The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #42847

Supporting Early Childhood Educators in Implementing and Adapting Research-based Engineering Activities Designed for Families (Fundamental, Diversity)

Dr. Gina Navoa Svarovsky, University of Notre Dame

Gina Navoa Svarovsky is the Faculty Director of the Center for Broader Impacts (CBI) at the University of Notre Dame and an Associate Professor of the Practice at Notre Dame's Center for STEM Education. For nearly two decades, she has been interested in how young people learn science and engineering in both formal and informal learning environments. Specifically, her research centers on exploring how youth and families from traditionally underrepresented populations in engineering are able to develop engineering interest, skills, knowledge, and ways of thinking as a result of engaging in authentic engineering activities within a wide range of learning contexts.

Catherine Wagner, University of Notre Dame

Catherine Wagner is a research staff member at the Center for STEM Education at the University of Notre Dame. She earned her Master of Education degree from Notre Dame in 2019 while teaching middle school science. She has collaborated with faculty in the Center for STEM on engineering research for several years, most recently leading an undergraduate research lab on early childhood engineering research. In the Center, she also supports other research projects on science pedagogy.

Mia Lettau, University of Notre Dame
Kimberly Marfo, University of Notre Dame
Scott Pattison

Scott Pattison, PhD, is a social scientist who has been studying and supporting STEM education and learning since 2003, as an educator, program and exhibit developer, evaluator, and researcher. His current work focuses on engagement, learning, and interest and identity development in free-choice and out-of-school environments, including museums, community-based organizations, and everyday settings. Dr. Pattison specializes in using qualitative and quantitative methods to investigate the processes and mechanisms of learning in naturalistic settings. He has partnered with numerous educational and community organizations across the country to support learning for diverse communities.

Smirla Ramos-Montañez
Viviana López Burgos
Amy R Corbett
Maria D. Quijano
Diana Contreras

©American Society for Engineering Education, 2024

Supporting early childhood educators in implementing and adapting research-based engineering activities designed for families (Fundamental, Diversity)

Introduction

Exploring engineering thinking and learning with young children has been an area of increasing focus for engineering educators over the past decade [1], [2]. The growing body of literature on early childhood engineering has focused on a number of key areas, such as young children's engineering thinking [3], [4], children's engagement with materials during engineering activities and play [5], [6], [7], early childhood educators' beliefs and confidence about STEM teaching and learning [8], [9], and engineering activities and curriculum within the preschool classroom [10], [11], [12], [13]. While most of these studies have been conducted within preschool contexts, an ecological, asset-based view [14], [15] of learning not only suggests that a myriad of opportunities for meaningful engineering learning exist within informal learning settings beyond the classroom [16], [17], but also that these contexts can contribute to, enhance, and inform what happens within the classroom.

In this study, we examine one example of how research-based engineering activities designed for informal learning can be leveraged for classroom use. Specifically, we explore how a set of three engineering activities, originally developed through design-based research for use by families in the home environment, can be implemented and adapted by early childhood educators within their classrooms. We also seek to better understand the array of professional supports - such as training sessions, materials, and collaboration structures - that early childhood educators find valuable when integrating engineering activities into their classrooms.

Background and Theoretical Framework

Ecological models of learning acknowledge that learning happens across the lifespan and across life's many contexts [14], [15], [18]. Bronfenbrenner's Ecological Systems Theory [14], [19] provides a useful lens to consider how an individual's development can be influenced by both proximal and distal factors in a series of nested systems - and how, over time, the impact of those systems can shift. Not surprisingly, young learners' engagement with others in the most immediate layer - the *microsystem*, which includes parents, siblings, and other close connections with whom children directly interact - have an outsized influence on their growth and development in their early years. As such, focusing on advancing our understanding of these interactions has great potential to inform early childhood education practices, activities, and techniques writ large.

To date, however, few studies in engineering education have focused on family learning. Parent-child interactions during engineering activities have been studied in museum contexts [20], [21], [22] out of school programs [23], and the home [24], [25]. These studies have shown that families with young children engage in a number of complex engineering practices [25], that different approaches and supports can be helpful in fostering engineering engagement during family interactions [26], [27], [28] that young children can develop engineering identities through these types of activities [29], [30]. Indeed, family interactions around engineering learning activities can provide rich insights and new pathways into engineering engagement for early learners, particularly when asset-based approaches [31], [32] are leveraged in order to honor, identify, and elevate the engineering happening within everyday settings.

More recent perspectives on learning ecologies call for the consideration of Bronfenbrenner's [14] nested systems to be considered more flexibly and dynamically [19] as well as further research that investigates connections across and between formal and informal learning settings [15]. At present, studies that have explored the home-school connections in STEM and engineering education highlight the ways in which parents and caregivers can engage with educators in co-constructing science and engineering activities that draw on the lived experiences of families [33], [34] and provide examples of how parents can engage with children within a teacher-facilitated setting [35]. However, there are numerous other types of home-school connections in early childhood engineering education that have yet to be examined.

Study Context

The goal of the present study is to examine one such connection by exploring how a set of three engineering activities, developed for families to use in their homes as part of a design-based research (DBR) study, could be implemented in a classroom-based early childhood learning context that is focused on supporting constructive parent-child interactions. The Research Exploring Activity Characteristics and Heuristics for Early Childhood Engineering (REACH-ECE) Project is a multi-year collaboration between the University of Notre Dame (ND), researchers from TERC, a non-profit STEM education research organization, and Metropolitan Family Service (MFS), a family-focused community organization in Portland, Oregon that provides low-income, racially, and ethnically diverse communities a wide range of family services. Within MFS, the collaborative team worked closely with early childhood educators and team members from the Ready, Set, Go! (RSG) program, which aims to support children's first educators - their parents and caregivers - by providing free, culturally-responsive programming to support kindergarten readiness and socioemotional development for preschool-aged children and younger. Specifically, the RSG program provides weekly opportunities for parent-child interaction sessions at ten different sites in their metropolitan area. Seven of the ten sites focus on providing programming for three- to five-year olds and their parents/caregivers; two of the sites focus on families with even younger children in the zero to three age range. One group of RSG educators also supports families by visiting their homes.

