Collaboration allows for groups to incorporate strengths and abilities of each group member into the problem-solving process to reach a better outcome (NRC, 2009). Successful collaboration can increase children's understanding of materials and engagement in deeper thinking. Collaborative problem solving has been associated with greater learning (Azmitia, 1988). Communication is an essential skill for collaboration and problem solving. Communication here goes beyond knowing vocabulary and includes understanding the needs and wants of others (Loveland & Dunn, 2014). Communicating ideas challenges children to clarify their thinking and in turn, exposes that thinking to either affirmation or correction by others (Lippard et al., 2019), which is key to the collaborative nature of engineering.

<u>Engineering in Early Childhood</u>

The natural curiosity of children aged three-five makes the preschool developmental period an important time for introducing and reinforcing engineering practices (Lippard et al., 2017). The *Framework* in recommending that students learn how to engage in engineering design practices to solve problems, notes that young children are natural engineers: "…children's capabilities to design structures and use a variety of tools and materials for their own playful purposes can be enhanced by having them pay attention to points of failure and asking them to create and test redesigns." (NRC, 2012, p. 70). Engineering, as previously explained, is defined here as goal-oriented thinking that addresses problems and decisions within constraints by drawing on available resources. Children use goal-oriented thinking to address problems and make decisions both within traditional engineering play such as block building (e.g. how to build a stable tower. Here, children have to think about their goal i.e. building a tower that will not fall, within the constraints presented, i.e. how tall it can be without falling over, and the available resources, i.e. blocks available), and in other activities such as dramatic play and art

(Lippard et al., 2017). In fact, preschool children are primed for engineering thinking. Recent work by Lucas et al. (2014) indicates that preschool-age children are particularly open to taking in information and effective at using that information to formulate hypotheses. Children are more likely to explore broadly and test hypotheses when given open-ended opportunities with materials, as opposed to direct instruction (Bonawitz et al., 2011). These situations arise authentically whenever children engage in solving problems within a given set of constraints to reach a decision or meet a goal.

When presented with situations with similar underlying problems but differing materials or contexts, children as young as three are able to transfer solutions from one context to another (Brown & Kane, 1988). Children as young as four years of age are able to transfer solutions from one context to another when peers provide the explanation as compared to when an adult provides the explanation (Brown & Kane, 1988). In short, children naturally identify problems and explore possible solutions, and more importantly, are able to offer and follow their peers' explanations to problems.

The developmental engineering hypothesis suggests that young children's exploratory, inquisitive, and creative behaviors resemble traits highly desirable in engineering (Adams et al., 2011). Evangelou et al. (2010) argued that engineering and early childhood education share quite a bit in common. In their research framework outlining the commonalities as well as precursor ideas that the two fields share, the researchers suggest that some of the most desirable engineering education outcomes are addressed via the same educational structures that are qualities that are important to early childhood education as well.

Preliminary research findings examining the developmental appropriateness of engineering in early childhood suggest that activities and materials related to engineering are suitable for young children (Bagiati, 2011). Additionally, these findings suggest that precursors to engineering knowledge and behaviors are already present in children of preschool age (Bagiati, 2011; Brophy & Evangelou, 2007; Evangelou et al., 2010; Van Meeteren & Zan, 2010). Studies of preschool students engaging in block-building activities and play projects have focused on instances and patterns of the engineering design process, and on ways in which children construct and communicate their designs as evidence of precursors to engineering thinking (Bagiati, 2011; Brophy & Evangelou, 2007; Evangelou et al., 2010; Johnsey, 1995). Brophy and Evangelou (2007) focused on the processes that young children use to build with blocks. In their analysis of a series of videotaped vignettes, the researchers concluded that children are as interested in the process of block building as they are in the product, i.e. the process of designing and building something stable with blocks; problem-solving when coming across obstacles; asking and offering suggestions; and following peers' suggestions. Of particular importance here is the finding that children demonstrated the ability to collaborate with each other to come up with the final construction, and the ability to follow a child identified as the 'expert' and work under his/her instructions. The researchers noted that in approximately half the videotaped vignettes, children were building in pairs or small groups. Findings from such studies support the notion that not only are early engineering behaviors present in young children's play, but also that young children can engage in collaborative work to complete a shared goal, an essential aspect of the EDP.

Another study by Evangelou et al. (2010) explored preschool children's interactions with artifacts under three different conditions: in sketches, as part of a story, and in actual physical form. The researchers hypothesized that the physical tangible object condition would elicit more questions and exploration, and results showed that this condition elicited the longest discussions and interactions with the artifacts. It was also the condition during which children demonstrated more knowledge and produced more ideas regarding the potential functions of the artifacts. More recently, Bagiati (2011) reported that engineering thinking was identified in a variety of instances such as during large group discussions, in small group hands-on activities with peers, and sometimes while carefully observing other children's final products or construction processes while playing.

Young children's learning hinges on their ability to explore their environments, ask questions, address problems, identify solutions, and make decisions. Yet, exposure to engineering in early childhood education is mostly incidental as part of teaching and learning through Science, Technology, and Mathematics, rather than exclusively through Engineering (Bagiati & Evangelou, 2009, 2015). This is made even more challenging when considering that most educators have not experienced engineering or participated in engineering pedagogical development while training in teacher education programs (Cunningham & Carlsen, 2014). Even though many early childhood educators believe in the importance and appropriateness of teaching STEM and in particular engineering to young children (Park et al., 2017), preschool teachers often report feeling unprepared to teach engineering (Greenfield et al., 2009).

Considering that there is no overarching curricular framework designed to teach engineering at the preschool level, leaving educators to choose from a range of instructional interventions and science lessons, this begs the question what does engineering in early childhood education look like? What do teachers need to do to ensure preschool students are engaging appropriately in engineering challenges? The following section of the review describes preschool engineering and learning outcomes addressed in the EDP. This is followed by a review of studies on the EDP in early childhood and what preschool participation can look like. In order to describe in detail what entails engineering in preschool education, this section is accompanied by a review of research on early engineering that outlines the teacher's role in implementing engineering: teacher strategies to ensure greater participation.

Engineering Design Process

The EDP is a method that engineers follow to individually or collectively come up with a solution to a problem. The EDP at an elementary level includes: defining a problem, brainstorming possible solutions, planning and creating a solution, testing and evaluating a solution, redesigning to improve a solution, and communicating solutions (Gruber-Hine, 2018). For young children, developing these practices means supporting them in becoming intentional about utilizing the EDP. Such skill development includes asking and answering questions, creating communicative drawings and other representations of designs, recording findings, and analyzing designs for improvement (Lachapelle & Cunningham, 2014).

Numerous categories of learning are identified within the EDP, including skills such as identifying a need, defining a problem to solve, conducting research, understanding constraints, developing criteria to evaluate ideas, coming up with alternative solutions, analyzing the outcomes, making decisions, documenting design specifications and communicating ideas (Mosborg et al., 2005). Categorized learning outcomes following the EDP specifically mention "learning by doing, learning from brainstorming and prototyping, learning by iteration, learning from feedback and failure, learning by noticing, drawing, and troubleshooting, learning by dialoging with ideas, materials and people, and learning from reflection". Furthermore, an evaluation from two years of field testing an engineering curriculum (Engineering is Elementary, EiE) by trained educators found that the value of engineering in the classroom extended beyond science knowledge and that "when tackling engineering design challenges, students practice twenty-first century skills such as creativity, collaboration, critical thinking, and problem-solving" (Lachapelle et al., 2013, p.75).

Recognizing that advances in knowledge occur through collaboration and established social norms, with many minds working together to communicate and share ideas over time (NRC, 2012), collaboration has been emphasized as being valuable for students to learn, especially when considering the inherently collaborative nature of engineering (specifically in brainstorming, dialoguing, troubleshooting, and reflecting). Considering that the benefits of student interactions during collaborative work include strengthening students' interpersonal skills (Wiedmann, 2015), collaboration and communication during engineering are the focus of this literature review.

The literature offers a few different EDPs to help preschool students participate in early engineering experiences. Despite the variety in methods describing the design process, they require implementation of a set of steps such as identifying a problem, exploring possible solutions, analyzing solutions, testing and evaluating solutions, and communicating the solution. For instance, one such program is Engineering For Kids

(EFK, as cited in Cinar, 2019) aimed at improving the problem-solving skills of children between 4-14 years of age. It follows the following steps of the design process: 1. Ask 2. Brainstorm 3. Design 4. Build 5. Test 6. Improve (https://www.engineeringforkids.com/). Another program follows the Engage-Explore-Reflect (EER) cycle (Chalufour & Worth, 2004) which is generally used to organize children's science explorations and facilitate interactions that promote conceptual development and inquiry. The EER cycle enables teachers to embed prompts within each phase of the cycle: during the Engage phase, teachers use prompts that elicit children's prior knowledge about the concept or activity and invite them to ask questions, identify problems and make predictions. During the Explore phase, teachers encourage children to observe their creations and identify, address, and solve any challenges pertaining to it. During the last phase (Reflect), prompts help children to describe their creations and their experience through the process using language, drawings, photos and demonstrations, and express their emerging ideas.

Finally, the third EDP is one used in the Engineering is Elementary program [EiE] (Hester & Cunningham, 2007). The EiE was designed to meet the need for an appropriate and engaging engineering curriculum in elementary and preschool education. The cyclical five-step process for the elementary level contains the following steps: 1. Ask, 2. Imagine, 3. Plan, 4. Create, 5. Improve (Hester & Cunningham, 2007, p. 5). Figure 1 below outlines each stage of the process as well as what student behavior at each stage is expected to look like. By following these steps, using additional scaffolding when needed, children are engaged in the problem-solving process that is at the heart of engineering.

ASK
What is the problem?
What have others done?
What are the constraints?
IMAGINE
What are some solutions?
Brainstorm ideas.
Choose the best one.
PLAN
Draw a diagram.
Make lists of materials you will need.
CREATE
Follow your plan and create it.
Test it out!
IMPROVE
Talk about what works, what doesn't, and what could work better.
Modify your design to make it better.
Test it out!

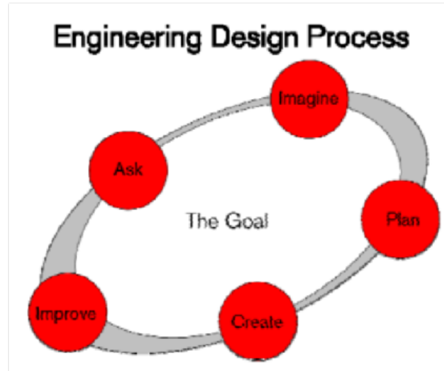

Figure 1 The EDP developed by EIE

The literature contains a few examples of students working collaboratively to solve engineering problems. For instance, Lottero-Perdue et al. (2016) introduced the EiE five-step engineering design process (EDP) to Kindergarten students by asking students to reflect on a previous lesson on changing an eggshell with vinegar and then posed a question, "How else can an eggshell be changed?" and then proceeded to read aloud the story introducing the protagonist (a cracked egg) that cracked when it fell off a fence. This set the problem and a clear goal for students (to design a package to protect an egg from a fall). Lottero-Perdue et al. note the example of EiE's EDP (in Figure 1 above) but altered the process to meet the needs of the Kindergarten students in the study. The EDP that the researchers used (see Figure 2) was a simplified four-step version of EiE's five-step design process.

EDP Step	Students:
Ask	Ask: • What is the problem? • What is the goal? • What are the rules? Consider: • What do we know?
Imagine	• Brainstorm how each material may be used and changed. • Brainstorm how materials can be used together to solve the problem.
Try	• Use materials to show the teacher an idea. • Create the design. • Test the design.
Try Again	• Reflect on testing results and how to improve. • Use materials to show the teacher a new idea. • Create this new design. • Test this new design.

Figure 2 The Four Step EDP

Following the above process, teachers paired students up and asked questions about the materials available for the activity. To assist in the 'Imagine' phase, teachers made use of open-ended questions such as, "What is a way you can change the materials? What would you want to put closest to the egg?" and observed students offering ideas during whole-group discussions. Researchers observed students using the materials to create packages based on ideas developed in the previous phase. Guided by teacher questioning, students reflected on their design and test results, discussed among themselves how they could improve their creations, planned, and created a secondary design. The importance of facilitating small group work and discussions along with intentional questioning strategies can be seen here. When working in groups, students were observed collaborating with one another in asking questions and developing ideas for their packages, brainstorming how materials could be used to create the package, working together to create and test the design, and in reflecting on test results and how to improve.

The impact of introducing students to a problem scenario, for instance, where students had to build a tall and stable tower for one of the stuffed animals in their classroom (Lottero-Purdue et al., 2015) or building a strong house for characters from a popular children's novel (Bradley et al., 2019) can be seen on the collaborative efforts students took to solve these engineering problems. Similar to the previous study, students were organized into groups of two. Pairing students together further encouraged them to brainstorm ideas of how the materials could be stacked and oriented, create communicative drawings, build the solution and record findings, and evaluate for improvement while working collaboratively, thus providing naturally occurring opportunities for peer interactions. Teachers' use of open-ended questions during this process enabled students to analyze and interpret their testing data, consider cause (i.e. their design) and effect (i.e. their testing results) and to consider the relationship between the structure and function in their design. While this allowed students to practice creativity and critical thinking while designing and testing, the focus here is on students' collaborative work and problem solving through the steps of the EDP. Being presented with a problem scenario for this investigation and being grouped together provided naturally embedded opportunities to collaborate in planning and creating a design, testing, and evaluating the data.

There are further examples in the literature of young children engaging collaboratively in engineering practices that range from designing playground renovations (Blank & Lynch, 2018) to construction homes for birds (Tippet & Milford, 2017) to designing an open and closed circuit using a variety of tools (Torres-Crespo et al., 2018).

In each case, students were presented with a problem relevant to their lives and then encouraged to and supported in engaging in the EDP. This meant that students defined a problem, brainstormed possible solutions, planned and created a solution, tested and evaluated the solution, redesigned to improve the solution, and tested it again. While engaging in the EDP, students have to verbally communicate with each other. This can take on various forms whether it be to ask questions about the problem, collaborate in brainstorming ideas and exploring materials, sharing materials, making predictions, collaborate in creating and testing solutions, and evaluating the solutions. Thus, the EDP contains immense potential for collaboration, negotiation, and problem-solving (Lachapelle & Cunningham, 2014), the kind of peer-related social skills that preschool students with disabilities require support in. This becomes especially important when considering that students with disabilities often do not receive opportunities to engage in collaborative efforts with their peers such as engineering challenges that require them to use their creativity, critical thinking and problem solving skills while working with peers.

Where other activities may be limited in scope for generalizing to other play scenarios in the classroom, or have specific, short-term goals (such as building a LEGO model), or target a narrow set of social skills through interventions designed to directly teach these skills, engineering activities present students with a meaningful context to a design problem, are not tied to a specific short-term goal, and therefore provide more scope for generalizability of social skills practiced to other activities of a collaborative nature. The series of steps in the EDP, while being the same across engineering activities, are to be viewed as a guide to solving a design problem rather than as an intervention to be followed. The path that students take in solving design problems is open to their creativity, problem-solving, and collaboration. This is an important distinction between engineering activities and interventions such as the LEGO play intervention. In not laying out a model to follow or limiting students' interactions to a narrow set of behaviors, the emphasis is on students' collaborations with each other and how they work together to progress through the steps of the EDP and solve the design problem. The engineering activities provide a naturalistic scenario in which students can collaborate, be it brainstorming and sharing ideas, making predictions, or creating a solution. Thus, it provides scope for spontaneous peer interactions that go beyond a narrow range of social behaviors to include complex peer-related social skills such as collaboration and problem-solving.

Engineering Design Process in Preschool

It must be noted that EiE's five-step engineering design process has mainly been used in elementary school settings (Kindergarten and higher grade levels). In order to operationalize engineering in preschool, EiE developed the 'Wee Engineer' Curriculum (Davis et al., 2017), which consists of three rather than five steps. Reasoning that some of the distinctions in the five-step EDP might be too subtle for preschool students to comprehend, the researchers reduced the process to three essential elements, as seen below in Figure 3: 1. Explore, 2. Create, 3. Improve.

