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Talking about Artifacts: Preschool Children's Explorations with Sketches, Stories, and Tangible Objects

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Abstract

Exploratory learning is recognized as a developmentally appropriate practice in early childhood education. During exploration, exposure to new things guides children in the acquisition of knowledge, while interactions with a range of familiar and unfamiliar artifacts can support developmental integration. Exploratory activity may occur spontaneously at any time, but it can also be structured and guided to achieve specific curricular and developmental goals. This paper explores preschool children's interactions during semi-structured exploratory activities in three different conditions. Thirty-five 4- to 5-year-old children, from six preschool classrooms, were randomly assigned to three different conditions. Each condition included the same set of 13 different artifacts that were either artistically rendered in black ink on white paper (sketch condition), included in a children's story book (book condition), or had the real artifact itself (tangible object conditions). Children's exploration and interactions were videotaped and analyzed to see which, if any, of the three conditions would appear to stimulate and encourage early engineering thinking the most. Initial hypothesis was that the tangible object condition would appear to be the most beneficial. Findings showed that this condition elicited the longest discussions and interactions with the artifacts, and it was also the condition during which children were demonstrating more knowledge and ideas with regard to possible functions of the artifacts. Regarding whether there was a condition that stimulated more interest toward specific artifacts, no clear pattern among the three conditions appeared. Implications are discussed in terms of preschool Science, Technology, Engineering, and Mathematics (STEM) and child development.

Introduction

We are interested in understanding engineering thinking as it is revealed in young children's activities and interactions with the world of artifacts. Engineering thinking is a new area of exploration within engineering education that is based on the developmental engineering hypothesis suggesting that young children's exploratory, inquisitive, and creative behaviors resemble traits highly desirable in engineering (Evangelou, in press). In this paper, we present initial findings from a study designed to investigate preschool children's explorations and discuss implications for developmental approaches to Science, Technology, Engineering, and Mathematics (STEM) in preschool settings. This study builds on prior research in early childhood development but focuses on questions related to precursors to engineering thinking (Brophy & Evangelou, 2007). Findings from this study will be useful in informing efforts to develop curriculum materials that integrate engineering thinking with ongoing classroom practices familiar to teachers.

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In contrast to engineering, the remaining three disciplines constituting STEM have an established presence in the early childhood education curriculum. Formally, mathematics has perhaps the

longest history (Saracho & Spodek, 2008) compared to science and technology. A rich theoretical and empirical understanding of the role that these three disciplines play in the education and development of young children has been achieved (National Association for the Education of Young Children, 2009; Bowman, Donovan, & Burns, 2001; Patrick, Mantzicopoulos, & Samarapungavan, 2009; Samarapungavan, Mantzicopoulos, & Patrick, 2007). Recently, two reports (Cross, Woods, & Schweingruber, 2009; Duschl, Schweingruber, & Shouse, 2007) summarized current knowledge and recommended practices in the three fields, thus placing early childhood education into the ongoing national STEM debate (Kuenzi, Mathews, & Mangan, 2006). Whether it is teaching mathematics with the use of tabletop manipulatives (Clements & Samara, 2009), getting involved in an in-depth inquiry of water puddles (Worth & Grollman, 2003), or playing with programmable blocks (Bers, 2008), the field of early childhood education has a wealth of well-developed ideas for curricular uses of math, science, and technology. In contrast, when it comes to engineering and engineering education, there is a lack of understanding, both of what engineering is and of how it can be integrated into early education (Brophy, Klein, Portsmore, & Rogers, 2008; Katehi, Pearson, & Feder, 2009; Oware, Capobianco, & Diefes-Dux, 2007). We propose that artifacts defined as any human-made object-provide a simple, effective way to bring engineering into the preschool classroom in a developmentally appropriate manner.

Why Explore Artifacts?