For clarity, Figure 1 below outlines the project team structure and the research participants for the study presented in this paper. It is important to note that the three members of the project leadership team from MFS - one who holds a senior leadership position in the organization, and two managers of the RSG program - are also included as research participants in this study. Additional details about the full set of study participants will be provided in the Methods section.

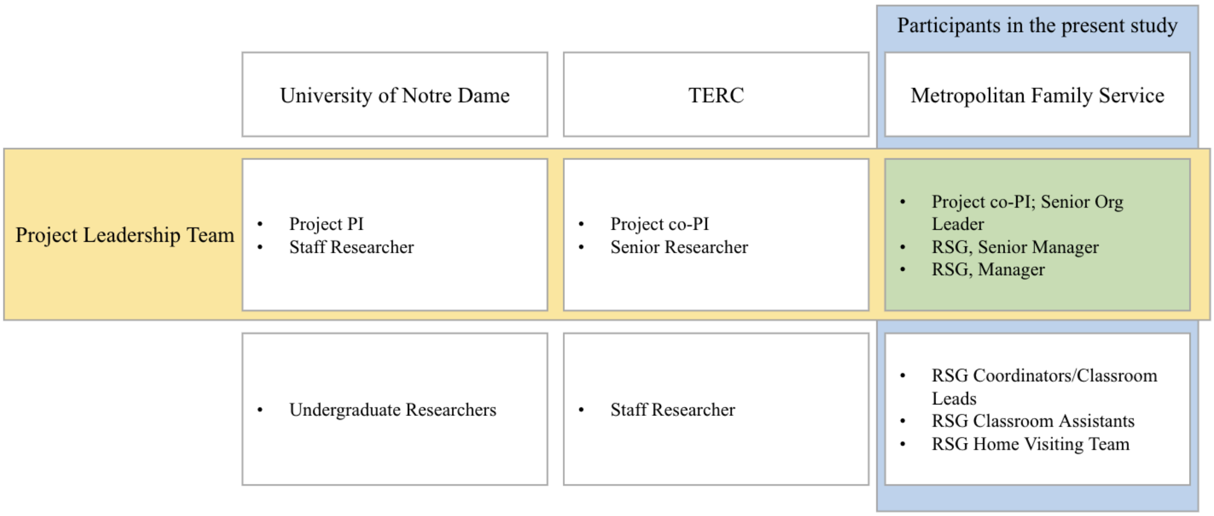

Figure 1. *Project Collaboration Structure and Relationship to Current Study Participants.*

During the earlier DBR study, a group of 15 participating families, distributed by Spanish and English language preference, were recruited with the help of the early childhood educator team at RSG. Three bilingual activities were iteratively refined over three DBR mini-cycles that took place over a six-month period. A description of these activities can be found in the Methods section below. Findings from the REACH-ECE DBR study have been presented elsewhere, describing a set of emergent design principles for family-focused, Spanish-English bilingual engineering activities for the home [36] and the engineering practices observed in videos recorded by families when using the activities for the first time [25].

In the current study, the RSG team during the 2022-2023 academic year worked together with the REACH-ECE researchers to implement and adapt the three activities from the earlier DBR study in the RSG classrooms and program activities. In order to best support the early childhood educators, the researchers worked together with the REACH-ECE team to develop a set of professional supports - including **professional development sessions**, **physical activity kit materials**, and **communication and collaboration structures** - to facilitate the use and modification of the engineering activities. Initial ideas for these educator supports were based on studies of effective teacher professional development [11], [37], [38], [39], studies of STEM-focused professional development for early childhood educators [6], [30], [33], [40], [41], and recommendations from a recent report from the National Academies entitled *Science and Engineering in Preschool Through Elementary Grades* [2].

Our specific research questions for the present study are:

- RQ1: How do the early childhood educators use and modify activities originally developed for the home context within their own classroom contexts?
- RQ2: What professional development activities, approaches, and resources did the educators find most helpful in supporting their implementation of these engineering activities within their classrooms?

Methods

Sample

Nineteen educators from RSG participated in a year-long study during the 2022-2023 academic year. Three participants, also listed as authors on this paper, hold administrative roles with RSG and were part of the project leadership team along with project researchers. The remaining 16 participants were early childhood educators interfacing with families through RSG. Educators' roles, listed in Table 1, included the "Coordinator" (lead classroom teacher), the "Classroom Assistant" (aide who supports the coordinator), the "Home Visiting Team" (educators who conduct visits to families' homes), and the "Leadership/Manager" (members also on the project team).

The participants come from a range of backgrounds with the majority of the RSG staff members identifying as bilingual (Spanish/English) and bicultural. While 35% of the participants have spent five or more years as part of RSG, the majority have spent less than five years, with 25% between two and five years, and 20% each between 1 and 2 and under a year.

At the time of the study, seven participants had been part of the REACH-ECE project and research collaboration for the entire four-year duration, and they were quite familiar with the researchers from ND and TERC. Five participants had been part of the project for two years; five had been part for a year; and two had been part for less than a year.

Table 1
Counts of Educators by Role in RSG

Role	Count	Participant ID
Leadership/Manager	3	M1, M2, M3
Coordinator	7	C1*, C2*, C3, C4, C5, C6, C7
Classroom Assistant	7	A1*, A2*, A3, A4, A5, A6, A7
Home Visiting Team	2	H1, H2

Note: (*) denotes members of the two case study sites.

Data Collection

During the 2022-2023 academic year, the four researchers delivered one in-person and two virtual professional development (PD) sessions, which focused on both advancing engineering understanding as well as introducing the DBR-developed engineering activities. During each PD session, participants were provided an interactive slidedeck to begin brainstorming with other educators at their site for ways to incorporate the given session's activity into different areas and activities of their classroom (e.g., the block area, the water table area, opening circle time when stories are often read), introduce it to families, adapt the design challenge or prompts, and enhance it with their classroom materials. Participants were given opportunities to engage in discussions with the project team and one another about engineering with young children and share what they saw in their classrooms or on home visits.