Figure 3 Wee Engineer EDP

The 'Wee Engineer' Curriculum is structured to include four challenges: 1. Noisemaker, 2. Fan, 3. Wrecking Ball, 4. Rafts. The engineering challenges are introduced to preschool students by first explaining to them who engineers are and what do they do. Teachers explain that engineers are people who collaborate with their peers and use tools available to them to create a product that will solve a problem. The three-step engineering design process is explained to the children in the following way: "Explore materials to find out more", "Create-try out an idea", and "Improve-to make it better". The premise of each challenge is that there is a problem to be solved and that as engineers, children need to go through each step of the engineering-design process to solve the problem. While the curriculum is structured in terms of the challenges children engage in and provides materials for children to begin using, the path that children take in solving the problem within the challenge is open-ended and left to their creativity and brainstorming abilities. Children are also invited to use any material in and outside the classroom as they see fit in completing the challenge. Therefore, the curriculum stresses process, not product. The focus within the curriculum is on the path children take in completing the challenge and their collaborative interactions with one another as they engineer something, rather than the product itself.

Van Meeteren and Zan (2010) argue that for young children, the engineering design process does not reveal itself as steps, but rather as nonsequential components that may often be enacted by students simultaneously and would often quickly result in new questions. In studying preschool students' use of the design process in building ramps, they found that the students often used, repeated, or sometimes skipped components of brainstorming, planning, testing, and improving as the project or question dictated. The students' use of the design process is also different in the manner in which they brainstormed, planned, created, and improved. For example, with regard to the 'Ask' stage from the EiE process, children were observed not always sticking to one question and seeing it through. Often, they became intrigued by a peer's work and would abandon their original question to work alongside or with their peer to solve the peer's design challenge.

The researchers also observed children at times merging the 'Imagine', 'Plan', 'Create' and 'Improve' phases and enacting the 'Plan' phase of the process more informally. This meant that sometimes children verbalized their plans or held a mental image rather than drawing on paper before, during, or after they began building. The researchers reasoned that this could be due to four reasons:

a) The fast-paced nature of a preschool daily schedule where children go from whole-group circle time to stations;
b) The variety of materials and activities laid out for children to try during free-play means that children are often accustomed to flitting between activities;
c) While young children can think three-dimensionally, they have difficulty representing a three-dimensional mental image on a two-dimensional plane;
d) Young children's design plans are dynamic and evolve as they work with the materials.

Considering these aspects of preschool education, a model of the engineering design process following the EiE's 'Wee Engineer' curriculum for preschool (Davis et al., 2017) is proposed below. However, this three-step process has been altered to include four steps as follows: 1. Ask, 2. Explore, 3. Create, 4. Improve

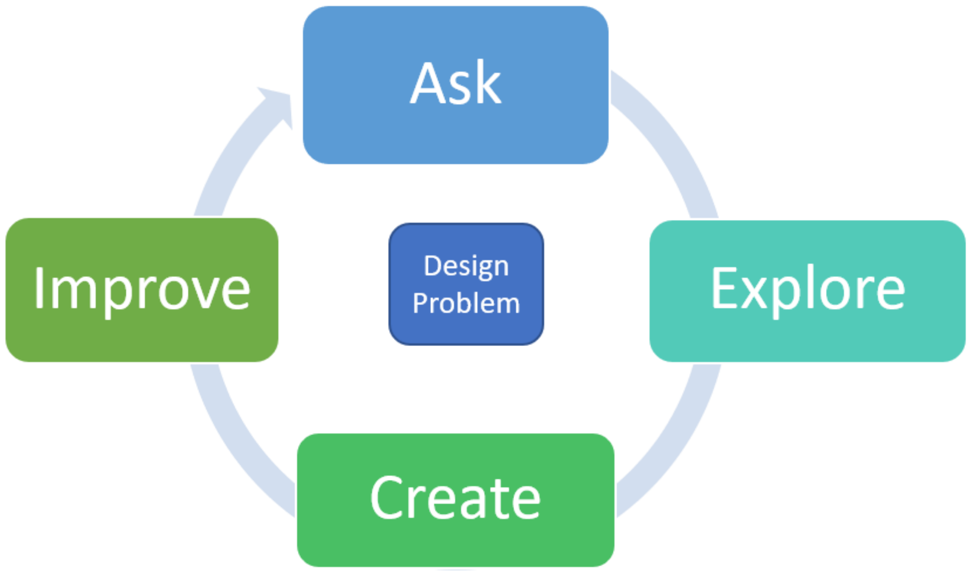

Figure 4 EDP for Preschool

This model follows the three-step process outlined in the Wee Engineer curriculum but with a few differences. Looking at previous studies' (Bradley et al., 2019; Lottero-Purdue et al., 2015) investigations into preschool students' engagement with the engineering design process, a consistent starting point for all investigations was for the teacher to ask a question to kickstart students' asking questions and delving into the engineering challenge. For instance, Bradley et al. (2019) noted how the teacher asked students what the pigs in the story needed (i.e. a big strong house) and also, why the first and second pigs' houses fell down. After eliciting student responses to these questions, the teacher was able to set up a problem scenario for the students to use the engineering design process on (i.e. to build a house strong enough that it would not fall down). Similarly, Lottero-Purdue et al. (2015) noted how the teacher kickstarted the engineering challenge by first presenting a problem-scenario (to build a tower tall and strong enough for a stuffed animal) to preschool students and asking them, "What should we do?" Once this scenario was posed to students, they began to identify the problem and what they needed to do. In order to begin the engineering challenge, however, asking the question was the crucial starting point. Keeping this in mind, the above model was designed to begin with ‘Ask’ and then transition to ‘Explore’, ‘Create’, and ‘Improve’. A breakdown of this process is provided below (Figure 5) along with a description of student behaviors at each stage.

EDP	Breakdown of EDP:	Students:
Ask	• Identify the problem • Ask questions about the problem	• Discuss • Ask and respond to questions
Explore	• Explore materials • Brainstorm • Identify and gather materials needed	• Share out ideas • Share materials • Demonstrate • Ask and respond to questions • Make predictions • Explain
Create	• Carry out the plan: create the design • Test the design	• Share materials • Ask for suggestions or help • Respond to questions • Collaborate in creating and testing
Improve	• Reflect on testing results and how to improve • Plan for, create new design, test new design	• Discuss in small groups • Ask for suggestions, help • Respond to questions • Make predictions • Collaborate in creating and re-testing

Figure 5 Breakdown of the EDP for Preschool

Following this EDP, students ask a question and define a problem, explore materials to brainstorm possible solutions, plan and create a solution, test and evaluate the solution, redesign to improve the solution, and test it again. While engaging in the EDP, students have to verbally communicate with each other. This can take on various forms whether it be to ask questions about the problem, demonstrate, collaborate in brainstorming ideas and exploring materials, share materials, make predictions, collaborate in creating and testing solutions, and/or evaluate the solutions (these can be seen in the column

'Students' in Figure 5). Thus, the EDP contains naturally embedded opportunities for collaboration and problem-solving.

A key distinction between this EDP and social skills interventions described earlier is that the EDP is not targeting specific social skills as interventions usually do. It presents a guide to engaging in engineering, however, the path that students take in solving the design problem is left to their creativity, problem-solving and collaborative efforts with peers. It contains embedded opportunities for collaboration at each stage of the EDP (these can be seen in Figure 5). In providing naturally occurring opportunities for collaboration during engineering, the emphasis here is on students' spontaneous collaborative efforts and how they work together to progress through the steps of the EDP and solve the design problem, rather than providing training for a specific set of social skills.

The developmental engineering hypothesis, as explained above, suggests that young children's exploratory, inquisitive, and creative behaviors resemble traits highly desirable in engineering (Adams et al., 2011). Studies of preschool students engaging in block-building activities and play projects have focused on instances and patterns of the engineering design process and on ways in which children construct and communicate their designs as evidence of precursors to engineering thinking. The purpose of the above section was to review a growing body of studies that have investigated preschool students' collaborative engagement in the EDP itself and not simply preschool students' free play that may or may not mirror engineering. While this is an emerging area of research, there is no overarching curricular framework designed for early engineering that outlines teacher strategies, leaving educators to choose from a range of short-term instructional interventions and science lessons. By outlining an EDP appropriate to preschool along with opportunities for peer collaboration, this section has made clearer what early engineering in the preschool classroom entails. In order to explain the teacher's role in preschool engineering experiences, further studies were reviewed to identify key teacher strategies that further make intentional students' collaborative engagement in engineering challenges and support them in moving through the steps of the EDP.

Teacher Strategies to Implement Engineering in Preschool

While the overarching goal of engineering is to solve problems through design, there are certain strategies teachers can implement with students that can facilitate the investigation, such as providing time and space to work in small groups, providing open-ended materials, asking open-ended questions, and the use of scientific language. These are explained in further detail below.

Providing Time and Space to Work in Small Groups

Collaboration is encouraged among students when placed in small groups of 3-4 at stations, especially when involving a problem-based approach (Durkin, 2018). Yuen et al. (2014) investigated how engineering projects in collaborative groups can increase student engagement in STEM. The researchers first presented a lesson on how to build robots and studied students' behavior during learner-centered activities, where students worked in assigned small groups to practice the concepts presented by instructors and build their own robots which they would later test. In observing students' on-task behavior, grouping, exclusion, and interactions during direct instruction, the researchers found that students were most engaged when observing, discussing, and building the robots. The students stayed on task, did not exclude their peers, and discussed their work with group members.

Similarly, Miller (2016) explored how science in early childhood education can develop through the use of learning centers where students collaborate in small groups. Miller studied a teacher who incorporated a lesson on sounds in the classroom wherein students used different materials to create noise and investigate different sounds that are made from different materials. The use of learning centers allowed small groups of students to deepen understanding, and to practice problem-solving, communication, and collaboration through hands-on exploration. Students were able to be more intentional in investigating the different sounds and how to create louder or softer sounds when collaborating in small groups as opposed to a whole-group exploration where with the number of students and materials, collaboration and intentional exploration of the materials might not have been possible.

For young children, engaging in the EDP includes asking and answering questions, creating communicative drawings or demonstrating their ideas, recording findings and analyzing their designs for improvement (Lachapelle & Cunningham, 2014). In this process, they are learning by doing, brainstorming, dialoguing with ideas, materials, and people, troubleshooting, and reflecting. Doing so requires them to practice skills such as collaboration, critical thinking, and problem-solving – twenty-first century skills deemed essential to engineering. Considering the benefits of student interactions during collaboration include strengthening students' interpersonal skills (Wiedmann, 2015); and that collaboration is part of peer-related social skills (along with problem-solving) that students with disabilities often need further support in; and that they often do not receive the time or opportunities to practice and generalize through naturalistic, open-ended activities in a nurturing social environment, providing time and space for young students with and without disabilities to work in small groups can encourage collaboration as they engage in the steps of the EDP.

Open-ended Materials

Open-ended materials are natural or synthetic, found, bought, or upcycled materials that students can move manipulate, control and change within their play (Daly & Beloglovsky, 2014). They are materials that can be used in multiple ways to create something or to interact with (e.g., loose parts such as popsicle sticks, paper clips, binder rings, string, and cardboard). For instance, Parks and Oslick's (2018) study investigated students' completion of design challenges based on the children's book 'Goldilocks and the Three Bears' where students incorporated the engineering design process in building and improving on their designs for safe chairs for each character in the story. Using common everyday furniture and tools, students followed the steps of the design process in finding a solution to their engineering problem. Similarly, Miller (2016) as highlighted above, studied a teacher who incorporated a lesson on sounds in a preschool classroom where students used different materials found within the classroom to create noise and investigate the different sounds that are made from different materials. Providing open-ended materials encouraged students to manipulate the materials, observe and discuss with each other about loud versus soft sounds and the ways in which the same materials can be manipulated to produce a variety of sounds.

Yuen et al. (2014) studied teachers' use of toy robot parts, sensors, and tools in engaging students in their own inquiry on how to build a robot. MacDonald et al. (2020) describe a real-life problem that preschool students faced in their outdoor area: how to get their bikes over a creek. Students were observed working collaboratively to brainstorm solutions and experimenting with different materials in the classroom. One such solution was to construct a bridge that students could use to cross the creek. Open-ended materials came in handy as students attempted to bring their solutions to life. There was "a lot of trial and error" as the teacher reported and they were "still working through a workable plan for a bridge". However, the example illustrates the value of providing open-ended materials to students to flesh out their ideas, create a design and test it out. In the process, students learn by doing, and by dialoguing with ideas, materials, and people (Mosborg et al., 2005).

Asking open-ended questions

The use of open-ended questions is noted in the literature on young children's inquiry in engineering. Studies indicate that teachers who use open-ended questions achieve higher levels of student involvement which in turn promotes learning (Rojas-Drummond & Zapata, 2004). Thompson et al. (2012, as cited in Cremin et al., 2015, p. 8) also note that teachers by asking open-ended questions promote speculation by modeling their own curiosity, potentially generating new questions on the part of the students, and 'developing 'intrigue' (Poddiakov, 2011), a core capacity of young scientists.

Trundle and Smith (2017) note the value in asking students questions as they engage in engineering as a way to expand ideas expressed during play. They provide an example of students' play with blocks and Oobleck and trying to use Oobleck as cement for building with blocks. Use of questions such as, "How are you going to use the Oobleck?" and "What are some other ways you can use Oobleck?" allowed students to think critically about the materials they were using, what they were doing with it, and why they were using it and communicate their ideas. The focus here is not on arriving at the right answer, rather it is on encouraging students to think deeper and creatively about solutions to the problem they are investigating and communicate their ideas: fundamental aspects of the EDP.

Martin et al. (2005) also explain how open-ended questions can engage students in thinking deeper and critically about the activities they are involved in, the science concept behind it, and plan next steps. For instance, when a teacher asks a student an open-ended question such as “What would happen if…?”, he/she is asking the student to predict or describe what would happen if they were to do something based on observation, experience, or scientific reason. Prediction is essential to doing science and asking open-ended questions during engineering activities would help make students’ thinking clearer as well as help them articulate their observations. Similarly, open-ended questions such as “What did you notice?” after observing something happen (for instance, after testing a design), can invite students to make inferences based on observational evidence. Inferential reasoning is also another process critical to science and scientific understanding (Martin et al., 2005). In the process of answering open-ended questions, students have to communicate their reasons for their inferences to teachers and peers. Communicating here goes beyond knowing vocabulary and includes understanding the perspectives and questions of others. Communicating ideas challenges students to clarify their thinking and in turn, exposes that thinking to either affirmation or correction by others (Lippard et al., 2019), which is key to the collaborative nature of engineering.

Scientific Language

In the literature on early childhood science, specific mention is made to the kind of language teachers use when participating alongside students in science activities. In this literature review, this has been referenced as ‘scientific language’, that is, language that describes what students are doing using scientific terms and intentional use of science vocabulary when communicating about science activities. For instance, Parks and Oslick (2018) in their study described how teachers while reading ‘Goldilocks and the Three Bears’ presented a problem that is discussed in the story and had the students find an engineering-based solution to the problem. Not only did the project involve the engineering design process but teachers also presented and explained new vocabulary as and when appropriate. For instance, when students had to build a chair suitable for all of the characters in the story, the teacher used the word ‘earthquake-proof’, i.e. safe , to describe how the chairs needed to be. In this process, teachers used scientific language while engaging with students in their investigation, such as ‘prediction’ and ‘hypothesis’ (when building and testing the chair), ‘balance’ (when talking about the chair legs balancing the seat), and ‘design’ (when talking about students’ ideas for a chair).

Conezio and French (2002) highlight an example of preschool students’ investigation into the concept of light and shadows. Students collected a variety of materials to see which ones would create a shadow in bright light and which ones the light would simply pass through. After several observations and days of experimentation, students came to understand that while opaque materials create shadows and transparent materials allow light to pass through easily, there are some materials that do not fit into either category (i.e. they are translucent) and cause very light shadows. The researchers note students’ use of terminology such as ‘transparent’, ‘opaque’, and ‘translucent’ especially in the context of the students’ investigation.

Although young children’s engineering investigations can begin in a variety of ways, are not limited to a set of activities, and do not emphasize arriving at the correct answer, the difference between students' incidental learning during free play at any station/center and intentional engineering education lies in the coherent approach teachers take in introducing students to a problem-based scenario and taking students through the steps of the EDP. Along with the EDP explained in Figure 4 and student behaviors at each stage of the EDP, the four teacher strategies outlined above help to clarify: a) what preschool students' engineering education should look like; b) how preschool students go through the steps of the EDP; c) opportunities to collaborate as well as what working collaboratively could look like at each stage; and d) strategies teachers should follow to assist students in engaging in the EDP and proceeding through the steps to collaboratively solve the design problem. Figure 6 presents this information with a further breakdown of the four steps of the EDP, student behaviors at each step as well as teacher strategies to be implemented at each step.