We chose to study children's engineering exploration through their interaction with artifacts for two reasons. First, the developmental value of concrete objects has been established from a cognitive perspective; starting in infancy, exploration and interaction with such objects contribute to the development of means-end behavior (Lobo & Galloway, 2008). We have a strong understanding from a developmental perspective of how children acquire meaning and build understanding of real objects, including artifacts (Gauvain & Greene, 1994; Jaswal, 2006; Malt & Sloman, 2006; Matan & Carey, 2001). Developmental research about children's interactions with real objects focuses on understanding the scope and sequence of children's knowledge about artifacts, the ways children ascribe meaning to form and function, and the ways they engage in the naming of artifacts. Children organize their understanding about artifacts around notions of original function—what the artifacts were made for (Matan & Carey, 2001). Children try to make sense of the intentions of whoever created the object; these assumptions about the creator's intentions play a role in how they use these artifacts (Gelman & Bloom, 2000; Malt & Sloman, 2006).

Furthermore, we wish to promote STEM in early childhood education, and to do so, we choose to use artifacts as exemplars of STEM, particularly of "the E in STEM." Children are surrounded by artifacts every day and everywhere they go. These artifacts are the result of engineering ingenuity and labor (Petroski, 1992). As such, they can introduce young children to engineering in a way that is concrete, accessible, and relevant. Thus, for the reasons explained above, artifacts are a developmentally appropriate way to make engineering salient in the preschool classroom.

Why Tangible Objects?

The concreteness of artifacts and various manipulative objects commonly found in early childhood education classrooms make them good learning devices because they can be used to instantiate and exemplify more abstract notions. Concrete objects—often called manipulatives—have long been accepted as part of the curricular infrastructure of a preschool classroom. Considerable empirical findings lend support to their overall educational use, although some scholars urge that we not overestimate their value in learning (Brown, McNeil, & Glenberg, 2009; McNeil & Uttal, 2009; Clements & Sarama, 2009). Introducing children to engineering by starting with

manipulatives is developmentally justified by assumptions about a sequence that places concrete understanding at the basis of all other understanding; we assume that visual and tactile perception, as afforded by tangible objects, assists in building more abstract thinking later on.

Why Books and Sketches?

Comparing children's interactions with real artifacts to their interactions with representations of artifacts in books and sketches may also inform us about developmentally appropriate approaches to engineering in early childhood.

One cannot overemphasize the significant contributions that early literacy makes to children's linguistic and subsequent overall intellectual development across the life span (National Institute for Literacy, 2008). Books and other printed materials are expected to be present in any high-quality preschool classroom and are often used as indicators of the developmental appropriateness and the overall richness of any early learning environment. Although the debate on best practices for promoting early literacy is ongoing, exposing young children to the world of ideas through books is a well accepted and thoroughly documented practice.

Symbolic understanding constitutes a significant part of the developmental literature in which a clear age-related developmental effect is documented (Ganea, Allen, Butler, Carey, & DeLoache, 2009; Pike, Barnes, & Barron, 2010). Sketches, picture books, text illustrations, posters, charts, and so forth are commonly used in preschool classrooms as pictorial representations of proximal or distal reality. Their presence is meant to facilitate referencing a larger world that is sometimes inaccessible to young children but possible though representational depiction. Sketches are used to promote symbolic thinking as they cultivate the child's understanding about one thing standing in for another. But this dual representation (DeLoache & Burns, 1994) can create challenges for actual classroom practice. The degree to which children are able to deal with representational specificity, understanding that a picture/photograph represents something other than what it depicts (DeLoache & Burns, 1994), determines the benefits they can accrue from using illustrations as learning aids.