Each PD session introduced a different engineering activity and was followed by a four- to six-week activity implementation period. During the implementation period, the participants were asked to use and adapt the engineering activities as much or as little as they desired. The three engineering activities - ***Pollitos***, ***Doggies***, and ***Tacos***, described in the next section) - included a book, a preliminary set of materials (such as craft materials), and a suggested design challenge. These activities were adapted from the final iterations of three activities distributed to families of the program the year before as part of the earlier DBR study. An abbreviated project timeline is presented in Figure 2 below.

2022-2023	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**		**Apr**	**May**
Engineering Activity	***Pollitos***			***Doggies***			***Tacos***		
PD & Implementation	In-person PD	Kit used in classroom		Virtual PD	Kit used in classroom		Virtual PD	Kit used in classroom	
Data Collection		Case Study Visits	Survey		Case Study Visits	Survey		Case Study Visits	Survey & EOY Interviews

Figure 2. *Project Timeline.*

Surveys were collected from participants at the end of each implementation period via Qualtrics. Survey questions included open-ended responses about the frequency and use of the engineering activities in the classroom or home visits, descriptions of how educators saw engineering happening, their views on engineering and their own classroom approaches, and parts of the project that have helped the ways they have brought engineering into their classroom or home visit. Surveys also included a scaled response question of educators' current levels of confidence in talking about engineering, using the activities, helping others with engineering, or creating/adapting activities [42]. Interviews with each site and member of the leadership team were conducted at the end of the year over Zoom. Interview questions solicited information about educators' views of engineering, experience with the project activities and supports, and ideas about future engineering opportunities in their classroom or home visits. The two case study sites (described below) were asked additional questions regarding how they implemented and adapted the activities over the year. Each of the interviews lasted around 45 to 60 minutes and were recorded for future analysis of responses.

The team also gathered additional data about activity implementation and adaptation at two RSG classrooms that were selected as case study sites based on the length of project engagement by the site staff teams and the family populations they served. This additional information gathering included two site visits in each classroom for each of the three engineering activities that they implemented. The visits consisted of structured observations of family and staff interactions with the activities, short post-interaction interviews with caregivers, and end-of-day reflective discussions with staff members. During the structured observations, researchers captured running notes of participant interactions and documented indicators of activity-specific talk and behaviors, parent and caregiver roles, staff facilitation, and engineering practice talk. Two researchers conducted these site visits and led staff reflections, including at least one bilingual (Spanish/English) researcher who collected data with Spanish-speaking families and staff The research team also facilitated ongoing video conference meetings with case study staff members before, during, and after activity implementation to better understand the ways they were adapting and implementing the activities and to document their evolving ideas about engineering education for young children and families.

Engineering Activities

The first of the activities was named ***Pollitos*** (Spanish for "baby chicks") and included strong ties to the popular Spanish language song, "Los Pollitos Dicen" (Figure 3). This activity asked families to use wooden blocks to keep a hen and her family of baby chicks safe and cozy. ***Pollitos*** included two books for educators to incorporate: *Los Pollitos Dicen* by Ashley Wolff and *The Chick That Wouldn't Hatch* by Claire Daniel. The second activity was named ***Doggies*** and based on the book *Big Dog… Little Dog* by P.D. Eastman. ***Doggies*** invited families to build beds or houses that are just the right size for a small and large stuffed dog using craft materials (e.g., popsicle sticks, index cards, sticky dots). The third activity was named ***Tacos*** and asked families to plan a taco party and test different processes for helping guests assemble their tacos. Based on the book, *How to Fold a Taco* by Naibe Reynoso, the version of ***Tacos*** educators received included reusable felt materials of multiple colors and shapes to represent different tacos ingredients and wooden palm leaf platters. During the PD sessions, educators were encouraged to make any adaptations or modifications to the activities as they brainstormed how to incorporate them into their classrooms or home visits, with a particular focus on considering additional physical materials to include in the activity, modifications to the narrative context or story grounding the activity, and changes to the design challenge prompt presented to families. Because these three foci were identified as high-leverage characteristics of the engineering activities during the earlier DBR study [36] they were routinely emphasized over the arc of PD sessions throughout the year - although at times, the emphasis on individual characteristics varied depending on the specific activity and in response to observations at the case study sites.

Figure 3. *Images of the three activities given to the educators during the study (from left to right): Pollitos, Doggies, and Tacos.*

Data Analysis

The first two authors led a team of undergraduate research assistants at ND in the thematic analysis [43] of the survey, interview, and case study data. After an introduction to the year-long study, the first two authors trained the undergraduates in developing emergent codes with the dataset, beginning with the survey data. Between seven and eight questions were selected from each of the activity surveys for qualitative analysis, chosen due to the survey questions' alignment to the stated research questions. For each activity survey, beginning with the first (Pollitos), the research assistants developed emergent coding schemes for each question, independently coded assigned questions, and wrote a research memo. During a weekly meeting, the first two authors and research assistants discussed the emergent themes together, adjusting the codes and recoding as needed. For the latter two surveys (Doggies and Tacos), the previously developed Pollitos emergent coding schemes were used as a starting point for similar questions across surveys. Often, the data suggested new, additional coding themes as educators continued to grow in their understanding of engineering and familiarity in using and adapting the activities.

Themes from across the three surveys were discussed before turning to the end-of-year interview data. Three multi-part interview questions were selected from the interviews due to their alignment with the research questions. Research assistants cleaned the interview data transcripts using the video recordings for reference. Using Dedoose, they thematically coded the transcripts, starting with the existing emergent coding scheme for the interview questions that overlapped with those from the surveys. The two first authors and the research assistants identified themes across the participants using Dedoose.

Finally, upon completion of the interview data analysis, the research assistants analyzed the case study data, which included the site debriefs after each activity and summaries captured by the TERC researchers conducting the site visits. To support this analysis, the researchers who had conducted the case study data collection developed case study summaries for each site and each round of data collection associated with one of the three engineering activities. The case study summaries included photos of the activities implemented at each site, images of the adaptations the sites had made to the activities, highlights from descriptive analyses of the classroom observation data, emergent themes identified from post-interaction caregiver interviews, and emergent themes from the end-of-day staff reflective discussions. Following a discussion of emergent themes and noticings as a lab group, the research assistants wrote research memos to capture the essence of each site and the experiences shared in each of the two case studies.