EDP	Breakdown of EDP:	Students:	Teacher:
Ask	• Identify the problem • Ask questions about the problem	• Discuss • Ask and respond to questions	• Ask open-ended questions • Use scientific language to name and notice
Explore	• Explore materials • Brainstorm • Identify and gather materials needed	• Share out ideas • Share materials • Demonstrate • Ask and respond to questions • Make predictions • Explain	• Provide open-ended materials • Provide space and time to work in small groups • Ask open-ended questions • Use scientific language
Create	• Carry out the plan: create the design • Test the design	• Share materials • Ask for suggestions or help • Respond to questions • Collaborate in creating and testing	• Provide open-ended materials • Provide space and time to work in small groups
Improve	• Reflect on testing results and how to improve • Plan for, create new design, test new design	• Discuss in small groups • Ask for suggestions, help • Respond to questions • Make predictions • Collaborate in creating and re-testing	• Provide open-ended materials • Provide space and time to work in small groups • Ask open-ended questions • Use scientific language

Figure 6 Overview of the EDP for PreschoolSummary And Current Study

As explained earlier, young children with or at risk for disabilities may display a unique trajectory of social development. Preschool children with or at risk for disabilities are found to engage in interactive social play with peers less frequently than children who are chronologically younger but have similar cognitive skills. Lack of reciprocal play as observed in children with or at risk for disabilities during the early childhood years is likely to continue to be an issue in elementary and middle school years.

As young children with disabilities are educated in more inclusive settings, they are often faced with increased opportunities to practice and improve their peer-related social skills (McCollow & Hoffman, 2019). Peer interactions are found to be a significant part of school experiences and influence adjustment to school (Koyama, 2011). This is one reason for a particular focus on developing peer-related social skills in young children with or at risk for disabilities.

A variety of interventions targeting foundational peer-related skills (such as greeting, sharing, and inviting peers to play) have shown varied outcomes. Overall, it appears that direct teaching of specific social behaviors when implemented with some intensity and combined with skill practice and systematic reinforcement has a positive impact for children with mild to moderate developmental delays. However, the literature also indicates that newly learned skills may not be maintained when reinforcement is faded and show limited evidence of generalizability to other settings. Although research-based strategies are available to teach students with disabilities these foundational skills, a gap remains in the research on more complex peer-related social skills such as collaboration and problem-solving.

There is, however, an emerging body of research investigating the "constructive" nature of young children's preferred activities such as LEGO building and the scope for improving peer-related social skills such as collaboration in young children with or at risk for disabilities. Such activities often involve an engineering component that requires brainstorming and using these ideas to create a product (e.g. a LEGO model). The LEGO play intervention attempts to embed opportunities for collaboration and communication between students while building the model. While it is more naturalistic than interventions that directly teach social skills and provides scope for spontaneous and meaningful interactions that go beyond initial greetings and sharing toys with peers, it is limited in its ability to generalize findings and restricts the interactions to the LEGO activity and the specific LEGO model students plan to build together.

The EDP is a cyclical method that students follow to collectively build a solution to a problem (Gruber-Hine, 2018). Engineering encompasses hands-on activity, inquiry, teamwork, and other instructional practices that develop children's twenty-first century skills, including critical thinking, communication, collaboration, and creativity (Lachapelle & Cunningham, 2014). While engaging in the EDP, students have to verbally communicate with each other. This can take on various forms whether it be to ask questions about the problem, collaborate in brainstorming ideas and exploring materials, share materials, make predictions, collaborate in creating and testing solutions, and/or evaluate the solutions. Thus, the EDP contains immense potential for collaboration and problem-solving (Lachapelle & Cunningham, 2014), the kind of peer-related social skills that preschool students with disabilities require support in.

Engineering activities provide a naturalistic scenario in which students can collaborate while not being tied to a specific short-term goal, and therefore provide more scope for generalizability of peer-related social skills to other activities. The series of steps in the EDP, while being the same across engineering activities, are to be viewed as a guide to solving a design problem rather than as an intervention to be followed. In not laying out a model to follow or limiting students' interactions to a narrow set of behaviors, the emphasis is on students' collaborations with each other and how they work together to progress through the steps of the EDP and solve the design problem. Thus, it provides scope for spontaneous peer interactions that go beyond a narrow range of social behaviors to include complex peer-related social skills such as collaboration and problem-solving.

Young children's preference for activities such as LEGO building involve an engineering component to them which calls for creativity, trying out different ideas, sharing of materials, and working together to build a structure. Engineering, as represented by the cyclical EDP, is defined by a number of qualities including brainstorming and sharing ideas, asking and answering questions while planning, creating, and testing a product, sharing materials, demonstrations, explanations, and most importantly, peer collaboration throughout the process. The benefits of student interactions during collaboration include strengthening students' peer-related social skills while also advancing knowledge construction. While researchers argue for the necessity of collaboration within engineering, little information is provided about what preschool students' engagement with the EDP looks like, and how they interact and work together while following the steps of the EDP.

Given that preschool students with or at risk for disabilities require further support in peer-related social skills such as collaboration and problem-solving and given emerging evidence of their interest in and preference for activities with a construction component, their engagement in the EDP working along with peers is a gap in the research that needs to be explored. Specifically, considering the naturally embedded opportunities for collaboration during engineering, there is a need to explore what preschool students' (with and without disabilities) engagement with the EDP looks like; and how they interact and work together while engaging in the steps of the EDP.

To that end, the purpose of this study was to explore the nature of social interactions that take place between preschool students with diverse social-emotional skills when engaging in engineering activities in order to study how they interact and work together while solving a design problem. Within the scope of social interactions, specific attention was paid to collaboration and joint problem-solving. The research question is as follows: what is the nature of social interactions that take place between preschool students with diverse social-emotional skills when engaging in engineering activities?

CHAPTER THREE: METHODS

The purpose of this study was to explore the nature of social interactions that take place between preschool students with diverse social-emotional skills when engaging in engineering activities. Therefore, using a qualitative case study design, this study explored the nature of social interactions that occurred between preschool students when engaging in the engineering activities implemented in this study. Within the scope of social interactions, specific attention was paid to the following peer-related social skills: collaboration and problem-solving. This chapter begins with a description of and rational for the research design used in this study. A description of the site, participants, and implementation of engineering activities at this site is provided, along with context regarding the teaching approach in place at the site. A description of the three data collection methods used in the study is provided, before concluding with an overview of data analysis strategies used.

A qualitative case study research design was used to observe participants (preschool students and the teacher) in their natural settings with the intent of interpreting phenomena (Creswell & Poth, 2016). Case study research involves the study of a case (or cases) within a real-life, contemporary context or setting (Yin, 2004). It is defined as a qualitative approach in which the investigator explores a real-life, contemporary bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of information and reports a case description and case themes (Creswell & Poth, 2016). By using multiple data courses, the researcher can discover and develop a “converging line of inquiry” (Yin, 2003, p. 92), and thus, strengthen the trustworthiness of the research.

Site

This single case study was bound by time (one month), site, and participants. The research site was a preschool classroom at an early childhood education program providing preschool education to children ages 3-5, including children with or at-risk for developmental delays. An inquiry-based learning approach is implemented in this classroom. This meant that each week the teacher would carefully observe and document students’ interests and questions, as well as the stations they would engage in the most and use this documentation to guide how she planned and set up stations and materials for the following week. Open-ended materials and loose parts (e.g., blocks, bottlecaps) are regularly used in the classroom. For example, building and tinkering with recyclables such as carboard boxes, Styrofoam, and popsicle sticks is an activity frequently set up at a station (with the teacher noting that students enjoy this station and spend a large portion of time tinkering at this station). The teacher, rather than directly showing and teaching students what to do with materials, guides their exploration with open-ended questions and demonstrations with the materials. She then encourages them to tinker with materials to produce something. The block area is also popular, often seeing 5-6 students tinkering, constructing, and using their designs during free-play sessions.

Participants

Participants included 13 students and the teacher in a preschool classroom (ages 3-5) at the site. While none of the students in the classroom had an Individualized Education Plan (IEP), five of the students had been identified by the teacher as needing everyday teacher support and strategies to navigate social situations and cooperative play in the classroom, especially during free-play sessions.

Implementation of EDP in the Classroom

In keeping with the inquiry-based teaching approach of the classroom, the teacher was not provided specific engineering challenges to implement in the classroom, however she was provided with a copy of the four-step EDP (Figure 4) and received guidance and information on the four stages of the EDP as relevant to the study, beginning with identifying an engineering problem to solve and asking questions about it, and ending with reflecting on testing results. The teacher was also provided with a handout of a breakdown of each stage of the EDP along with what students are expected to do at each stage (Figure 6). The teacher received further guidance on the four strategies that can be used to intentionally implement the EDP and move students along each stage along with where each strategy would be most relevant (outlined in Figure 6: asking open-ended questions, providing open-ended materials, using scientific language to name and discuss what students are doing, and providing time and space to work in small groups). A practitioner article highlighting an example of preschool students' engagement in the EDP (Blank & Lynch, 2018) was shared with the teacher. Examples of engineering activities using the EDP (e.g., the *Picture-Perfect Science Lessons* series (Ansberry & Morgan, 2007); *Making and Tinkering with STEM: Solving Design Challenges with Young Children* (Heroman, 2017)) were also provided to the teacher as references. Instances of how other teachers have asked questions and guided students in engaging in the EDP, as well as the language they used in these examples were highlighted and further discussed during planning meetings to demonstrate what the teacher could do. The teacher was also guided on planning a question or a problem to solve in the engineering activities.

The purpose here was not to instruct the teacher on what to do, but rather to provide a guide to implementing the EDP with intentional strategies to facilitate students progressing through the steps of the EDP. Two 30-minute meetings with the teacher at the site prior to the study were conducted. In addition, at the end of each week of data collection, as requested by the teacher, I joined in co-planning meetings to brainstorm engineering challenges for the following week.

Data Collection

Three data collection methods were utilized in this study to obtain thorough understanding of students' social interactions during engagement in the EDP.

Video Recorded Observations

Students' engagement in the target engineering challenges while following the EDP was video recorded five days per week over a one-month period. Engineering challenges were implemented during free-play sessions held every morning (10:00-10:50am) in the classroom. As an information source that is relatively unfiltered through the eyes of researchers and unconstrained by preliminary hypotheses, video recording has a number of advantages over other types of data (Jacobs et al., 1999). Video can be used to capture information on participants' actions as well as verbal content. As a data source, video data can be watched, coded, and analyzed in multiple passes, enabling the researcher to watch the same sample of events again, each time looking into a different dimension of the recorded verbal and physical behavior.

While some students played at other stations during the free-play sessions, the focus of this study was on the engineering challenges and how students worked together using the steps of the EDP to solve the problem. Central to this focus was the clear identification of an engineering problem to solve (this was initiated either by the teacher's questions or prompts to students; or teachers posing a problem to students). These video recordings were later coded using a list of codes determined beforehand (Appendix A).

Semi-Structured Interviews

In order to collect data through multiple sources of information on students' engagement in the EDP and how they interacted and worked together during this process, two semi-structured interviews were conducted with the teacher in this classroom: one prior to implementation of engineering activities, and another at the end of the last week of data collection. Semi-structured interviews are based on a set of questions or topics that need to be explored by the interviewer. The interviewer determines the structure and agenda of the interview through certain questions asked, but the participant controls the amount of information provided in responses (Corbin & Morse, 2003). Semi-structured interviews are well suited for the exploration of participants' observations and opinions regarding complex issues and enable probing for more information and clarification of answers (Bariball & While, 1994). Considering the potential semi-structured interviews offer to attend to the complexity of a topic in need of contextualization, this format was used to interview the teacher on her observations of how the EDP unfolded in the classroom, and her observations of social interactions that occurred between students as they engaged in the EDP. These interviews were transcribed, and the transcriptions were analyzed along with the video data in order to provide a rich, comprehensive, and robust account of students' engagement in the EDP. While the interview protocol consisted of a list of pre-determined questions, the main goal was to let the teacher share her observations of students' social skills, peer interactions, how each phase of the EDP unfolded, and how students responded to each phase. An interview protocol can be found in Appendix B.

Unstructured Interviews

In addition to the semi-structured interviews, four unstructured interviews with the teacher were conducted at the end of each week of data collection where the teacher was asked to share her observations of students' work and interactions specific to the engineering challenge that week and how it progressed. An unstructured interview resembles a conversation more than an interview and is thought to be a "controlled conversation", which aims to gather in-depth information and usually does not have a pre-planned set of questions (Jamshed, 2014). In such an interview, researchers establish what will be studied or what Spradley (1979) calls a "grand tour question" but participants determine where to begin the narrative, what topics to include, and the amount of detail. An interview protocol can be found in Appendix C. Vignettes based on student interactions were written and used as discussion points for this type of interview (see Appendix D). A vignette here implies a concrete example of people and their behaviors on which participants can offer comment or opinion (Hazel, 1995). While vignettes can be employed in different ways and for different purposes, the main purpose here was to interpret actions and occurrences that allow situational context to be explored and influential variables to be elucidated (Barter & Renold, 2000). Doing so allowed the teacher to express in her own way what she observed happening during the EDP in terms of the activity, student behavior and interactions with one another, and how students progressed through the steps of the EDP, week after week, in order to obtain a weekly description of students' engagement in the EDP.

Data Analysis

Qualitative data gathered using the three data collection methods was analyzed to gather evidence on the nature of peer interactions during the engineering challenges. I used Dedoose (Dedoose Version 8.0.35, SocioCultural Research Consultants, 2018) to store, organize and analyze all video clips of students participating in engineering challenges as well as interview transcripts from teacher interviews. In total, 112 video clips (average length of clips was 20-25:00 minutes) were collected and uploaded to Dedoose. I then watched these video clips to identify the ones that would be included in the data analysis. Only video clips of students participating in the engineering challenges was included in the data analysis. Of 112 clips, 30 were included in data analysis (average length of these clips was 25-27:00 minutes). The remaining 82 were recordings of students either: a) in the engineering station but not actually working on any of the challenges, or b) engaged in other activities or conversations that are not relevant to the study, and therefore were not included in data analysis (e.g., participating in art activities).

I started data analysis by first reviewing all data sources (video clips of students participating in engineering challenges, semi-structured and unstructured interviews with the teacher) from the entire study to see and hear the data in a holistic manner. I watched video recordings and reviewed interview transcripts and began noting down key points of interest in memos. These memos served to store data points of note (Birks et al., 2008), such as the types of collaborative behavior and specifically between which students these occurred (e.g., if a student who is known to need a lot of support with social skills was seen approaching a peer and offering suggestions for the design, this was jotted down in the memo as a note-worthy data point). Similarly, if purely collaborative behavior between students was not seen but a teacher facilitated such interactions between students or if a student wanted to approach his/her peer, but the peer was not responsive and the teacher stepped in to facilitate such interactive moments, this was jotted down in a memo. The memos were also useful for storing pieces of information such as if an engineering challenge lasted an entire week, the context of that challenge and how it evolved from day 1 through 5, which students participated the entire time and which students joined and soon left (and sometimes would rejoin the challenge).

Video recordings were coded for each of the four stages of the EDP as well as for social interactions using a list of codes determined beforehand (Appendix A). These codes include definitions for each stage of the EDP, collaboration, problem-solving, independent work, or teacher-student interactions and were drawn from the literature on preschool engineering and social skills interventions.

Once this was complete, I analyzed the teacher interviews in order to triangulate noticings, specifically around patterns of collaborative interactions, and gain further detail on the nature of social interactions. Using descriptive coding (Saldaña, 2013) I first deconstructed data from interview transcripts into smaller, manageable sections and organized them based on the research question. For instance, data were coded for collaboration, problem-solving, teacher involvement, and individual work (where observed). In vivo coding was used to uncover concepts with "terms used by the participant(s) themselves" (Strauss, 1987, p.33), in this instance, the teacher for two reasons: a) to go beyond the codebook developed prior to the study in capturing additional observations and teacher perspectives of students' interactions, and b) to honor the teacher's voice in narrating her observations of the classroom. In addition, process coding (Charmaz, 2002) was also used to connote action in the data and was useful in coding observable activity (such as when students were 'gathering materials') but also for conceptual action (such as when students 'persevered' in problem-solving). Values coding (Saldaña, 2016) was used to code data on the teaching approach with emphasis on the teacher's beliefs on classroom expectations, what she wanted to see in terms of students' work and participation in the challenges, as well as what she deemed important or "special" (TI2). This was especially helpful in analyzing data that reflected the teacher's values and beliefs about the classroom and her teaching approach, her perspectives on students' participation in the context of her teaching style and objectives. Subcoding (Saldaña, 2016) was used to assign child codes after a primary code in order to provide further detail on the parent code (this was especially useful in further analyzing data coded using descriptive coding) such as when coding for 'length of time' students engaged in the challenges or when coding for 'materials' to provide detail on the nature of the materials provided.

First cycle coding was completed using the above methods to initially summarize the data on peer interactions and the engineering challenges. Later, pattern coding (Saldaña, 2016) was used to group these codes into three major categories that are reported in the next section. The first two categories describe two distinct patterns of peer interactions during engineering challenges. For each of the two patterns, excerpts from video clips and teacher interviews are presented to paint a clear picture of how students interacted and worked together to complete the engineering challenges. The third category 'nature and type of materials' provides insight into the variety and manner in which open-ended materials were set up for the engineering challenges, as a result of which students were drawn to the engineering station.

CHAPTER FOUR: RESULTS

What is the Nature of Social Interactions During Engineering Activities?

Qualitative data analyzed from video recordings of student engagement in four engineering challenges as well as from teacher interviews associated with the challenges in this study unearthed two distinct patterns of peer interactions: 1. Collaboration, and 2. Precursors ("Baby Steps") toward collaboration. In addition, findings emerged related to the nature of materials made available at the engineering stations and the possibilities those provided for students to come together and work on various designs. Although not directly connected to the research question, these emergent findings shed light on how teachers might best construct interactive opportunities within engineering activities.

Collaboration and joint problem-solving were the most common types of social interactions that were captured in the data. Thirty-one instances of collaboration and 80 instances of problem-solving from the video clips were coded and excerpted. Excerpts of students' conversations and interactions with each other from video clips as well as the teacher's observations from the interview transcripts are provided to highlight how students engaged in and worked together during the engineering challenges. Transcription conventions detailed in Mercer (2002) and outlined in Appendix E will be used to report students' interactions and conversations during engineering challenges. Altogether, these findings are presented as three categories below: 1. Collaboration 2. "Baby Steps" toward collaboration and 3. Nature of materials provided.

Collaboration

The first pattern of peer interactions that emerged from the analysis was of collaboration. When students decided on a common goal within the engineering challenge, assigned responsibilities to each other and were invested in it, they worked together to complete it. Within instances of collaboration there were also three types of interactions that are reported below: a) asking and responding to questions; b) demonstrating; and c) persevering and/or cheerleading. These provide further detail on what it was that students did together as they engaged in the challenges. Of these, 'persevering and/or cheerleading' as a type of interaction emerged during teacher interviews.

For example, in engineering challenge 1 (EC1), students worked together to build a fort out of plastic straws and connector pieces. Each piece had to be linked to the next using connectors. The teacher taped pictures of two structures built using the same plastic straws to serve as inspiration to the students who came to the station where the materials were set up. Pointing to these pictures, the teacher described how different-sized plastic straws were linked together using connector pieces and how it was made to stand on the floor. The teacher also used open-ended questions such as, "What could we make with the plastic straws and connectors here?"; "How can we build a structure that will stand tall?"; "How do you think we should start?" to ask questions and identify the engineering challenge that students then embarked upon. A group of three students took on this challenge and decided to build a plastic 'fort' that would be big enough for them to crawl into and play inside as well as sturdy enough to hold the weight of a blanket over its roof. In building the fort, they had to not only link the pieces together tightly enough that the pieces would stay and not come apart, but also build horizontally as well as vertically. The group of three students worked together in exploring what materials were available and the different sizes, gathering the ones they would need, and building the fort. Worth noting here is how students assigned a responsibility to each member of the group and performed their responsibilities in contributing to the construction of the fort, with an understanding of what each member was doing and why it needed to be done. It began with one student (BB) sifting through the plastic straws in the container and laying out the appropriate-sized straws that could be used in building, the second student (AE) then brought over the straws and connectors to the area where the fort was being built and handed them to the third student (WL) who linked the plastic straws together to build the fort.

BB: Maybe we need all these pieces. (*BB picks up a handful of plastic straws from the container and begins placing them on the rug. Noticing this, AE goes over to him and begins helping him in unloading the container full of plastic straws while WL is connecting the pieces to begin building the foundation of the fort*).

Although this collaboration continued for a further period of time, students soon identified a problem while creating their fort and problem-solved amongst themselves:

WL: AE, look! It came apart (*points to a section of straws on the left side of the creation that came apart*)

AE: No, you can connect it to that (*AE proceeds to demonstrate why the straws were not connecting successfully – they were not inserted tightly enough – and explains what could be done instead*).

Following this, AE took over building the fort with the pieces while WL sorted through the pile and provided the pieces needed.

AE: I need one more connector piece

WL: Here you go (*supplies the materials needed)*.

This pattern of peer interactions where students assigned responsibilities to one another and worked together to accomplish their goal was raised by the teacher in the interviews as well. In responding to a question on how students responded to the engineering challenge that week (EC1), the teacher narrated her observations of students' participation:

> I thought that [the station with the plastic straws set up] had the most kids I've seen working together, like cooperatively and successfully instead of moments of frustration. I felt like that was a huge moment to see them working together and to be proud of themselves and to be problem solving and getting the different stool…where they are coming together to work together, like giving each other jobs or roles, like, OK, you're holding the straws and you're holding the connectors and I'm going to stand on the stool. And so I thought that was a great example of everybody having a job, but all coming together, like each person had a purpose to create something or to do something for the creation. (TI2).

Rather than the teacher having to step in and facilitate students working together or deciding how best to tackle the challenge, students were observed discussing amongst themselves what needed to be done and who would perform each task. Further, instead of an "all-in" approach where students tackle the challenge as a whole and simultaneously pick up the plastic straws and build the fort, they decided to break the challenge up into tasks where each student was in charge of a specific task and performed that task in order to contribute to the overall construction of the fort.

…There'd be one standing on the stool and one would say, OK, you hand me the pieces and I'll put them together. And then someone who would identify…I noticed at one point also there was one boy who would identify when there were any little things that had to be ironed out. Like he'd say, "oh this one is a little wobbly or this is a little weak". And so it almost felt like each person had a role in this big sort of construction project which is important to me because, that sense of, like you have a purpose in this creation instead of just observing…because often that's what I'll see is like one kid is really invested in play or building something, but the other kid is just observing what's going on and not really being able to do much…but over here seeing that they each have a role and a job and are contributing to something…I think that's special" (TI2).

Asking and Responding to Questions

Within instances of collaboration, there were also different types of interactions that are worth noting. These provide further detail on what it was that students did together as they engaged in the challenges. Of these types of interactions, the first is asking and responding to questions while collaborating on the design problem at hand (EC1).

In the excerpt presented below, two of the students (AE and WL) are in conversation with each other; the group had built a foundation for the fort by linking plastic straws to resemble a cube-shaped structure that would be the base of the fort. The group was now attempting to add to this by bringing over more pieces and building on top of this cube to make the overall structure taller. WL was at one corner of the structure and AE at the other corner. WL was attempting to hold his end of the structure together (two of the pieces were loose and had to be tightened).

WL: Hey, can you connect that piece over there…(*Points to the two loose pieces. AE looks to where WL is pointing and goes over to tighten the pieces together.)*

WL:…And can you hand me the connector pieces. I need two connector pieces.

(After helping WL with what he asked for…)

AE: What do we need to do next?

WL: We need to make it taller. AE, can you build on that side and I'll work on this side.

Students monitored their own work as well as that of their group members while working on the fort. Although they each had a role in completing the fort, they also jumped in to help when a member of the group would ask for help with something specific. AE and WL had one such exchange as the fort was being built. WL was working on connecting the pieces together while AE was bringing over the pieces needed and handing them to WL one at a time. While WL built the fort he noticed that it was starting to look lop-sided since he alone was working on one corner of the fort while the other corners had no one tending to them (the other two members of the group were each bringing over more materials and sorting them according to size and providing them to WL as he built the fort).

WL: Can you connect the pieces on that side? *(Points to the corner of the fort opposite where he is standing. AE looks to where WL is pointing and begins building on that corner of the fort so that it is not lop-sided anymore.*)

AE: We need more pieces on this side…

AE:…Hey can you give me the connectors, I need more on this side.

BB: Here you go. (*Brings over more materials and provides them one at a time to AE*).

While students each performed their own tasks, they would also jump in to help with a different task where needed as seen in the above excerpt. When this happened, they would either interchange roles (AE and WL both built the fort while BB supplied the materials; where before WL alone was building the fort while AE provided the materials one at a time to WL and simultaneously fixed any loose pieces in the fort and BB brought over all materials from the container and sorted them according to size) and continue working together, or step in to help temporarily and once complete would go back to performing their original task.

Demonstrating

A second type of interaction that was coded within collaboration was that of demonstrating. Demonstrating here represents a moment during the challenge when a student shows a peer how to use materials to create a solution, uses materials to show an idea, or to show how the designed solution works after building/creating it. For instance, when AE and WL were standing at two different corners of the fort, WL demonstrated his idea for the fort using the plastic straws:

WL: You build on that side and I'll build on this side…(*points to each corner of the fort*)

WL:…No, no not like that. Like this, see (*WL corrects AE on what he wanted done and demonstrates how the pieces fit within each other with the connectors and how to link them to the existing structure and continue building*).

Students used materials to demonstrate their ideas for the fort in the early stages of building, particularly when discussing what it should look like. In these discussions, students would bring over a handful of straws from the container and build makeshift versions or a smaller model of the structure to demonstrate their ideas for the fort. Here I present an excerpt where the group discussed where the entrance to the fort should be. Having built the foundation for the fort, the group was now building on top of it to create their fort. In the midst of this, WL noticed that a portion of the structure which was meant to be left uncovered/open had been built over. This was meant to serve as the "door" to the fort through which students could crawl in and sit inside. A discussion about the "door" ensued:

WL: We're making a door right here (*points to the corner of the structure that was meant to be left wide open*)

BB: I'm inside the fort see! (*he steps over the foundation – as the structure is not yet complete – to show they can 'enter' the fort*)

WL: But we're gonna make it as tall as the ceiling we need a door so we can go inside (*he then proceeds to take out the connected pieces from the existing structure to make way for the "door"*).

After this, AE attempted to crawl through the entrance that WL created by removing a handful of the straws from the structure. However, this entrance was not wide enough for AE to go through. He got stuck and a handful of straws began to loosen and come apart.

Seeing this, WL: No, we need to make it bigger (*proceeds to demonstrate by removing some more pieces to make the entrance wider*).

BB and AE then attempted to crawl through the entrance once again to check whether it was wide enough for them to go through.

BB: "I'm inside the fort!" (*after crawling through the entrance*)

BB: This (*points*) is the door!

WL: We're making a door right here …(*points to the corner where he just removed the pieces to make the entrance, indicating that this corner would be left open*)…You can build on that side (*points to the opposite corner of the structure*).

While students used materials to demonstrate their ideas in the early stages of building, demonstration was also observed later in the process, particularly when students needed to explain their solutions and suggestions for problem-solving if any obstacle arose. For instance, if the fort started tilting to one side, if a piece fell apart, or even when a few connector pieces in the middle of the fort were noticed missing, students used materials to illustrate their thoughts. For example, having brought a big pile of straws and connectors over to the building site, BB then joined AE and WL in building the fort.

BB: We're like engineers! We build things and we fix them! (*helps AE and WL in building)*

WL: Hey there's a piece missing! BB you need to connect those two pieces or it will fall. *(demonstrates what needed to be done. He brings over a connector and using it, shows BB how the two pieces need to be linked and tightened in place.*)…See, you need to do it like this.

Having the materials ready and available made it easier for students to demonstrate their thinking. To be clear, only demonstrating that pertained to the engineering challenge at hand were included in the analyses. While students sometimes demonstrated how the materials could be used to make other structures (in one instance, a student began building a glider plane with the plastic straws while this challenge was ongoing), only the instances where students demonstrated ideas, suggestions or solutions pertaining to the plastic fort was included in the analysis.

Persevering and/or Cheerleading

The last feature to emerge from the data analysis is that of persevering and motivating group members to persevere when faced with unexpected problems or obstacles. Although this was not originally included in pre-determined codes, it emerged during interviews with the teacher.

In responding to a question about an engineering challenge ("What have you observed during students' engagement in the EDP in terms of interactions and working together while following the steps of the EDP?), the teacher shared her observation of students persevering:

> I think also what was surprising but amazing to see was that they just kept going. Even though I think while they were building during that one hour or seventy-five minutes, I think, at least two different times it (the fort) did fall down, like the structure they were building did fall down. But then they didn't just stop or get disappointed because of that and say, "Well, okay whatever" and move on. (TI2)

Specifically, within this type of interaction, what was noted was the motivational/cheerleading aspect in which individual students would not only persevere, but also encourage group members not to give up and instead, try again or try a different approach to the engineering challenge.

> And I think I remember especially there was one student in particular who said, "It's OK, we can try again". I think that skill of persevering varies in the class. So when there is that one kid who has that persevering, like, I'm not going to give up, I'm going to keep trying even though it's hard mindset, it affects the rest of those kids in there who could have been like the kids who would have given up or gotten emotional or frustrated or unable to express those feelings about being mad that it (the structure) crashed. (TI2).

The instance highlighted above by the teacher occurred during EC1 where four students were attempting to build a fort using plastic straws and connector pieces. Upon completing the construction, students attempted to place a blanket over the fort and test whether the fort could hold the weight of the blanket while standing. However, when students placed a blanket over the fort to test its strength, one side of the fort collapsed under the weight of the blanket and some straws came loose. It was during this moment that a student (WL) remarked, "It's OK, we can try again" and persevered to rebuild it.

> WL: don't step over it, it's really fragile. Get that…(*points to two straws that came apart*)…at the bottom.
>
> AE: Here, use this (*picks up a fallen connector and straw and hands it to WL*).
>
> WL: I know what we can do, we can connect the pieces like this (*removes straws that came apart or became loose when the blanket was placed over the fort, and begins linking them tighter than before using connector pieces that fell and got scattered on the floor*).

It was when WL remarked, "It's OK, we can try again" and made these suggestions that the other group members stepped in, followed his suggestions and began bringing over pieces that were scattered across the floor and rebuilt the fort. One of the students (BB) even sat down in the midst of this area, built a smaller piece of the fort by connecting 7-8 straws with connectors, and brought it over to the remaining group members when he completed it, and stated, "I just fixed one of the pieces". He handed it to WL as he and AE worked on rebuilding the fort using straws from the original creation as well as extra pieces from the set provided by the teacher.

WL: I need two more. Can you push that piece in?

BB: OK WL, here you go.

Therefore, when faced with obstacles during the engineering challenges, students who would normally have become frustrated with the lack of success, given up and moved on to other activities, continued by first listening to the suggestions of the student who persevered and then chiming in with their ideas and suggestions:

> You have those kids with more, for lack of a better word, like mature social and emotional skills in terms of, 'not giving up attitude' which can impact and affect everybody in that area, which is great, because…talk about your role model, which is really awesome. (TI2).

A point to note here is that group members and in particular, the student who persevered and encouraged his peers not to give up, did not simply abandon the existing creation to start building something new. They persevered to rebuild the existing creation by first problem-solving what went wrong and reflecting on how it could be improved using the same materials.

> …Not just trying to build something else from scratch or saying, "OK well, that didn't work so what else can we do?" but trying to get back to that same structure

> and actually seeing those problem-solving moments of, "OK, these two pieces, one connecting and the other not connecting, and that's why it fell apart" and so thinking specifically like, "How do I fix *that*?" (TI2).

"Baby Steps" Towards Collaboration

The second pattern of peer interactions is that of peers working together on engineering challenges, but only intermittently rather than from the very beginning of a challenge through completion. The data reveal individual students working on their creations with peers bouncing in and out as they observe each other's work, look toward one another for ideas, offer suggestions and help, sometimes follow the student's lead, and then transition to another area of the classroom. These interactions often occurred with teacher facilitation and involved students who have been identified by the teacher during interviews as needing further support with social skills – particularly cooperative play, expressing feelings, and conflict resolution.