Findings

The analysis conducted by the ND team addressed the two focused research questions posed earlier in the paper. Findings 1 and 2 address Research Question 1 (RQ1), which asks how the RSG educators used and modified the three activities for use within their own classrooms. Findings 3 and 4 address Research Question 2 (RQ2), which seeks to identify the professional development supports that were most helpful to the RSG educators when integrating the activities in their contexts.

Finding 1: Educators frequently integrated the engineering activities into different areas of their classroom, and they used a wide range of integration approaches when doing so.

To begin understanding how, if at all, the RSG educators were using the three DBR activities, we asked them to indicate about how frequently they were including the activities within their classrooms on each of the three post-implementation period surveys. Table 2 below summarizes the educators' responses.

Table 2

Frequency of Using DBR Engineering Activities during the RSG Sessions

Frequency	Activity Pollitos (n=16)	 Doggies (n=15)	 Tacos (n=15)
Rarely	12.5%	6.7%	0.0%
About once a month	0.0%	6.7%	20.0%
About once every two weeks	25.0%	20.0%	20.0%
Weekly	62.5%	66.7%	60.0%

As seen in Table 2, at least 60% of the RSG educators reported using the activities weekly, and at least 80% reported using the activities at least once every two weeks, suggesting relatively high levels of use and integration in RSG overall.

RSG educators demonstrated a wide range of approaches to integrating the engineering activities into their existing classroom structures and activities. Educators were given autonomy in the PD sessions to bring the activities into desired locations in their classroom, which resulted in several intentional decisions about where they introduced the activities to families and how they incorporated them into their classrooms or home visits. For the Pollitos activity, some educators chose to include the activity in areas where children would find it on their own: “We put the activities on one of the tables. After circle time, children are free to explore the activities they want to play” (A7). Sometimes, educators placed the materials in many different spots, so that there were multiple options, such as “offering the chickens in different areas such as the sensory area, building blocks, and storytime” (C4).

Other educators used the activity to transform an area of their classroom. For the Tacos activity, one educator shares that the Tacos activity “became a permanent fixture in our Drama area. It is in the kitchen area, in its own table” (C3). Not only did educators make the activities more than temporary parts of their classroom, but they enhanced the context around the activity by changing the scenery. Another educator describes, “We have created an environment around the taco activity and have transformed our pretend play area from a kitchen to a taco truck and prep kitchen to even restaurant” (C6). All of these approaches demonstrate the educators’ creativity and extensive knowledge of how their families may want to engage in the activities and what they can do to prepare for - and deliver - an engaging experience.

The case study sites provide an opportunity to observe the unique ways that different sites brought the activities into their classroom. Site 1 was an example of one style of full integration of the activities into all aspects of the classroom environment, focusing on the entire classroom as a system to weave the Pollitos context into all classroom areas. At the end of the observation visit of the Pollitos activity deployment at Site 1, the educators reflected on how they brought the activity into their classroom in a myriad of ways: by reading the book and talking about the chicks during circle time, singing the “Los Pollitos Dicen” song, including chick-themed books in all classroom areas, including feathers in the art area, and adding popcorn as part of the snack. The RSG educators intentionally wove the context and characters of the Pollitos activity throughout all elements of their classroom environment and procedures. Figure 4 shows one of these stations with the Pollitos materials on a table, including the addition of corn husks and corn kernels.

Figure 4. *Site 1 staff set up the Pollitos activity (left) with the addition of corn husks and kernels in the far bin in the table. The Tacos activity (right) included a labeled menu for families to use to select their ingredients when ordering tacos at Site 1.*

Site 1 approached the Doggies activity with the same philosophy: they had almost every classroom station include something related to Doggies - ranging from the variety of colors to paint dogs and dog prints in the art area to the many books throughout the classroom which included dogs as central characters. During one of the observation days, the educators added a grooming station and an additional doggy sensory area. In one of the survey responses, an educator lists the many ways they incorporated doggies into their day: "Reading during circle time a book related to dogs, singing a song about pets, adding different activities about dogs in the classroom, asking questions about dogs and pets in general…giving them the chance to ask for extra items to fulfill their imagination" (C1). The educators seemed to value the connections to all parts of the day's activities to create a holistic experience for the children and families. For the Tacos activity, Site 1 focused on the drama and art stations for the integration of the activity. In the drama station, they included a cash register and labeled menus of ingredients for families to use (Figure 4). As this case study site shows, there were a variety of approaches across the three activities even for one site; thus, this description is meant to serve as one example of the rich ways that educators approached the integration of these engineering activities into their classrooms and home visits.

Finding 2: Educators modified and adapted the activities that deepened engagement and relevance for families in their classrooms.

RQ1 also asks about how the RSG educators potentially modified and adapted the activities while implementing them in their classrooms. Most frequently, educators reported adding supplementary materials to the standard activity kits and modified elements of the design context that deepened engagement and relevance for the families they were working with. Oftentimes, their choices for material additions stemmed from their knowledge of the children's preferred materials. For the Pollitos activity, one educator describes, "Instead of the blocks provided, we set them up with our Magna Tiles, since those seem to be a big hit in our classroom" (A6). Other reasons for additions resulted from the educators' knowledge of what materials are best for preschool-aged children. As one educator explains in the Doggies activity, they added popsicle sticks and pipe cleaners "that can be easily manipulated and can be handled a bit better for tiny hands" (A3). Not only did educators add new materials themselves, but they also encouraged kids to be creative and include their own ideas, which resulted in children adding "their own materials to create houses for the hen (out of blocks, magna tiles, fabrics and baskets)" (C6).