This type of interaction is characterized by one person working from start to finish and others popping in to help, following lead, and then adding ideas. Within this pattern of peer interactions individual students would be working on their ideas for designs – for example while planning to build a house for toy animals, exploring what materials they could use and beginning to gather materials and begin building – while other students would either: a) be in the same station/area working on their own creations, or b) come over to this area (set up for the engineering challenge) and observe what this student was creating and how he/she was using the materials. Interactions would then involve these students popping in to ask what the student was doing, and if/how they could help, listening to the student as he/she explains his idea and what they could do to help, and then contributing by either bringing more materials over or helping build the creation. They would stay for a further period of time and add their own ideas or suggestions, and then leave. While these students would work together for this period of time, it was more along the lines of the 'pop-in' students following the lead of the student who originally began working on the creation. These students would not stay the entire time but came in and out of the area with suggestions or ideas, and contributing in a smaller way, rather than working together with the student on the creation from start to finish. Therefore, this type of interaction is different from the first pattern 'Collaboration' reported above where students truly collaborated from start to finish on a creation, assigned responsibilities to one another, provided help and problem solved as they created and improved their designs. In the 'baby steps' type of interaction, it would start out as an individual effort with one student's ideas taking off, and along the way, peers joining in to observe and contribute in smaller ways and either stay until the end or transition to another area of the classroom. While this type of interaction was not collaborative in the truest sense of the word, the efforts and ideas of the students who joined in later cannot be discounted and were meaningful additions to the engineering challenge at hand – thus, they were 'baby steps' towards true collaboration. These interactions were also acknowledged as a significant part of the engineering activity and interactions as shared by the teacher during interviews. It allowed students who otherwise would not have such meaningful interactions with their peers during free-play the opportunity to engage in open-ended inquiry-driven activities such as the engineering challenges and work alongside their peers.

In a different engineering scenario, the teacher had set up the block area with loose parts such as blocks and ramps of various shapes and sizes, pieces of fabric, and recyclables for an engineering challenge of building a sturdy house for toy animals. While students engaged in that challenge, it was not restricted to that challenge alone, and students who had ideas for other creations were encouraged to gather materials and try out their ideas.

In the following excerpt, students were building their own houses but also making bridges to each other's houses to connect them; engaging in pretend play with animals living in the house playing with their "friends" (the teacher also drew a river and trees on a big piece of paper and taped it to the rug for students to pretend the animals were outdoors and there was a river flowing by); conversations about the weather outside (this was during the winter) and if the animals want to stay warm. WL had been working on his own creation, a parking garage for his toy cars. MM and RR were also present in the block area, each working on their creations. WL was counting out and trying to work out how to balance some of the blocks on the roof of his creation. Initially, he put some heavy block pieces on top of a sponge but then realized that they would not balance well on the sponge. He was trying to figure out the type of wooden blocks that would work best, given his design. MM was observing WL experimenting with the block pieces:

> MM: Here try this…(*offers a small block piece*)…That's too big (*points to the bigger block that WL had just been experimenting with unsuccessfully*)…You need another one.

Similarly, in another corner SW and CL were building a house with the materials provided for their toy animals. They had completed a square-shaped foundation and proceeded to put the animals inside it.

SW: We need a roof! (*proceeds to bring over more blocks from the shelf and attempts to place these over the existing creation*).

Her idea was to use these blocks to cover up the entire creation but these were not large enough to fit the entire creation. Noticing this, CC joined in:

CC: That's too small. You can't use that…(*takes out block pieces from the shelf and brought over a larger piece and offered it to SW*)…You can use one of these.

SW followed his suggestion and tried out the larger block that CC offered and all three students experimented with placing it over the foundation in a way that it would fit (although they tried placing it down the length of the creation, it eventually fit diagonally).

Thus, while the three students started out working on their own creations, they made observations about what each other was doing. This slowly transformed into a play scenario where having built their own houses, students were engaging in a pretend play scenario with their toy cars driving around the block area and parking their cars at their 'houses'. Soon, WL had a suggestion to build a fire station for their neighborhood and proceeded to bring out more blocks from the shelves:

WL: Maybe we could build a fire station (*proceeds to bring large blocks to begin building*).

At first, MM and RR did not join in. They continued their play sequence. Once WL had made a structure of considerable height, it became wobbly and fell apart. MM and RL noticed this:

MM: Let's rebuild it (*joins in with RR and begins stacking different blocks at this site*)

WL: You need to put it like that (*demonstrates how he envisioned the longer blocks being positioned on this structure*).

MM and RR followed WL's lead in placing the blocks the way he originally planned. However, changes were made to this plan as the three students continued building. At one point:

RR: We need to make a chimney (*proceeds to get cylinder-shaped blocks from the shelf*).

The teacher also noticed these 'baby steps' towards collaboration during engineering tasks. When asked what she had observed in the classroom in terms of peer interactions during the engineering challenges, the teacher observed that some of the students were "starting off with independent play and then gaining more of an interest in working together, like group play" (TI5). It should be noted that the teacher coined the term "baby steps" to explain her observations of this pattern of peer interactions. Further detail on students' skill set and pattern of interactions is provided in the next section.

"Baby Steps" and Students Requiring More Support

The interactions described above occurred between or involved one or more students who often required further support with social skills, particularly cooperative play, conflict resolution, and expressing feelings appropriately. The teacher would often step in to facilitate social interactions between these students, and even prior to implementing engineering challenges had identified these areas needing further support. I narrate some of the teacher's observations on how these students responded to the engineering challenges with emphasis on their social skills, as well as when and how the teacher stepped in to facilitate social interactions.

> They notice a peer doing something and they want to ask them about it or they want to do the same or they want to try and incorporate that in what they're doing and then that translates into them working together. It's not like they sit down and go, "OK, how about…what is your plan and what is your plan?" They seem to start independently, and they start observing and noticing what others in the same area are doing and then they try to…you know? It's baby steps to working together, like first they are observing each other's work, then they're sharing their ideas and talking about it and then starting to work on building it together, equally. (TI3)

The teacher continued these observations in the next interview:

> …And so, seeing those kinds of things. They notice things first, like, "…Oh, so and so is doing this" and "Why don't I try that?" or like, "BT is trying this and I want to try something with the tape too!" and beginning to observe one another and get ideas from one another. It's funny, as I think about the three students that were in the area and their social skills or lack of, for a better word. I think that was a good first step for them to be in there [the same area] together and to start by observing one another and starting to get interested in what each other is doing, and then eventually go on to work together. But these three students are still at that stage where they're doing more of parallel play or just a few steps behind collaboration or working together but eventually they will get there. (TI4)

The teacher further explained why she felt that (for these students in particular) expecting them to begin working collaboratively from the very beginning would have been too big a leap and instead, how they would "eventually" get there, stating:

> Thinking about their social skills, even individually, and what they are working on …for them to even be together in the same area itself…that was a good opportunity for them to get comfortable working on things with peers, and it was an introduction to working together or at least sharing ideas. You can't expect them to just go from playing by themselves or even parallel play to them collaborating by themselves. I think just to see the progression towards collaborating, like, maybe they are doing their own thing but they may start by making those observations about what each other is doing. And then maybe start staring their ideas and suggestions. And then try those ideas out. That's how it progresses step-by-step." (TI4).

The teacher explained that the 'pop in' or 'helper' students were the students who often needed teacher support to approach peers in play and successfully join in their play in the classroom. Therefore, it would not be realistic to expect them to go from where they currently are skill-wise to fully working cooperatively with peers from start to finish on a project. However, she acknowledged that their interactions are like "baby steps" or precursors to collaboration and cannot be discounted.

To provide further insight on other students' skillset, the teacher added:

> For kids like WL, I want them to be able to share their ideas confidently and advocate for their ideas or their plan instead of allowing other kids to take over instantly and agreeing to something. And then when I think about kids like CL who get along with everybody but have that more reserved temperament or kind of on the shy side where I feel…CL has so many great ideas for play but a little uncomfortable sharing it. She has grown leaps and bounds with expressing her ideas and herself in the classroom, but while I see that growth, I still think there's so

> much room for students like her who are becoming more confident in expressing their ideas and not just following what other kids do or being quick to kind of shut their own ideas down. (TI3)

While these are examples of some students needing support in expressing their ideas and feelings, there were also students who were "on the other end of this spectrum" (TI3) in terms of needing support navigating social situations (i.e., students who express strong interest in following through with their ideas rather than taking in the ideas or suggestions of their peers). Below are excerpts from the teacher's perspectives on this:

> For example, TL has…not a lot of interest in working together with kids. Like, during the start of any project or his play, he's very focused on what he wants to do, and he has a plan, like I can tell when he's working…which often does not involve other kids…and he'll take up a big area (of classroom space). I feel like it's been a difficult thing for them to navigate…sharing the space. (TI3)

It is students like TL who often require support expressing their ideas and feelings appropriately, initiating and continuing cooperative play, as well as navigating conflicts during play that displayed the second pattern of peer interactions (precursors to collaboration/"baby steps") described above. Primarily, these students would pop in and out, observe peers' work and offer suggestions or help, stay for a short period of time before moving to other areas of the classroom or trying out their own ideas at the station.

Teacher Facilitation

Often with the 'baby steps' pattern of interactions, teacher facilitation played a key role in supporting students to ask each other for help, to approach others to explain and demonstrate a suggestion, or to join in an existing activity. This is best exemplified by certain scenarios during the Ramps challenge (EC2). This engineering challenge came about as a result of students' interest in recreating their own "maze" in the block area. The teacher had showcased pictures from a previous action research project in another classroom (completed three years back) where preschool students worked together to build a system of ramps using wooden blocks. Participants in the current study studied pictures to see how students had gone about this challenge with the blocks provided. They soon began exploring with the blocks and ramps available in this classroom. At first, three students (TL, AE, WL) began gathering blocks and ramps for their own creations. Soon, AE started observing how WL went about setting up the ramps for his creation and asked, "Can I help you?" to which WL agreed. They attempted to create their own system of ramps using blocks. This entailed a process of asking questions and exploring with the different sized blocks, offering suggestions to one another, and demonstrating their ideas using the blocks. At one point to demonstrate his idea, AE remarked:

AE: Look WL, it's more of a ramp shape, we can use this.

Later AE and WL test out their ramps using toy cars. They experiment with making the car go up and down the ramp without falling off. However, when this does not work, they take apart some of the pieces from their creation and try a new configuration of blocks to make a shorter ramp.

Soon, the teacher brings marbles over and makes a suggestion, "I wonder if you could build something that collects all the marbles at the end of the ramp". The three students (TL, AE, and WL) took up this challenge and began building new configurations. However, they soon encountered a problem: there were not enough marbles for each student in the block area. The teacher provided only three marbles in total, each a different size; there were six students in the block area and some of the students were wanting two marbles to themselves. The teacher encouraged students to think about how they could work together and use the existing marbles. Students started discussing amongst themselves and offered their suggestions:

TL: Maybe we can take turns.

WL: Maybe we could all play together.

RR: Maybe we could connect them.

The teacher encouraged students to think about how they could connect their individual creations to create one large system of ramps that they could all play with. It was then that TL said, “We can make a maze” and demonstrated what he meant by rearranging some of the pieces.

TL: Can you give me a ramp?

AE jumped in and handed TL the piece he was looking for. TL then used this to connect his and WL’s creation and tested a marble down this connecting ramp. He demonstrated how the marble went down the ramp and suggested that all the creations be connected, giving them a chance to not only build with the blocks but also get a chance to use the marbles. The teacher explained this to WL and AE so they could join in this new scenario. The three students (TL, AE, and WL) then began reconfiguring their creations to start connecting them to one another in a way that the marbles could travel across this “maze”. Throughout this scenario, this core group of three students first started out building their ramps individually and testing it out with different sizes as well as experimenting with the slope of the ramp. Along the way, teacher facilitation helped in bringing the students to work together to create a bigger “maze” that each of them could have the opportunity to play with. This was especially important to the students considering there were a limited number of marbles as well as space in which they could all build. Rather than building individual creations and taking up more space, the teacher also pointed out how the space could be used more efficiently when all of them worked together on a single design.

Students simultaneously created their "maze" and tested it out rather than completing the entire design and then testing it. During this time, they tested out and improved their "maze" by trying new configurations of ramps to see how successfully the marbles traveled each time. They would then share their observations on what happened:

> WL: You gotta use the little marbles because the big one is stuck, see! (*attempts to explain that smaller-sized marbles only could fit through some of the arched blocks used in the "maze" while the larger marbles got stuck. He also demonstrates this using a big marble*).

<u>Atypical or Unlikely Peer Pairings</u>

A final feature of the 'baby steps' pattern of peer interactions was of peers who are not each other's preferred play partners (i.e. students who do not typically play or interact with one another in the classroom) working together on the engineering challenges. This sometimes included students who usually require teacher support in social situations. Below I provide excerpts from an engineering challenge (building houses for toy animals – EC 3) where such pairs (and in some instances, a group of three) worked together.

On Day 1 of this challenge, students (AP, WL, DB) started out building their own houses using various materials provided: recyclable materials, pieces of fabric, and cardboard boxes. None of these students were each other's preferred play partners and initially began work on their own designs. Soon, however, requests and offers for help were provided and two of the students began helping each other out, which then morphed into a common design in which both students were contributing:

WL was attempting to cut the flaps off a cardboard box for his design:

WL: Can you help me?

DB: WL, I can help you with your plan (*approaches WL*)

WL: I need to cut on this line (*points to where the flap is*)…I need to cut all the pieces (*points to all four flaps on the box*)

DB took over and attempted this task while WL proceeded to explore and gather more materials needed for the house. After a few minutes, BB (who was also neither of these students' preferred play partners) joined in:

BB: WL I can help you

WL: We're cutting these pieces off (*demonstrates what DB is doing*)

BB then joined in helping with this design: while DB was on one side of the box cutting a flap off, BB was working on the other side of the box. WL brought over different pieces of fabric, some cotton balls, and glue. He then checked in on DB and BB:

WL: Are you cutting on the line? (*demonstrates how he wanted it done*)

Noticing this, AP joined in:

AP: What are you doing?

DB: We're trying to cut these pieces off but the scissors is not working

AP: I know what you can do, let me show you…(*she goes to the shelf and brings over a different pair of scissors and demonstrates cutting the flaps off with it*)…I used the same scissors on mine, see!

The teacher also stepped in at this point to suggest that one student could hold the box so that it did not keep moving across the table while cutting, while the other student could cut the flaps.

After a few minutes, DB left but rejoined this challenge:

DB: What are you doing WL?

WL: We finished cutting now we need to glue the paper (*demonstrates to DB how he is coloring on the paper and then gluing it*)

DB: I can glue it for you (*proceeds to help*)

AP: Here's some tape. Use this.

On Day 2 of EC3, WL continued working on this design. He was attempting to apply glue inside the box to stick pieces of fabric on it. SW was observing this for a period of time. Noticing this, and remembering that SW and WL are not each other's preferred play partners, the teacher encouraged her to approach WL and discuss with him the plan for the design and how she could help.

WL: You can get that glue and use it on that side.

SW joined in and helps with this. Soon, both WL and SW completed this task.

SW: Let's put it over here *(points to the floor where there is more space to walk around this design and materials gathered for it*)

WL agreed and further explained his idea: "Now let's put the glue on the inside, crumple up the paper and stick it inside. We're making a bed for the animals." Although this was WL's idea for the design and SW only joined in later to help, SW provided certain suggestions for the design as well:

SW: Let's use the cotton to make the bed for the animals…(*she demonstrates her idea with the cotton balls)*

When quizzed by the teacher on why she chose this material, SW explained to the teacher and WL that "it's soft, see, touch it" and therefore would make for a good choice of material to create the bed for the animals. WL agreed to this suggestion and proceeded to gather more cotton balls for the creation.

After ten minutes, AP joined in:

AP: Can I help?

SW: We're making the bed for the animals

WL: You can glue over there, I'm sitting here (*points to where AP can start from*)

WL: We're using the cotton. Feel how fuzzy they are (*he shows the cotton balls*)

The three students continued working together on the house: using the original ideas that WL provided but along the way incorporating new ideas suggested by SW and AP. This challenge continued into Day 3 with WL, SW, and AP coming back to the station to continue where they left off. At this point they had completed the bed for the house and decided to build a roof over their house and add windows to it (using small wooden square pieces).

WL: Let's make cracker windows. We're gonna glue the squares…(*points to the wooden square pieces*)…on our house to make cracker windows.

First they decided that one of them would apply the glue while the other applies the squares. They tried this idea with glue sticks but quickly realized that it did not work well:

WL: SW, how are we going to fix this?

SW looked around the area and approached the teacher, looking for liquid glue. The teacher then provided some liquid glue to SW and WL:

SW: Here, let's try this

SW and WL resume working on the windows:

SW: You work on that side and I'll finish gluing over here. And when I'm done, you can come over here and I'll go over there (she *points to opposite ends of the box*).

WL agreed and they divided up this task in a manner that SW applied glue on the walls and WL glued the square pieces on the box.

In an interview, the teacher also noted how pairs of students who do not typically play together were coming together in these engineering challenges in a way that they not only observed one another's work and offered to help, but also raised new ideas for the design while working together which were then incorporated into the design.