These additional materials often were part of a larger modification of the design context that led to deeper engagement by families. In the Tacos activity, educators added new materials such as a "cash register, tip jar, instructions on how to order, a tortilla press, and pots and pans" in order to modify the design context (A6). Instead of the original design challenge of planning for a taco party, this engineering challenge became multi-faceted as children and families ordered tacos from the taco truck, while other children practiced collecting orders and took turns working the cash register. The process-engineering focus of the original activity was extended by the educators' imagination and creativity. The taco truck set-up was a modification that was evident in many educators' responses in their surveys.

The case study Site 2 provides a more detailed example of how educators approached each activity's modifications and adaptations and how these approaches changed over the course of the year. For the first activity, Pollitos, Site 2 made very few changes on the day of their initial observation. As one educator described, she "wanted this week to be a baseline for the activity" (C2), thus showing an intentionality to introducing the activity in its original configuration to families. In the Pollitos debrief with the research team after the observation, the Site 2 staff noted their appreciation for the layout of the activity: since there was no specific way to play, the families could explore however they wanted. This minimally-adapted activity exploration during Pollitos was followed by a slightly different approach by the Site 2 educators during the Doggies activity. They decided to adjust the materials to better suit the children, using tape instead of the provided sticky dots and adding fabrics, jumbo popsicle sticks, cardboard from the Pollitos activity, and index cards (Figure 5). One educator also shared a desire to use "less perishable materials" which adds to the activity's sustainability (C2). In the debrief, the staff noticed that families seemed to connect with the doggies more so than the chicks from the previous Pollitos activity.

Figure 5. *Site 2 staff set up the Doggies activity (left) with additional materials of fabric, tape, and jump popsicle sticks. The Tacos activity (right) included adjusted felt materials as well as a clipboard with an ingredient list and prompts.*

Following the materials modifications in Doggies, as the Site 2 educators approached the final activity, Tacos, they made even more significant changes to the activity. Similar to Doggies, they made changes to the materials, cutting some of the green felt into smaller pieces to be more like cilantro (Figure 5). They noticed that families could also think about the green felt materials as different taco ingredients: cilantro, lettuce, chiles, nopales (cacti), or espinaca (spinach). They also added a clipboard with a list of ingredients and prompts at the activity table. For Tacos, the Site 2 staff also created modifications to the design challenge itself. They changed the activity prompts to ask how many tacos can families make, and they introduced the activity to families during circle time. They even encouraged students to bring items from home to make the activity more realistic. One family brought in a tortilla maker from home to enhance the Taco activity design context. As this progression shows, the Site 2 educators made more modifications and adaptations as they continued to bring in the different engineering activities into their classroom. While educators from each site brought their unique lenses, this case study site shows one example of how educators brought in their own expertise and creativity to modify and design engaging engineering activities and experiences for their families.

Finding 3: Educators found the professional development sequence and programmatic supports effective in empowering them to use the original activities from the DBR study.

In response to RQ2, interviews with RSG educators suggested that they found the PD sequence and programmatic supports effective, not only in empowering them to use the original activities from the DBR study, but also in brainstorming modifications and adaptations - and in some cases, even creating their own engineering activities for their families. One of the most frequently shared programmatic supports that helped influence how educators incorporated engineering into their classroom were the materials in the activity kits themselves, which included the book and materials related to the design challenge. The materials in the kit seemed to provide a degree of flexibility and creativity, giving educators a starting point but also allowing educators space to think more creatively about items they want to add or remove to enhance their activity. The convenience of these materials was also noted: “I didn’t feel like I had to go the extra mile to, like, go and buy them all” (C3). One educator shared the value of the book: “It [the book] gave me another way to connect the child to the activity that they would be able to play with…those ones I feel like, especially for my Spanish speaking students” (C7). In addition to the activity kit materials, the provided handouts and guides were also often named and valued. One educator describes, “I think that the handouts have been helpful. Just sort of as a starting point of letting them know. Here’s what we are trying to do” (A6). The programmatic support also included an engineering design handout that sites appreciated because they were “great to share with families. We could have had those materials together and talk to families more about it” (C2).

In addition to the physical programmatic supports, educators shared two other types of supports: collaborative spaces and interactions with the project team. For each of the three PD sessions, a Google slide deck was created for each site to have a structured brainstorm for how they might incorporate the engineering activity into their classroom. The brainstorm included items such as activity prompts (both ‘explore’ & ‘design’ prompts), materials (from kits and classrooms), introduction and framing for families (‘When would they introduce the activity?’), and other notes. One educator describes the value of these slides: “I think it’s good and helpful because it does make us kind of think of like, ‘Oh, how else can we modify it?’” (H2). This arrangement seemed to help educators work together to brainstorm how the activity could be woven into their classroom. The project team also had a collaborative Google Space where educators could post pictures of how they were using the kits in their classrooms. One educator described, “Being able to see how other coordinators were integrating the activities [in the Google Space] was great” (C2).

Educators also seemed to value the time that they spent interacting with the project team and one another in the conversations about engineering. The PD sessions provided a space to discuss engineering, how engineering relates to their classrooms’ inquiry approach, and raise any questions about implementing the activities with their families. One coordinator shared, “Coming together in person with the with our team and you guys, was so great and beneficial for us because we were brainstorming together” (C5). This sentiment of collectively brainstorming ideas was shared by many other educators in their end-of-year interviews as well. In the first survey, one of the project team members shared more about the benefit of the interactions with the team and the educators during the PD sessions: “I noticed that when the subject of engineering was talked about during meetings or gatherings, there was more ideas shared and it encouraged Coordinators to incorporate it it more in the weeks following” (M3). The PD sequence was intentionally structured so that these sessions occurred at the start of each activity introduction cycle. Over the course of the year, there was a convivial atmosphere to the trainings, which one coordinator shared "made people be able to connect with it [engineering], made myself able to connect with it and my team" (C6).

Finding 4: Educators' confidence in talking about engineering, using the engineering activities, or creating their own activities seemed to increase over the course of the year.

Quantitative analysis of the Pollitos, Doggies, and Tacos surveys provided additional insight into the effectiveness of the professional supports and indicated an increase in confidence in the early childhood educators over the course of the 2022-2023 academic year (Table 3). Educators were surveyed for the following categories: talking about engineering with a member of the early childhood team, caregivers, or young children, using the engineering activities in their classrooms or on home visits, and creating their own (or adapting) engineering activities or helping others create their own.

Table 3
Educators' Levels of Feeling Confident and Extremely Confident throughout the 2022-2023 Year

Category	Activity		
	Pollitos (n=19)	Doggies (n=18)	Tacos (n=15)
Talking about engineering with someone on the team	65%	75%	79%
Talking about engineering with a caregiver	71%	75%	79%
Talking about engineering with young children	59%	69%	79%
Using the Pollitos activity in my classroom or home visit	88%	88%	100%
Using the Doggies activity in my classroom or home visit	--	81%	93%
Using the Tacos activity in my classroom or home visit	--	--	93%
Creating my own (and/or adapting) engineering activities	47%	60%	71%
Helping others create their own engineering activities	47%	56%	64%

Across the three surveys, the percentage of educators who felt confident or extremely confident in each of the categories increased. Other options of the four-point scale were not confident at all and somewhat confident. In the third survey near the end of the year, 79% of the educators reported being confident or extremely confident in talking about engineering with someone on the early childhood education team, a caregiver, or young children. Educators exhibited slightly less confidence in creating their own engineering activities, with 71% feeling confident or extremely confident in creating their own and 64% for helping others. By this third survey, 100% of the team reported being either confident or extremely confident in using the Pollitos activity. Ninety three percent shared they were confident and extremely confident in using the latter two activities, Doggies and Tacos.

Discussion

In this study, we seek to better understand how engineering activities designed for family use in the home environment could potentially be used, modified, and adapted by early childhood educators in their classrooms. The analysis of survey, interview, and case study data suggest that the RSG educators integrated the Pollitos, Doggies, and Tacos activities into their classrooms with relative frequency and in a variety of ways, including setting the activities out in different areas of their classrooms, adding different materials, and modifying the design contexts and prompts to make them more relevant to the families they were working with. The findings also indicate that the RSG educators found the professional supports provided by the REACH-ECE project team helpful, particularly the professional development sessions and the actual activity kit materials themselves. Notably, the RSG educators also pointed to the collaborative structures - both with the team as well as with each other - to be extremely valuable. The educators reported increases in their confidence in using the DBR activities, talking about engineering with others, and even creating their own engineering experiences across each of the rounds of activity.

Applying an ecological, asset-based lens to family learning can catalyze new pathways for early childhood engineering learning

Exploring the home-school connection in early childhood engineering has great potential to advance the state of the field in terms of understanding how young learners and their families can meaningfully engage with each other to build enduring familiarity, fluency, and identities around engineering. And yet, this area continues to be considerably under-researched, despite a post-COVID shutdown era when many innovations in home-based educational STEM and engineering education were developed with early learners and their parents and caregivers. Taking an ecological approach to learning encourages the acknowledgement of the significant assets and strengths of learning opportunities both within and outside of the classroom. Moreover, applying an ecological lens to engineering learning fosters the positioning of parents and caregivers as full participants and partners in early childhood engineering education, suggesting there is much the field can learn from - and be informed by - family interactions.

Other considerations for early childhood educator uptake of engineering activities

Several members of the RSG team had worked with the broader REACH-ECE project team for three years by the time this study started, which likely contributed to the level of activity integration and the shifts in educator confidence over time. The three RSG team leaders who were also part of the REACH-ECE leadership team provided extremely high levels of enthusiasm, commitment, and buy-in to the REACH-ECE project, which provided a strong foundation for the REACH-ECE project team to engage with the RSG educators. In addition to these favorable relational conditions, one other factor that may have contributed to findings of the study could be the intentionally broad definitions of engineering and engineering practice that anchored the REACH-ECE project. Again drawing on asset-based approaches, the REACH-ECE project constructed an equity-focused stance on engineering, positing that families regularly engage in engineering processes and practices within everyday situations as they iteratively problem solve difficult challenges and optimize resources [26]. This broadened and inviting perspective on engineering seemed to empower and encourage the RSG educators to identify and connect more with engineering overall, leading to more comfort and confidence in implementing and adapting the DBR activities within their own contexts.

Limitations, implications, and future work

The study presented in this paper has a number of limitations. Certainly, the context of the RSG program - where parents and caregivers are part of the classroom environment - is quite unique, thereby limiting the broad applicability of these findings. In addition, the long collaborative relationship between RSG leadership and the REACH-ECE team created a set of favorable conditions for the RSG educators to be primed to integrate the DBR activities into their classrooms. Finally, although the two case study sites provided deep and varied insights into the ways in which RSG educators approached using, modifying, and adapting the activities, additional case study data would further enrich the nuanced understanding of common processes, beliefs, and approaches.

Despite these limitations, the study still has a number of implications, including making a contribution to the home-school connection literature around early childhood engineering. In addition, the findings from this study can potentially inform the design of future engineering-focused professional development for early childhood educators. Future work includes further exploring how early childhood educators integrate engineering activities within their classrooms, with a specific eye towards how modifications made by educators can influence the ways in which early learners engage in engineering practices as well as how educators and families see engineering as connected to everyday contexts. Additional investigation of the potential constraints and affordances of integrating engineering activities designed for unfacilitated family use in the home into the more formal classroom setting would also be a potentially fruitful avenue for deeping the field's understanding of novel approaches to the home-school connection around early STEM learning. Finally, future studies focused on examining family-based engineering learning in the home can not only inform activities in the early childhood classroom but also lead to a movement of empowerment for young children and their parents and caregivers, particularly those who have been traditionally marginalized across engineering fields.

References

[1] T. J. Moore, K. M. Tank, and L. English, “Engineering in the Early Grades: Harnessing Children’s Natural Ways of Thinking,” in *Early Engineering Learning*, L. English and T. Moore, Eds., in Early Mathematics Learning and Development. , Singapore: Springer, 2018, pp. 9–18. doi: 10.1007/978-981-10-8621-2_2.