> Over the course of three days they started naturally joining or working together on the project and being more open…like today I felt they were more open to working together and when other kids wanted to join, allowing them versus saying, "no, this is mine". Over these three days seeing them go from that more independent work to being open to working with others, but not just that. Seeing, for example, WL and SW…they are not each other's preferred play partners, but they worked together on the house. They both worked on it and had this joint idea or end result in mind. (TI5)

And,

> I thought that activity was great because it encourages them to interact with different people than they normally interact with. WL and SW were interested in it for two whole days…and they don't normally work or play together either. I think this was a really big accomplishment. (TI5)

The teacher went on to explain why she felt such unlikely peer pairings were noticed while working on the engineering challenges. She highlighted how the nature of the challenge, being hands-on and placing the students' ideas and suggestions centerstage rather than being given a specific task or activity by the teacher, along with the nature of the materials (open-ended and loose parts) invited students to explore and try out their ideas. Since the challenges were open-ended, students could take the challenge in the direction they wanted by ideating, creating, and problem-solving. It placed emphasis on students' ideas and problem-solving rather than on simply playing together with friends during free-play time. This is expanded upon in the third and final key finding/category.

Nature of Materials Provided

While open-ended materials were provided throughout the study, the variety and manner in which they were set up for the engineering challenges attracted and drew students in to the challenges in ways that other stations did not. Importance is given not so much to the exact materials but to how and where they were set up. An example of this is as follows: typically, only blocks are available at the block area and they are neither taken out of the area nor are other materials brought in to this area. The block area is usually preferred and frequented by a core group of four students who play there throughout free-play sessions while other students do not venture into the area. However, for the engineering challenges, the block area was one of the heavily used stations in the classroom. It was set up with blocks of different sizes and shapes, but also with various open-ended materials such as fabric, cotton, sponges, recyclable materials, Styrofoam, cardboard, as well as tools such as glue, scissors, tape, and markers. More students were drawn to the block area and began ideating and creating their designs when it was set up with these materials and the teacher invited students to also gather other materials from different stations of the classroom as they saw fit. These instances also included students who do not typically venture into the block area (for instance, SW, BT, and AP) and are known to prefer other stations.

> Not to stereotype, but often the same group of four boys would be in the block area when it was open and it was only blocks…other students just weren't that interested in… the block area. But when I think about them, when did they start becoming interested in it, it was when we incorporated animals and other materials. They all really love anything that has to do with animal play. So adding animals and different kinds of materials meant a lot of different kids started getting involved…kids who don't usually come to the block area if its only blocks. And they started creating these scenarios in the block area using the animals and building shelters and working together, but there's also this dramatic play element happening. (TI4)

Not only were more students drawn to the area when it was set up with these open-ended materials but also, they began creating pretend-play scenarios revolving around some of their favorite/preferred items of play (toy animals) where students would first create their designs (for example, a house for their animal), then proceed to engage in elaborate pretend-play scenarios involving their creations (examples of this are described in excerpts above).

> I feel like they've been interested…especially the kids who maybe weren't interested in the STEM related play invitations or provocations, became more interested as the weeks went on and as we incorporated maybe different things into it to try to get their attention and interest, like animals or the different materials like fabric and the books. It's allowed them, like CL to be much more vocal with what she wants to do and more creative in terms of expressing her ideas and being able to fully get into play. (TI4)

Further, the teacher described:

> To see BT stay in the block area…I feel like she was able to show…I mean I know that she gives so much attention to her tasks but I feel like there are more, there are different types of work and play that she prefers instead of blocks. And so for the first time I feel like she was able to show how in-depth she can get with for example creating the house and adding on to it and just really getting into it with her ideas, which was great to see because sometimes I feel like in the block area she just hasn't shown us what she has, skill-wise. But I think it just goes to show the block area can really meet the needs of whatever students are in there. (TI4)

The block area, but more importantly, the manner in which it was set up with a variety of open-ended materials and an invitation to expand to other areas of the classroom, made it more inclusive and versatile in the types of challenges that could take place as well as the manner in which students participated in the challenges. It allowed students who typically did not frequent the block area and who also needed support with their social skills to try out their design ideas, articulate and demonstrate their ideas to one another, and approach and work with one another. Not only were students trying out ideas for the engineering challenge identified but also coming up with ideas for their own engineering challenges and trying those out with the materials provided.

Summary of Findings

Qualitative data analyzed from video recordings of student engagement in four engineering challenges as well as teacher interviews associated with the challenges in this study unearthed three main findings. Two distinct patterns of interactions were unveiled during data analysis:

a) Collaboration: When students have assigned responsibilities to each other and work towards a common goal, they work together to complete it.

b) Precursor to collaboration: Students who often need teacher support with social skills bounced in and out as they observed each other's work, look toward their peers for ideas or to offer suggestions and help, sometimes following a peer's lead. Unlike collaboration described in the first finding, interactions within this finding involved these students popping in to observe and ask what each other was doing. It began as an individual effort with one student's ideas taking off and students (who often need teacher support) joining in and contributing in smaller ways and either staying until the challenge was completed or transitioning to another area of the classroom.

The third, emergent finding concerns the type of materials available during the engineering challenges:

c) Nature and type of materials provided: The variety of and manner in which open-ended materials were set up for the engineering challenges attracted and drew students in to the challenges. Importance is given not so much to the exact materials but rather to how and where they were set up. This allowed students who did not frequent particular areas or ‘stations’ within the room to begin approaching this space, articulate and try out their design ideas as well as begin to approach and work with one another.

CHAPTER FIVE: DISCUSSION AND CONCLUSION

Discussion

This study sought to explore the nature of social interactions between preschool students with diverse social-emotional skills while participating in engineering challenges. Peer interactions are a significant part of school experiences and influence adjustment to school (Koyama, 2011), however preschool students with and at-risk for disabilities are found to display a unique trajectory of social development, often requiring intentional instruction in social skills (McCollow & Hoffman, 2019). Engineering encompasses hands-on activity, inquiry, teamwork, and other instructional practices that develop children's communication and collaboration skills (Lachapelle & Cunningham, 2014). Engineering activities provide a naturalistic scenario in which students can collaborate while not being tied to a specific short-term goal, and therefore provide more scope for generalizability of peer-related social skills to other activities. Considering the naturally embedded opportunities for collaboration and the emphasis placed on students' interests and ideas, the focus of this study was on how students interacted and worked together while engaging in the engineering challenges implemented in this study.

Qualitative data analyzed from video recordings of student engagement in four engineering challenges as well as teacher interviews associated with the challenges in this study unearthed three main findings. They were as follows:

a) Collaboration: When students have assigned responsibilities to each other and work towards a common goal, they work together to complete it.

b) Precursor to collaboration: Students who often need teacher support with social skills bounced in and out as they observed each other's work, look toward their peers for ideas or to offer suggestions and help, sometimes following a peer's lead. Unlike the collaboration described in the first finding, interactions within this finding involved these students popping in to observe and ask what each other was doing. It began as an individual effort with one student's ideas taking off and students (who often need teacher support) joining in and contributing in smaller ways and either staying until the challenge was completed or transitioning to another area of the classroom.

c) Nature and type of materials provided: The variety of and manner in which open-ended materials were set up for the engineering challenges attracted and drew students in to the challenges. Importance is given not so much to the exact materials but rather to how and where they were set up. This allowed students who did not frequent particular areas or 'stations' within the room to begin approaching this space, articulate and try out their design ideas as well as begin to approach and work with one another.

Before discussing these findings, a point to be emphasized here is the manner in which students embarked on the EDP. Since the engineering challenges were framed around the four-step EDP, I initially broke them down step-by-step in order to gain perspective on whether peer interactions clustered around particular steps of the EDP. However, evidence from video recordings of student participation in engineering challenges and teacher interviews indicated that rather than solving engineering challenges while following the EDP step-by-step, students were observed approaching the EDP as nonsequential components that were often enacted simultaneously by the students (sometimes within a few seconds). Students often used, repeated, or skipped components of the EDP (particularly, the second stage of the EDP: 'Explore') as the challenge unfolded/evolved. Students' use of the EDP also differed in the manner in which they discussed, collaborated, and problem-solved their creations. In some instances, with regard to the 'Ask' stage of the EDP, students did not always consistently ask one question and see it through. They would become intrigued by a peer's work and abandon their original question to work with their peer and solve their peer's design problem. In other instances, students were observed problem-solving to improve their creations while creating or coming across obstacles in creating. Students improved their designs constantly as their understanding of their design as well as its constraints grew, making it challenging to tease apart the 'Improve' step (fourth step) of the EDP from 'Create' (third step).

The somewhat jumbled nature of the enactment of the EDP is in line with previous studies that suggest that for preschool students, the EDP does not reveal itself as steps, but rather as nonsequential components that are approached simultaneously and often quickly result in new questions (Van Meeteren & Zan, 2010). The researchers further explain that young children often merge steps of the EDP and enact their ideas or plans informally. This could be due to a number of reasons. When thinking of preschool engineering, it is important to consider the fast-paced nature of a preschool daily schedule where students transition from whole-group activities or circle time to small-group stations. Secondly, the variety of materials and activities laid out for students to try during free-play sessions means that students are often accustomed to popping in and out of activities. Lastly, students' design plans are dynamic and evolve as they work with the materials.

Nonetheless, a question that arises here is that of preschool students' participation in the EDP and whether it is fundamentally different from participation in older grade levels. Specifically, the nonsequential nature of preschool students' participation in the EDP and why it may be the case will help unearth further knowledge on preschool engineering as well as assist teachers in planning and implementing future engineering activities.

Collaboration

In this study, when students decided on a common goal within the engineering challenge and assigned responsibilities to each other, they worked together to complete it. Even when they encountered problems, they were involved in providing ideas and demonstrating solutions, as they were invested in the challenge. The teacher noted that during free-play sessions where small groups are involved, often, one student is invested in the activity and has clear ideas that they are trying to implement while another student is a bystander, often observing and sometimes even helping in smaller ways, but not really contributing to the overall activity in a meaningful way. However, worth noting here is that during the engineering challenges, students assigned a specific role or responsibility to themselves and group members and contributed to the overall engineering challenge within their designated responsibilities, all while keeping the goal of the challenge in mind. This also meant that students monitored their own work as well as that of their peers in the challenge. If a student asked for help or a peer noticed a problem with the design, they stopped to help each other and then got back to their task.

Collaboration, as described here, is a critical component of the EDP. When students work together in groups and take on certain roles and responsibilities, they simulate the actions of engineers who work collectively to solve problems or create novel solutions (Gruber-Hine, 2018). In engineering education, students are required to discuss, consider each other's ideas, and negotiate shared solutions (Cunningham & Kelly, 2017). Engineering researchers further state that collaboration is an essential intrinsic construct of engineering: "Studies of engineering practice note the importance of collaboration and the need to bring together expertise across types of knowledge" (Cunningham & Kelly, 2017, p. 7). Therefore, it was interesting to observe in this study how students came together as a group not only to ideate and create their shared solution, but also to reflect upon and improve their constructed solutions when encountering problems. Working together as a group while simultaneously breaking the challenge up into smaller tasks that each was in charge of meant that students not only had their own meaningful role to play in the challenge but also monitored and were on hand to jump in with ideas and help when problems were encountered. As the teacher also noted, it also meant that they were invested in the challenge and seeing it through until completion.

Even when faced with unexpected obstacles (for instance, if a structure fell down) at least one member of the group would persevere, provide ideas for what could be done, and begin improving the creation. This would motivate others in the group to persevere and try again or try a different approach, rather than giving up and moving on to another activity. This underscores the impact that one persevering and motivating group member with a different idea or solution can have on peers. Persistence is frequently necessary for successful problem-solving. Regardless of whether a student seeks out challenges or is required to complete a difficult task, perseverance varies from student to student and can influence both academic achievement and skill development (Amari et al., 2011).

Furthermore, exploratory and open-ended activities with a focus on creative thinking and problem-solving place emphasis on students' ability to collaborate (Land, 2000; Resnick & Rosenbaum, 2013) as well as persevere (Wang et al., 2021). Studies point to the importance of perseverance on young students' engagement in exploratory and open-ended activities, arguing that it not only advances and sustains students' interest and engagement but also constitutes a critical part of exploratory early STEM activities (Gomes et al,, 2018; Wang et al., 2021). In such activities, students have to continually reassess their goals, explore new paths, and imagine new possibilities, as a result of which they inevitably engage in a process of trial and error and have to persevere through initial missteps (Tissenbaum, 2020).

Interestingly, in the current study, when even one student persevered while encountering problems in the engineering challenges, it had an impact on the rest of the group members. They would feel motivated to try again, as witnessed in EC1. However, the role of peer interactions during exploratory, open-ended activities in supporting students to persevere is underreported. When thinking about students in the classroom who become easily frustrated when encountering obstacles and are known to give up soon, the implications for this type of support and motivation that a persevering group member can provide as well as its potential impact on how students pick back up and continue working together to complete the activity are significant. One study (Tissenbaum, 2020) has explored the role that peer interactions play in supporting students' perseverance and productive engagement in STEM-based open-ended activities. In describing their findings, the authors emphasize the importance of making the work of others visible. In other words, the ability to see the work of others allowed students to reflect on what they were doing and ask new questions of themselves or others. In some cases, this was all the student needed to get "unstuck" (p. 10). In other cases, this became the launching off point for more detailed inquiry and collaboration between students. In examining the types of interactions that led to "trying again," the authors describe interactions where joint attention and making suggestions, direct explanations, as well as where the student would observe what the persevering student was doing and borrow materials from them to try again as most prevalent when students encountered obstacles and needed assistance. This reinforces the importance of making the work of others (specifically, the persevering student) visible in order to assist students in comparing and contrasting their work to that of the persevering student, tackle the obstacle, and try out a new/different approach. Such a finding highlights the value of having even one persevering student as a peer model in a small group.

However, this is only an initial attempt at exploring how making students' perseverance and ideas visible opens new avenues for collaboration and supports other students to persevere. The descriptive nature of the study demonstrates the novelty of this area of research and underscores the need for further research that not only identifies the unique peer interactions and collaboration that unfold during such activities, but also offers implications and suggestions for future open-ended activities. How students would respond to unexpected obstacles, and especially, what kinds of support or strategies help them pick up where they left off and try again or try a different approach is worth investigating.

<u>Precursor to Collaboration</u>

As described earlier, within this pattern of peer interactions, individual students worked on their designs while other students either popped in to ask what the student was doing and if they could help, and/or contributed by bringing more materials over or helping to build. They stayed for a further period of time and added their own ideas and then left for another activity. This is in line with previous studies that have investigated instances of engineering and the ways in which children construct and communicate their designs (Bagiati, 2011; Brophy & Evangelou, 2007), which noted instances of problem-solving when coming across obstacles, asking and offering suggestions, and following peers' suggestions. While this type of interaction was not collaborative in the truest sense of the word, the efforts and ideas of the 'pop-in/helper' students cannot be discounted and were meaningful additions to the engineering challenge. Thus, they were 'baby steps' towards true collaboration. Interestingly, it was the 'pop-in/helper' students who often needed teacher support to approach peers in play and successfully join in their play in the classroom. As the teacher noted, it would not be realistic to expect the 'helper' students to go from where they currently are skill-wise to fully working cooperatively with peers from start to finish on a project, and in acknowledging their contributions to the engineering challenges, coined the term "baby steps" or precursors to collaboration.

This indicates that these precursor patterns of peer interactions could be intermediary steps toward collaboration and that students who often need support with social skills could progress step-by-step towards collaborative behavior. Collaboration, then, could be seen as being on a spectrum wherein students inch towards collaboration with certain indicative patterns of interactions rather than engaging in either purely collaborative interactions (as seen in the first theme) or non-collaborative patterns of interactions. These smaller indicative patterns may include – as seen in this study – observing each other's work, looking to one another for help or also offering suggestions and help, following the student's lead, and then adding their own ideas to the design. This perspective on the study's finding is in contrast with literature on preschool students' collaborative free-play and social skills interventions for students with diverse needs.

Previous studies on social skills interventions have focused on modifying deficiencies rather than building on strengths and activities of high interest and preference to develop social skills (LeGoff, 2004; Reichow & Volkmar, 2010). These interventions include direct teaching of specific social skills by way of modeling and prompting during interactive social routines (Antia et al., 1993); use of commercially available social skills training programs (Guglielmo & Tryon, 2001; Hyatt & Filler, 2007); and puppet modeling (Hundert & Houghton, 1992). Often, such interventions have either: a) focused on tier 2 systematic instruction tied to foundational skills such as sharing toys and taking turns (Antia et al., 1993; Guglielmo & Tryon, 2001; Hyatt & Filler, 2007), b) overlooked opportunities to generalize social skills (Leblanc & Matson, 1995; Matson et al., 1991), c) included activities and a set of actions prescribed by the teacher rather than activities of interest or preference to the students (Brown et al., 2001; Odom et al., 1999).