[2] National Academies of Sciences, Engineering, and Medicine, *Science and Engineering in Preschool Through Elementary Grades: The Brilliance of Children and the Strengths of Educators*. Washington, DC: The National Academies Press, 2021. Accessed: Dec. 02, 2022. [Online]. Available: https://doi.org/10.17226/26215

[3] C. N. Lippard, M. H. Lamm, and K. L. Riley, “Engineering Thinking in Prekindergarten Children: A Systematic Literature Review,” *J. Eng. Educ.*, vol. 106, no. 3, pp. 454–474, 2017, doi: 10.1002/jee.20174.

[4] Z. S. Gold, J. Elicker, A. M. Kellerman, S. Christ, A. A. Mishra, and N. Howe, “Engineering Play, Mathematics, and Spatial Skills in Children with and without Disabilities,” *Early Educ. Dev.*, vol. 0, no. 0, pp. 1–17, Jan. 2020, doi: 10.1080/10409289.2019.1709382.

[5] D. Bairaktarova, D. Evangelou, A. Bagiati, and S. Brophy, “Early Engineering in Young Children’s Exploratory Play with Tangible Materials,” *Child. Youth Environ.*, vol. 21, no. 2, pp. 212–235, 2011.

[6] A. Bagiati and D. Evangelou, “Engineering curriculum in the preschool classroom: the teacher’s experience,” *Eur. Early Child. Educ. Res. J.*, vol. 23, no. 1, pp. 112–128, Jan. 2015, doi: 10.1080/1350293X.2014.991099.

[7] Z. S. Gold, J. Elicker, C. D. Evich, A. A. Mishra, N. Howe, and A. E. Weil, “Engineering play with blocks as an informal learning context for executive function and planning,” *J. Eng. Educ.*, vol. 110, no. 4, pp. 803–818, 2021, doi: 10.1002/jee.20421.

[8] A. MacDonald, L. Danaia, S. Sikder, and C. Huser, “Early Childhood Educators’ Beliefs and Confidence Regarding STEM Education,” *Int. J. Early Child.*, vol. 53, no. 3, pp. 241–259, Dec. 2021, doi: 10.1007/s13158-021-00295-7.

[9] M.-H. Park, D. M. Dimitrov, L. G. Patterson, and D.-Y. Park, “Early childhood teachers’ beliefs about readiness for teaching science, technology, engineering, and mathematics,” *J. Early Child. Res.*, vol. 15, no. 3, pp. 275–291, Sep. 2017, doi: 10.1177/1476718X15614040.

[10] A. S. Bustamante, D. B. Greenfield, and I. Nayfeld, “Early Childhood Science and Engineering: Engaging Platforms for Fostering Domain-General Learning Skills,” *Educ. Sci.*, vol. 8, no. 3, Art. no. 3, Sep. 2018, doi: 10.3390/educsci8030144.

[11] C. M. McWayne, B. Zan, W. Ochoa, D. Greenfield, and J. Mistry, “Head start teachers act their way into new ways of thinking: Science and engineering practices in preschool classrooms,” *Sci. Educ.*, vol. 106, no. 4, pp. 956–979, 2022, doi: 10.1002/sce.21714.

[12] C. M. Cunningham, C. P. Lachapelle, and M. E. Davis, “Engineering Concepts, Practices, and Trajectories for Early Childhood Education,” in *Early Engineering Learning*, L. English and T. Moore, Eds., in Early Mathematics Learning and Development. , Singapore: Springer, 2018, pp. 135–174. doi: 10.1007/978-981-10-8621-2_8.

[13] M. E. Davis, C. M. Cunningham, and C. P. Lachapelle, “They Can’t Spell ‘Engineering’ but They Can Do It: Designing an Engineering Curriculum for the Preschool Classroom,” *ZERO THREE*, vol. 37, no. 5, pp. 4–11, May 2017.

[14] U. Bronfenbrenner, *The Ecology of Human Development: Experiments by Nature and*

Design. Harvard University Press, 1979.
[15] B. Barron and P. Bell, “Learning environments in and out of school,” in *Handbook of educational psychology*, 3rd ed., Routledge, 2015, pp. 337–350.
[16] M. Fenichel, *Surrounded by science: learning science in informal environments*. Washington, DC: National Academies Press, 2010. Accessed: Feb. 07, 2024. [Online]. Available: http://www.nap.edu/catalog.php?record_id=12614
[17] B. Rogoff, M. Callanan, K. D. Gutiérrez, and F. Erickson, “The Organization of Informal Learning,” *Rev. Res. Educ.*, vol. 40, no. 1, pp. 356–401, Mar. 2016, doi: 10.3102/0091732X16680994.
[18] B. Barron, “Interest and Self-Sustained Learning as Catalysts of Development: A Learning Ecology Perspective,” *Hum. Dev.*, vol. 49, no. 4, pp. 193–224, Oct. 2006, doi: 10.1159/000094368.
[19] J. W. Neal and Z. P. Neal, “Nested or Networked? Future Directions for Ecological Systems Theory,” *Soc. Dev.*, vol. 22, no. 4, pp. 722–737, 2013, doi: 10.1111/sode.12018.
[20] M. E. Cardella, G. N. Svarovsky, and B. L. Dorie, “Gender Research on Adult-child Discussions within Informal Engineering Environments (GRADIENT): Early Findings,” presented at the 2013 ASEE Annual Conference & Exposition, Jun. 2013, p. 23.635.1-23.635.13. Accessed: Apr. 26, 2024. [Online]. Available: https://peer.asee.org/gender-research-on-adult-child-discussions-within-informal-engineerin g-environments-gradient-early-findings
[21] B. Dorie, M. Cardella, and G. Svarovsky, “Capturing the Design Thinking of Young Children Interacting with a Parent,” *Sch. Eng. Educ. Grad. Stud. Ser.*, Jan. 2014, [Online]. Available: https://docs.lib.purdue.edu/enegs/52
[22] G. N. Svarovsky, C. Wagner, and M. Cardella, “Exploring Moments of Agency for Girls during an Engineering Activity,” *Int. J. Educ. Math. Sci. Technol.*, pp. 302–319, Jul. 2018, doi: 10.18404/ijemst.428200.
[23] A. Simpson, P. N. Knox, and J. Yang, “Children’s engineering identities-in-practice: An exploration of child–adult interactions in an out-of-school context,” *J. Eng. Educ.*, vol. 112, no. 4, pp. 1056–1078, 2023, doi: 10.1002/jee.20553.
[24] M. Marcus, G. Solis, S. Sellars, and C. A. Haden, “Promoting children’s science, technology, engineering, and mathematics learning at home through tinkering and storytelling,” *Front. Psychol.*, vol. 14, 2023, Accessed: Jan. 31, 2024. [Online]. Available: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1146063
[25] C. Wagner *et al.*, “Exploring the nature of engineering during home-based engineering activities designed for Spanish-and English-speaking families with young children (Fundamental, Diversity),” presented at the 2023 ASEE Annual Conference & Exposition, 2023.
[26] S. Pattison, S. Ramos Montañez, and G. Svarovsky, “Family values, parent roles, and life challenges: Parent reflections on the factors shaping long-term interest development for young children and their families participating in an early childhood engineering program,” *Sci. Educ.*, vol. 106, no. 6, pp. 1568–1604, 2022, doi: 10.1002/sce.21763.
[27] D. I. Acosta and C. A. Haden, “Museum-based tinkering and engineering learning opportunities among Latine families with young children,” *J. Appl. Dev. Psychol.*, vol. 80, p. 101416, May 2022, doi: 10.1016/j.appdev.2022.101416.
[28] S. H. Kim and A. Simpson, “Parents’ epistemic supports during home-based engineering design tasks: opportunities and tensions through the use of technology,” *Educ. Technol. Res.*