Such direct teaching interventions often make use of strategies such as teacher reinforcement (Guglielmo & Tryon, 2001), immediate feedback, prompts, and praise (Hundert & Houghton, 1992) in activities prescribed by the practitioner rather than following children's interests and observing their interactions in an activity that is of interest to them and which does not contain a set of prescribed actions. This literature, therefore, is in direct contrast with the findings in the current study, specifically the precursor patterns described here, in that they are limited to a set of activities and contexts in which the social skills can be observed. In contrast, the engineering challenges here placed students' interests and questions at the center of the activity and focused on their collaborative and problem-solving efforts. The precursor patterns of interactions described in the current study provide insight into how students needing support engaged in the engineering challenges with their peers. In not prescribing a goal or set of actions, the challenges allowed students more freedom in directing the path of their collaborative and problem-solving work. This not only leant authenticity to students' work and social interactions during the engineering challenges but also provided opportunities to observe interactions as they occur spontanesouly, thereby providing better chances of generalizing skills to other activities and areas of the classroom.

The importance of the precursor patterns of peer interactions becomes even more evident when considering the teacher's observations of how often activities are not truly collaborative: one student has strong ideas for how to proceed with the activity and is implementing these ideas, while his peer who needs support to join in and work together with him is merely a bystander, observing. At best, this peer would provide a suggestion or two, but not really be involved in the activity. Research on preschool social-emotional development and social skills interventions have extensively studied preschool free-play, and specifically peer interactions among students with diverse needs (e.g., commercially available social skills training programs: Guglielmo & Tryon, 2001; Hyatt & Filler, 2007; puppet modeling: Hundert & Houghton, 1992; direct teaching by way of modeling and prompting during interactive social routines: Antia et al., 1993). However, there are certain caveats concerning their findings. They often target a specific set of interactions limited to foundational social skills such as play initiations and turn-taking while overlooking more complex peer-related skills such as collaboration.

Such interventions are also often implemented during activities or environments chosen by the teacher rather than engaging students in activities of their interest or preference; and involve systematic direct instruction while overlooking provision of nurturing social environments to support generalization of a variety of peer-related social skills. Even LEGO play interventions, which utilizes a more naturalistic approach to student-driven collaborative work in completing a LEGO model, are limited in their ability to generalize findings, since they are restricted to the construction of a specific LEGO model and are found to vary greatly in length, duration, number of sessions, and delivery format (Lindsay et al., 2017). Students, especially those with diverse needs and requiring teacher support, receive limited opportunities to participate in activities that place their interests, ideas, and questions at the center, and which require them to use their creativity, critical thinking and problem-solving skills while working with peers (LeGoff, 2004; Reichow & Volkmar, 2010). Considering that preschool students are observed to have more social interactions when they are engaged in preferred activities (Koegel et al., 1987) and the naturally occurring opportunities for collaboration during engineering (Cunningham & Kelly, 2017), these engineering challenges provide insight into how students approached and began working together. Specifically, the contributions of students needing teacher support toward the engineering challenges in the form of the above precursor interactions demonstrates what ‘working together’ looks like.

As explained above, while it is not realistic to expect these students to move from not working together to fully collaborating with peers on activities, engineering challenges such as the ones implemented in this study provide a meaningful context and space for students to demonstrate their thinking and to work together. In such open-ended activities, students continually reassess their goals, explore new paths, and in the process, imagine new possibilities (Resnick & Rosenbaum, 2013). Such hands-on activities, while being acknowledged to provide opportunities for students to engage in disciplinarily authentic engineering and science practices (Berland et al., 2013; Lamers et al., 2013; Lyons et al., 2015), also encourage students to explore content/skills/building together (Peppler et al., 2016). The opportunities during open-ended activities for making students' thinking and exploration visible and for immediate feedback support collaboration and group discussion (Evans et al., 2016; Means, 2018; Yoon et al., 2012).

Since the emphasis in these engineering challenges was on *how* students worked together in solving the design problem rather than *what* the solution was, it meant that students could direct the path that these challenges took. This provided naturalistic scenarios in which students were observed offering suggestions, and beginning to demonstrate their ideas using materials provided, following the lead of another student and later adding their own ideas, and helping to build the creation.

Equally important here was the role of the teacher in supporting students to ask each other help, offering suggestions and demonstrating ideas, or to join the activity. Whether it was in helping a student approach a peer working on a design or in encouraging a student to ask for help from peers at the station, the teacher's role in these interactions supported students in moving away from individual work towards engaging in these precursor patterns of collaboration. This aligns with research on the teacher's role in developing children's play. The teacher's involvement in play interactions can increase the frequency, duration, and complexity of children's play (McAfee & Leong, 2010).

In providing such suggestions and encouragement, the teacher did not "give away the answers" to how to proceed with the engineering challenge, nor did she instruct students as to what to do next. This leant further authenticity to how students approached and worked with one another. In phrasing them as open-ended questions and "I wonder…" statements the teacher prompted students to not only view each other as friends/resources to rely on and seek each other out, but also continue working on the challenge. This was especially important as there were moments when students were stuck and unsure on how to proceed but also had not thought of approaching a peer or the teacher herself for help. In thinking about discourse during science and engineering learning and how meaningful discussions can be supported and further encouraged, studies have identified certain features of productive interactions including asking students open-ended questions, which includes questioning that promotes reasoning as opposed to directly explaining or 'teaching' the students (Alexander, 2006). Classrooms that generate productive interactions also seem to foster a supportive and confident culture around classroom talk where students' wrong answers are treated as a way into understanding, their ideas are received and questions (both among teachers and students) used to seek clarification, elaboration, or alternative ideas and to challenge thinking and reasoning (Erdogan & Campbell, 2008; Koufetta-Menicou & Scaife, 2000). In this manner, questions and discussions during activities become dialogic and cumulative. Teachers' use of both open-ended questions to encourage students to "present a range of ideas" (Erdogan & Campbell, 2008, p.4) as well as follow-up questions to seek clarification of ideas and alternative ideas for consideration supports students to collectively make sense of ideas, elaborate, and clarify meanings on the social plane. Therefore, the teacher's role in the current study was a balancing act of knowing where and how to push with suggestions or questions but equally, knowing when to step back and allowing students to work together and complete the challenge.

Nature of Materials Provided

The variety of and manner in which open-ended materials were set up at the stations attracted and drew students who typically did not participate in such activities to the station. For example, when the block area was set up with not only blocks and ramps but also various loose parts and recyclable materials, more students were drawn to the block area and began ideating and creating their designs. In acknowledging the different types of play that students participated in across the classroom, the teacher pointed out how some students almost never ventured into the block area nor engaged in construction activities. However, after the block area was set up with additional materials and the teacher invited students to explore and also bring over materials from other areas, students who ordinarily would never come to the block area were observed not only approaching but also staying for an extended period of time while creating their design. It allowed students the opportunity to "show what they are capable of skill-wise" (TI4).

Not only were these students more drawn to the block area during these challenges but they also began creating elaborate pretend-play scenarios involving their preferred items of play and creations. For example, a challenge of huge interest to the students was building a house for toy animals. Students who usually were not interested in engineering-related play invitations in the classroom became more interested as the days went on and as the teacher incorporated different materials into the area. These students were observed to be more invested in the engineering challenge when there was a clear purpose for their creation. For example, students built houses using a variety of open-ended materials, and then used these houses in their pretend-play scenarios with the toy animals. Similarly, a group of students began building houses for their toy cars, and once this was complete, engaged in an elaborate pretend-play sequence racing with the cars around their 'neighborhood'. This is consistent with previous research on preschool cooperative play which found that preschool students are more likely to stay engaged with a problem when they have chosen an activity that interests them and when they establish the goal of their activity (Moyles et al. 1989; Verba, 1993). Specifically, activities that are flexible in terms of both the problem and solutions (Ramani, 2005). The flexibility of such activities provides opportunities for students to explore, develop, and discover solutions to a problem that they are invested in. Additionally, studies suggest that during play, preschool students are active in their manipulations and exploration of objects, problems and possible solutions (Garvey, 1990). Even students' pretend play involves active engagement with objects, as well as physically acting out pretend themes (Howes et al., 1992; Verba, 1993). Exploration with open-ended materials may thus provide students with opportunities to not only engage with peers in activities of their choosing but also to suggest novel solutions to problems (Pepler & Ross, 1981; Vanderburg, 1980).

Another benefit of using a variety of materials may be unlikely peer pairings (students who are not each other's preferred play partners were observed working together on engineering challenges). The open-ended nature of the challenges and materials placed students' ideas and suggestions centerstage rather than setting a specific task or activity by the teacher. This invited students to come together, ideate, provide suggestions, and problem-solve while building their creations, regardless of their preferences for other types of play. The open-ended nature and flexibility of such challenges provided opportunities for students to explore and develop solutions to problems they were invested in, regardless of who (preferred play partner or not) was at the engineering station. In placing emphasis on students' ideas and problem-solving rather than on simply playing together with friends during the free-play sessions, it provided the platform for students to come together and work on shared ideas.

Summary

While engaging in the EDP, students have to verbally communicate with each other. This can take on various forms whether it be to ask questions about the problem, brainstorm ideas and explore materials, share materials, make predictions, collaborate in creating and testing solutions, and evaluating the solutions. It is different from other activities (and also from social skills interventions highlighted earlier) in that engineering challenges do not have specific short-term goals or target a narrow set of social skills through an intervention. Rather, engineering provides a meaningful context to a design problem while leaving the problem-solving process and solution open-ended. The nature of these engineering challenges, in emphasizing students' ideas and their approach to ideating and problem-solving rather than placing importance on the solution itself or teacher's ideas, meant that it provided a platform for students to come together to discuss, demonstrate, and create their solutions. As a result, authentic interactions between students were recorded as they came together to discuss and demonstrate ideas for designs rather than simply because they were friends or preferred play partners.

Therefore, in providing these naturalistic scenarios, materials, and teacher support (where needed), the engineering challenges and the interactions seen between students - particularly those who needed teacher support – demonstrate the possibilities for rich, authentic experiences that go beyond a narrow range of social behaviors. Because of the naturally embedded opportunities for working together and the range in open-ended materials provided, students (even those who are not each other's preferred play partners) began approaching one another and worked together. Previously, some of the students would not venture into the block area or engineering stations. But when the avenue to participate in meaningful design challenges and a variety of open-ended materials were provided along with the appropriate amount of teacher support, students (even those who would not participate earlier) joined in. Simply because they were not at the stage where they can engage in cooperative play successfully, it did not mean that students could not join in and participate in the challenges. Rather, when provided with the opportunity, time and support to engage in such challenges, students were not only enthusiastic about their ideas but also expanded on them and continued to use their designed creations during free-play in meaningful ways.

Implications and Recommendations for Future Research

This study lends perspective on how students engage in preschool engineering activities. Crucially, given the support that students with diverse needs require to successfully engage in social interactions and the scope that engineering activities provide for collaboration and problem-solving together, these findings shed light on students' collaborative and problem-solving efforts in activities driven by them, not the teacher. Given the limited opportunities students with diverse needs receive to engage in inquiry-driven activities that follow from their interests and ideas, these findings provide a glimpse into what their participation in such activities looks like. Because there is not much research on preschool engineering and students' participation in it, let alone what participation for students with diverse needs looks like, this study was exploratory in nature. However, this is a field in its nascent stages and a considerable amount of research is yet required to ascertain how students with diverse needs engage in this space, what supports they need, the teacher's role, and more. Below, I enumerate some implications from these results as well as recommendations for future directions.

First, it is important to keep in mind that this is a developing field of research. As more studies are conducted, more knowledge on preschool engineering, student participation, and teacher roles will be unearthed. Nonetheless, this study provided insight into how students – especially those requiring teacher support – approach and participate in this space. However, it should be noted that this study was not conducted with preschool students who have diagnosed disabilities and were receiving services through an IEP, although some students required everyday teacher support and strategies to navigate social situations and cooperative play in the classroom. The review of the literature on preschool students and social skills (and personal conversations with preschool teachers, including the teacher in this study) revealed that the trajectory of preschool students' social skill development varies greatly irrespective of whether or not they are being assessed for and are receiving special education services. Often, certain students require teacher support navigating social situations and interacting with peers – for instance, initiating and sustaining collaborative play, expressing ideas and feelings appropriately, or resolving conflict. These students would not necessarily receive special education services but still require teacher attention and support above and beyond what is normally given to all students during classroom routines and activities. Even in the current study, the teacher identified students who needed this level of support and how she normally stepped in to provide support, despite these students not having IEPs.

Nevertheless, in thinking about students with disabilities, the types of interventions that have been designed to address their areas of need, and how most interventions target a narrow set of social skills while overlooking the social skills studied here, it would be important to investigate what their engagement in similar inquiry-rich engineering activities looks like. Preschool students with disabilities receive limited opportunities to participate in activities that place their interests, ideas, and questions at the center, and which require them to use their creativity, critical thinking and problem-solving skills while working with peers (LeGoff, 2004; Reichow & Volkmar, 2010).

Therefore, it would be worth investigating how students with disabilities can access and meaningfully participate in engineering and, broadly speaking, inquiry-driven activities. Specifically, what supports do they need in order to meaningfully participate? Consider the example of a student with autism who needs support with social interactions but also in navigating different areas of the classroom. What type of strategies could best support this student in not only approaching peers in this space but also in providing his ideas and demonstrating his suggestions (as is frequently needed in engineering)? Further consider the example of a second student who has challenges in self-regulation. Could a peer model such as the student from EC1 known to persevere and be a ‘cheerleader’ be a good choice for placing in a pair/small-group with this student? While the possibilities seem endless, designing similar activities in the future and engaging students with disabilities in them requires careful thought and planning, keeping in mind: a) areas they are known to need support with, b) their peers, c) the type of materials, and d) the environment.

Bearing in mind the scope for collaboration during the engineering challenges, it would also be worth considering how social skills – particularly peer-related skills – can be promoted during engagement in engineering activities. Students with disabilities have specific IEP goals often connected to social-emotional development and expressive communication. Could engineering activities be planned and implemented in a manner that intentionally targets these goals and gives students the platform to practice such communication? Considering the meaningful contexts that engineering challenges provided to students' problem-solving and the scope for directing the course of the activity, there are many opportunities to practice the kind of skills that students have IEP goals for.

A second area that could be fruitful for future explorations is that of precursor patterns to collaboration and the notion that collaboration, rather than being binary, exists on a spectrum. Students who needed teacher support did not automatically go from working individually to working collaboratively with their peers to solve the engineering challenges. They were observed engaging in 'baby steps' toward full collaboration, such as observing one another's work and making suggestions, asking for or offering help, and popping in and out. When considering students with disabilities who have IEP goals for social and communication skills, a topic worth investigating is not only how they participate in engineering activities but also whether they 'inch towards' full collaboration;

more generally, what their 'baby steps' towards full collaboration look like. If engineering activities truly promote social skill development, then a potent area for study is if and how social skills of students with disabilities improve, or what the trajectory of change in their social-emotional development may look like.

Seeing engineering through the teacher's eyes, it is also interesting to think about how much detail and insight such activities provide the teacher on students' skill-sets. As the teacher remarked during interviews, these activities gave students "a chance to show what they are capable of, skill-wise" and were particularly valuable in shedding light on how students who have not played much in the block area or with similar materials in previous engineering challenges approached this space. While numerous learning categories are identified within engineering, including skills such as identifying a need, defining a problem to solve, understanding constraints, identifying alternative solutions and analyzing outcomes, learning by brainstorming and prototyping, dialoguing with people and learning from reflection (Mosborg et al., 2005), of prime interest here is the opportunity to learn by dialoguing with others, by brainstorming and prototyping, and by noticing, iterating, and troubleshooting: in essence, the opportunities to collaborate and problem-solve with peers. Given that engineering activities provide insight into the other learning outcomes mentioned above, they also provide rich perspective on students' social-emotional skillset – specifically, where students currently stand in terms of their strengths and areas of need. Recall that a few of the codes used to analyze video clips (persevering and motivating others, as well as offering suggestions) were not originally included in the coding schema. However, they were patterns of behavior that were observed and described by the teacher during interviews. In fact, in describing these patterns, the teacher remarked that she did not expect to see such interactions during engineering activities, but that they “stood out”, especially among students who did not typically engage in such activities or in the block area. This implies there is still a great deal that the teacher can learn about the students’ capabilities, strengths, and areas in which she can step in to support. The engineering activities provided students the space to not only work alongside each other, but in not prescribing an end ‘goal’ or outcome, left the problem-solving process and solution to the students. This meant that students’ engagement with one another as they solved design problems took a myriad of directions, as a result of which the scope for social communication included, but was not limited to, discussion, demonstration, and negotiation. In a manner of speaking, engineering provided an empty canvas on which students came together, asked questions, discussed ideas back and forth, tested and reflected on solutions, and helped one another. These are patterns of behavior and communication which might not ordinarily have been seen in other classroom areas. Such observations could not only provide insight into students’ skills, but also assist the teacher in planning for future activities as well as supports to facilitate peer interactions and participation.