Dev., Nov. 2023, doi: 10.1007/s11423-023-10322-0.
[29] A. Simpson and P. Knox, “Children’s Engineering Identity Development Within an At-Home Engineering Program During COVID-19,” *J. Pre-Coll. Eng. Educ. Res. J-PEER*, vol. 12, no. 2, Dec. 2022, doi: 10.7771/2157-9288.1345.
[30] S. Pattison *et al.*, “Understanding Early Childhood Engineering Interest Development as a Family-Level Systems Phenomenon: Findings from the Head Start on Engineering Project,” *J. Pre-Coll. Eng. Educ. Res. J-PEER*, vol. 10, no. 1, May 2020, doi: 10.7771/2157-9288.1234.
[31] B. Habig, P. Gupta, and J. D. Adams, “Disrupting deficit narratives in informal science education: applying community cultural wealth theory to youth learning and engagement,” *Cult. Stud. Sci. Educ.*, vol. 16, no. 2, pp. 509–548, Jun. 2021, doi: 10.1007/s11422-020-10014-8.
[32] S. Pattison, S. Ramos Montañez, G. Svarovsky, and S. Tominey, *Engineering for equity: Exploring the intersection of engineering education, family learning, early childhood, and equity*. Cambridge, MA: TERC, 2022.
[33] C. M. McWayne, G. Melzi, and J. Mistry, “A home-to-school approach for promoting culturally inclusive family–school partnership research and practice,” *Educ. Psychol.*, vol. 57, no. 4, pp. 238–251, Oct. 2022, doi: 10.1080/00461520.2022.2070752.
[34] X. Dominguez *et al.*, “Integrating Science, Mathematics, and Engineering: Linking Home and School Learning for Young Learners,” Digital Promise, Apr. 2023. Accessed: Jan. 28, 2024. [Online]. Available: https://eric.ed.gov/?id=ED629965
[35] A. Ata-Aktürk and H. Ö. Demircan, “Supporting Preschool Children’s STEM Learning with Parent-Involved Early Engineering Education,” *Early Child. Educ. J.*, vol. 49, no. 4, pp. 607–621, Jul. 2021, doi: 10.1007/s10643-020-01100-1.
[36] S. Pattison *et al.*, “Activity Design Principles that Support Family-Based Engineering Learning in Early Childhood,” presented at the NARST Annual Meeting, Vancouver, BC, Mar. 2022.
[37] L. M. Desimone and K. Pak, “Instructional Coaching as High-Quality Professional Development,” *Theory Pract.*, vol. 56, no. 1, pp. 3–12, Jan. 2017, doi: 10.1080/00405841.2016.1241947.
[38] L. Darling-Hammond, M. Hyler, and M. Gardner, “Effective Teacher Professional Development,” Learning Policy Institute, Jun. 2017. doi: 10.54300/122.311.
[39] C. M. McWayne, D. Greenfield, B. Zan, J. Mistry, and W. Ochoa, “A Comprehensive Professional Development Approach for Supporting Science, Technology, and Engineering Curriculum in Preschool: Connecting Contexts for Dual Language Learners,” in *Supporting Children’s Well-Being During Early Childhood Transition to School*, IGI Global, 2021, pp. 222–253. doi: 10.4018/978-1-7998-4435-8.ch011.
[40] K. Brenneman, A. Lange, and I. Nayfeld, “Integrating STEM into Preschool Education; Designing a Professional Development Model in Diverse Settings,” *Early Child. Educ. J.*, vol. 47, no. 1, pp. 15–28, Jan. 2019, doi: 10.1007/s10643-018-0912-z.
[41] A. Eckhoff, “Engineering to understand: reflections on a learning and teaching partnership for preservice early grades teachers and preschoolers,” *J. Early Child. Teach. Educ.*, vol. 44, no. 1, pp. 118–142, Jan. 2023, doi: 10.1080/10901027.2021.2015492.
[42] M. F. Maier, D. B. Greenfield, and R. J. Bulotsky-Shearer, “Development and validation of a preschool teachers’ attitudes and beliefs toward science teaching questionnaire,” *Early Child. Res. Q.*, vol. 28, no. 2, pp. 366–378, Apr. 2013, doi: 10.1016/j.ecresq.2012.09.003.

[43] K. L. Peel, “A beginner’s guide to applied educational research using thematic analysis,” *Pract. Assess. Res. Eval.*, vol. 25, no. 1, p. 2, 2020.