Ultimately, all of the above directions for future research must be considered alongside the teacher’s role in planning and implementing engineering activities as well as their perspectives on student participation in the EDP. This goes beyond identifying students’ interests and planning specific activities to include mindfully designing engineering challenges, keeping in mind students’ skillset and areas of need, and careful monitoring of student engagement in the EDP. The teacher’s use of open-ended questions and suggestions in this study propelled students’ collaborative work, especially the kind of work observed during precursor patterns to collaboration. However, it did require careful consideration of: a) which student was at the station as well as the dynamics of their peer interactions in the classroom, and b) the engineering challenge and knowing what students were capable of to meet that challenge. Even then, as the teacher acknowledged, it was a balancing act wherein she had to gauge just how much support to provide, where and how to step in but also when to stand back and allow students to “figure things out”. The teacher dove into and further discussed her role in these activities during unstructured interviews; however, reflections on her role and where she felt she could make adjustments to activities and teaching strategies go beyond the scope of this study. Nonetheless, these reflections were an interesting aspect of the data collected that could be built upon in future studies. What is this ‘balancing act’ that teachers play in such activities and how can teachers prepare for it? Follow-ups from this reflection could look at what the teacher learned from this process, what she would change or adjust for implementation of future activities, and what other teachers can learn from such reflections before engaging in such a space themselves.

Conclusion

As explained in the rationale for and problem statement of this study, young children with or at-risk for disabilities may display a unique trajectory of social skills development. Preschool children with or at risk for disabilities are found to engage in interactive social play with peers less frequently than children who are chronologically younger but have similar cognitive skills (Guralnick & Weinhouse, 1984). Lack of reciprocal play as observed in children with or at risk for disabilities during the early childhood years is likely to continue to be an issue in elementary and middle school years

(Guralnick et al., 2007; Sigman & Ruskin, 1999). A variety of interventions have been designed to support these students, such as direct teaching of specific social skills by way of modeling and prompting during interactive social routines (Antia et al., 1993); use of commercially available social skills training programs (Guglielmo & Tryon, 2001; Hyatt & Filler, 2007); and puppet modeling (Hundert & Houghton, 1992); however, they target foundational skills such as inviting peers to play and taking turns with toys (LeGoff, 2004; Reichow & Volkmar, 2010), leaving a gap in the research on more complex peer-related social skills such as collaboration and problem-solving.

The EDP is a cyclical method that students follow to collectively build a solution to a problem. Engineering encompasses hands-on activity, inquiry, teamwork, and other instructional practices that develop children's twenty-first century skills, including critical thinking, communication, collaboration, and creativity (Lachapelle & Cunningham, 2014). While engaging in the EDP, students have to verbally communicate with each other. This can take on various forms whether it be to ask questions about the problem, collaborate in brainstorming ideas and exploring materials, sharing materials, making predictions, collaborating in creating and testing solutions, and evaluating the solutions. Thus, the EDP contains immense potential for collaboration and problem-solving, the kind of peer-related social skills that preschool students with or at risk for disabilities require support in.

A major reason that engineering activities were chosen as the medium of study was due to the scope for naturalistic scenarios in which students can collaborate while not being tied to a specific short-term goal. In not prescribing a goal or set of actions, the activities allowed students more freedom in directing the path of their collaborative and problem-solving work. This provided opportunities to observe interactions as they occur spontaneously, thereby providing more scope for generalizability of peer-related social skills to other activities and areas of the classroom. Consider the example of students designing a house for toy animals at the station. While students share a goal of designing and building a house, the activity, unlike an intervention, does not prescribe or instruct students on how or what to do (i.e. in building the house). Being an open-ended activity, emphasis is placed on students' questions, collaborations, and problem-solving, as well as how they work together to create the house. In contrast to the social skills interventions traditionally used, it did not lay out a model to follow or limit students' interactions to a narrow set of behaviors. Rather, the emphasis was on students' interactions with each other and how they worked together to progress through the steps of the EDP and solve the design problem.

Taking into consideration the high number of studies that investigate systematic direct instruction for students with disabilities while overlooking the provision of nurturing social environments to support generalization of a variety of peer-related social skills (i.e. not limited to specific skills such as greeting a peer or sharing a toy), this study was a first step in the research on students' peer interactions (going beyond foundational peer-related interactions) on activities of mutual interest, as opposed to teacher-directed. In exploring the nature of peer interactions during engineering challenges, the study revealed two distinct patterns of interactions: a) collaboration and working within assigned responsibilities, and b) precursor patterns to collaboration, which students needing teacher support often displayed. Even students who typically did not participate in such activities were observed being drawn to the station and trying out their ideas. The role of the teacher and nature of materials provided and its impact on the type of interactions observed, while not the focus of this study, were also features of interest.

These findings, while a first step in the research on preschool engineering and collaborative work, provide insight into what engagement in engineering activities for preschool students with diverse needs looks like. Crucially, given the support that students with diverse needs require to successfully engage in social interactions and the scope that engineering activities provide for collaboration and problem-solving together, these findings shed light on students' collaborative and problem-solving efforts in activities driven by them, not the teacher. Importantly, the engineering station was open to all students, not only the ones who frequented it and preferred playing in it. When the environment and materials were set up, and the teacher support and the avenue to participate were provided, students regardless of their needs were found engaging in this space. Their engagement went beyond mere observations of their peers' work to include meaningfully participating in the activities, albeit in different ways. This highlights students' propensity for similar student inquiry-driven activities: students are enthusiastic about their ideas and try them out, but it is a matter of providing the appropriate opportunities, supports, and space for them.

Given the limited opportunities students with disabilities receive to engage in similar inquiry-driven activities that follow from their interests and ideas, future studies can shed light on their engagement in such activities, areas of need, as well as the role of the teacher in not only designing and implementing these activities, but also in monitoring students' work, scaffolding and providing other supports as needed, and in documenting students' work and learning trajectory. As a first step, this exploratory study provides insight into students' collaborative work during engineering activities. But it is only the first step in understanding the nature of students' work and interactions during open-ended, inquiry-rich activities. To better understand how students with disabilities engage in this space and how to support them in meaningfully participating in such activities will require further extensive studies.

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APPENDIX A

Codebook for Video Clips

Codebook for steps of the Engineering Design Process (EDP)

Date Observed:
Total Time Observed (minutes):
Learning Environment:
Materials used:
Number of peers:
Notes about environment, set up, what students were doing:

The following practices are in relation to the steps of the EDP: ask, explore, create, and improve. Each practice is viewed as part of the larger picture, i.e. the design problem that students are trying to solve and the four steps of the EDP and thought of in connection to the next step.

a. Asking a question: to ask a question about the engineering problem at hand and identify constraints. While students ask teachers and peers questions during play, asking a question here is related to the engineering activity and identifying the problem that students have to solve. In a scenario where the teacher presents a problem to students, or prompts students to identify a problem and constraints, that will also be documented here.

   Example: after reading the story 'The Three Little Pigs', students identify a problem scenario based on the story by asking, "Why did the pig's house fall down?", identifying the reasons why (i.e. because it was built using materials like twigs which are not sturdy), and defining a problem to solve based on the question, i.e. we need to build a house strong enough that it will not fall down. Essential to asking a question here is that an engineering problem has been identified to be solved (by either the teacher or students).

   Non-example: During free play, a student says, "I'm going to build a house for my bear" and a peer asks, "what are you going to use?" (while this is a question, it is not related to any engineering problem per se).

b. Explore: once a design problem has been identified by asking questions (above), students explore and discuss with materials available to consider what to use in creating a solution and make a plan. Students may sketch designs to communicate their ideas or demonstrate with materials; students gather materials to begin creating the solution.

   Example: students identify and gather shoe boxes, egg cartons, tape and glue to build a strong house as needed to solve the problem. While doing so, they may discuss what kinds of materials should be used and for what purpose: a student may suggest fabric for the house, while another student states that that would be better for making a bed because it is soft.

Non-example: a student is building a house for his bear. To do this, he is collecting blocks from the block area and begins stacking one on top of the other. (there is no engineering problem to solve here and the student does not have to consider what materials to use or make a plan)

c. Create: students carry out the plan to create a solution using materials gathered during the previous step. Once completed, students test it out to see how it works.

   Example: once students have a plan to build a house and materials ready after exploring in the previous step, they begin building the house using those materials. When complete, students test their house to determine if it could withstand strong winds (using a fan to simulate wind)

   Non-example: a student is building a house for his bear in the block area. Once complete, he proceeds to play with the completed structure and toys. (this is different from 'Create' with relation to the EDP because the student is not creating a solution to solve a particular design problem, he is creating a house to play with. Once he has finished, he does not test it out to see if it works).

d. Improve: students reflect on testing results by discussing what happened when they tested their creation (meant for solving the design problem) and what could be done to make it better. If it did not work, students discuss alternate solutions. Based on these discussions, students then plan for, gather materials needed, and either: tweak the existing design or create a new solution. They then test the improved design.

   Example: after building a house and testing it to see if it can withstand strong winds, students found that while it did not fall down, it swayed a lot. They discuss what to do and decide to reinforce the structure with tape and glue and test it out again. This time, they find that the house stood strong. (the emphasis here is on solving the design problem by improving on the previous design and testing again to ensure that there is a workable solution).

   Non-example: a student builds a house but finds that it keeps falling once it reaches a certain height. The student picks up other materials and builds something new.

<u>Codebook for social interactions</u>

Code name and operational definitions:

a. Collaboration: two or more students working towards a shared goal (i.e. solving the design problem).
   i. Asking and responding to questions: Student asks or answers a question related to the design problem at hand

      Example: a student asks, "what should we use to build a strong house?" or a student responds to this question stating, "we need cardboard to make it stand"

Non-example: while building a house, a student says, "I can't make it stand, what should I use?" (this is tied to problem-solving when encountering an obstacle)

ii. Explanation: Student explains an idea or a prediction of what might happen when exploring materials to come up with an idea to solve a design problem, or when reflecting on test results after testing a solution to explain what could be done to improve the solution, or to plan for and create an alternate/improved solution

Example: while constructing a tower, the student says, "if we add to it, it will fall down"

Non-example: student says, "I'm going to build a tower" but this is not related to a problem scenario as relevant to the EDP: the student is building a tower for play, not with the goal of solving a design problem with peers.

iii. Brainstorm: a student (along with a peer) or a group of students spontaneously generate a set of ideas to find a solution to the design problem.

Example: having identified a design problem (to build a strong house) and explored materials, one of the students in the group says, "let's use cotton for the house". His peer states, "no, cotton is soft, we can use it to make the beds. We need something strong"

Non-example: having identified a design problem and explored materials, a student proceeds to create the solution based on his idea.

iv. Demonstrate: Student actively shows peer how to use materials to create a solution to the design problem (while exploring materials) or actively shows how the designed solution works when testing it out.

Example: when exploring materials to build a house (to solve a design problem), a student uses recyclable materials to show how they can be used to create a roof for the house.

Non-example: when exploring materials to build a house, a student gathers recyclable materials to build it, and a peer who happens to be near by is observing him.

b. Problem-solving: Student asks for help or a suggestion in relation to the design problem that the group is trying to solve/Student offers a suggestion in response to a peer's question or request for help/Student follows a peer's suggestion or demonstration. These are in the context of the design problem that the group is working on.

Example: while building a tower together as a group either of the scenarios falls under problem-solving: a) one of the students says, "I can't make it stand" (needs a suggestion); b) one of the students says, "no it needs something at the bottom to make it stronger" (offering a suggestion); c) one of the student says, "let's make the tower stronger" (following a peer's suggestion)

Non-example: while building a tower by him/herself, the student says, "this keeps falling down" but is not working collaboratively with a peer to problem-solve what to do; the student is building a tower for play purposes rather than to solve a design problem using the EDP.

c. Independent work (in relation to the design problem that students have to use EDP for):
    i. Investigate: Student is using materials to create a solution to the design problem (but this is an individual effort)
        Example: the student is using blocks to build a bridge by himself to solve a design problem.
        Non-example: a student playing with or using the finished product in play (e.g. playing with the bridge that has already been constructed).
    ii. Problem-solving: Student is independently trying to problem-solve a way out when stuck while creating a solution.
        Example: while building a bridge, the student is stuck but persists in trying to problem-solve a way out (i.e. by adjusting the construction so that it does not fall) or says, "this keeps falling, I can't make it stand"
        Non-example: while building a bridge, the student is faced with construction problems and leaves it to play with something else.

d. Teacher-student interaction: Student's attention and actions are directly focused on the teacher (this may be in attempt to converse with the teacher during the engineering activity, to show the teacher what he/she is exploring or creating, or to obtain assistance from the teacher. This includes watching and/or listening as the teacher asks a question, explains or demonstrates.
    Example: a student is using the fan he just created out of loose parts to demonstrate to the teacher how much wind it generates; a student answers a teacher's questions about materials he used to build a house.
    Non-example: two students are playing at the sensory table (but this is unrelated to the design problem at hand) and a teacher comes over and remarks, "I see you're playing with the soap and water in the sensory area!"

APPENDIX B

Semi-Structured Interview protocol

This interview protocol was used for the semi-structured teacher interview prior to beginning engineering challenges in the classroom.

Date and time of interview:
Place:

1. What are the areas or skills that students with disabilities in your classroom need support with?
2. Can you tell me more about the students who have needs in social skills; what skillset do they need support in?
3. Can you tell me about free-play sessions in the classroom before implementation of the engineering challenges: what it looks like; when and how do students interact? (note: this is to paint a picture of what student interactions already look like prior to the study, and what, if any, collaboration used to occur, rather than to compare students' interactions before and after implementing the study)

This interview protocol was used for the semi-structured teacher interview after completion of all engineering challenges.

Date and time of interview:
Place:

1. How have students responded to the engineering challenges and participating in the EDP?
2. What have you observed since implementing engineering activities in your classroom in terms of student interactions with one another while engaging in the EDP?
3. At which stage in the EDP did you feel most student interactions occurred and what did you observe during these stages?
4. Can you tell me more about students' interactions during the EDP, with examples, in terms of: a) collaborations; and b) problem-solving between students with and without disabilities.
5. Which aspect of the design process do you feel students struggled with most? Can you tell me more about what you noticed.
6. During the EDP, did you intervene to facilitate student interactions/students working together? At which point in the EDP did this happen and can you tell me more about what the student(s) needed help with?

APPENDIX C

Unstructured Interview Protocol

This interview protocol was used for unstructured interviews with the teacher at the end of each week of data collection.

1. How have students responded to the EDP in this week's engineering activity?
2. What have you observed during students' engagement in the EDP in terms of interactions and working together while following the steps of the EDP?
3. At any point did you have to intervene to facilitate student interactions? Can you tell me more about what happened?

APPENDIX D

Vignette for Unstructured Interview

On Wednesday morning I noticed WL and TA in the block area. TA was building his creation and WL was working on his. Both were building ramps for their own mazes. After a while, WL was concerned that he did not have sufficient space for his maze and was trying to communicate with TA about this. He said, “TA, you’re blocking my space” but TA did not notice. You went over and discussed with them how they could both use the space and materials provided to build a maze together. You also talked about how they worked together yesterday and tested out marbles on the block creations.

Can you tell me more about what they did with the marbles, and what did you notice? How did you encourage them to work together on the creation? How did the marbles come into this equation: did they already have an idea to use marbles or was it your suggestion?

APPENDIX E

Transcription Conventions

Adapted from Mercer (2002)

1. When someone continues after an interruption this is shown as:

   Ellen: But we had someone appointed to the PTE ...

   Bill: Yeah

   Ellen: ... who was earning about the top of the lower scale.

2. Simultaneous speech is shown as:

   Peter: Ok, then I'll [go.

   Donna: [so will I.

3. Emphatic speech is shown underlined:

   Hector: Even though I <u>told</u> him

4. The location of inaudible words or passages is shown as:

   Ellen: But if (...) knows.

5. Words which are unclear or uncertain appear in parentheses:

   Alan: And (inevitably) so.

6. Gestures and other non-verbal actions are explained in italics in parantheses:

   Anne: Hah uh (*laughs*)

   Trevor: Okay (*long pause*)