Research Questions

This research project was designed to explore children's interactions with artifacts presented in a variety of ways. The artifacts were artistically rendered in black ink on white paper (*sketch condition*), included in a children's story book (*book condition*), or presented in their actual physical form (*tangible object condition*). The *tangible object condition* represents one way for young children to learn—hands-on exploration with real-world objects. This is a common experience in preschool classrooms, though it is rarely used to focus on engineering-relevant learning. The *book condition* represents another common learning experience for young children—learning about new concepts or objects in the context of a shared storybook reading experience. These two conditions are quite different from one another: The *tangible object condition* presents actual, 3-dimensional artifacts, but without relevant context; the *book condition* presents 2-dimensional representations of artifacts in a visual and narrative context. We included the *sketch condition* as a mid-point between the other two conditions. In the *sketch condition*, the artifacts are presented as 2-dimensional representations (as in the *book condition*) without any context (as in the *tangible object condition*).

How would children interact with the artifacts across these different conditions? What knowledge would they demonstrate? What relationships or connections would they make? In this paper, we report how children's behavior differs across the three different conditions. More specifically, we

report on the duration of interactions, the interest displayed by the children, and the frequency with which children suggest typical and novel uses for the artifacts.

Method

Theoretical Framework

This study, motivated by recent interest in early childhood STEM, focuses on how preschool children behave in three different conditions in which they interact with artifacts. In the first condition, children read a simple story that included the artifacts. In the second condition, they looked at sketches of the artifacts, while in the third condition, they were presented with the physical artifacts. From a developmental perspective, it was hypothesized that the three conditions would evoke different types of exploratory behavior from the children (Schulz & Bonawitz, 2007). It was further hypothesized that interaction with the physical artifact during the *tangible object condition* would evoke the most complex, longer, and engaging interaction of the three conditions, as it permitted the children to engage multiple sensorial inputs compared to the other two and would therefore be the most probable condition to lead to forming new knowledge relevant to an artifact's construction, internal mechanisms, and possible functions. All are fundamental aspects of development of engineering thinking.

Pilot Study

The research started in 2008 with a pilot study that included only two of the three conditions—the book condition and the tangible object condition. Children in the pilot study were randomly assigned to one of the two conditions, and their interviews were audiotaped. The interviews conducted with the children elicited many interesting questions with regard to the design of the study and the appropriateness of the data collection method, but the interviews also made obvious that when children lacked the vocabulary (e.g., to describe the function or to talk about different components of the artifact), they grimaced, imitated sounds, and motioned with their hands rather than communicating verbally. Children's verbal responses and conversations with the researchers are currently being analyzed and are not reported in this study.

Therefore, the research group decided that videotaped sessions would be more appropriate for the main study. A question regarding what the children's responses would be if the artifacts were represented without context was also elicited. This consideration resulted in the inclusion of a third condition in the study, namely the *sketch condition*.

Main Study

Participant Characteristics. Data collection for the main study took place from September 2008 until December 2008. Parental consent was obtained for the participation of 43 children, ages 4-5, from six suburban child care programs in the midwestern United States, intentionally selected to allow participation of populations with diverse socioeconomic status. Three of the child care programs were university affiliated and served populations of well-educated families of moderate-to-high socioeconomic status. The other three programs were Head Start programs and served families in poverty. For every child who participated, data were also collected from a parent or guardian and the child's teacher. Of the 43 children, three transferred to different schools before data collection, and one child refused to participate in the study during data collection, so a total of 39 children were interviewed. Technical problems with the videotaping equipment resulted in

missing data for four of these interviews. Thus, this paper reports the results of videotaped interviews with 35 participants. These 35 participants included 19 girls and 16 boys, with a mean age of 4.5 years (SD = .36 years). The participant group was 46% White, 14% Black, 14% Latino, 3% Asian American, 20% multiracial, and 3% unknown.

Procedures and Measures. The set of 13 artifacts used in this study were carefully selected by the research team to meet certain criteria. All of the artifacts met the criteria of being human-made, relatively inexpensive and easy to transport, and able to provide opportunity for interaction. That is, each artifact could potentially "do" something (or perhaps many things). Additionally, the set was selected to vary in familiarity to preschool children (see Table 1). The research team intentionally selected some artifacts that were likely to be quite common in children's environments, as well as some that were likely to be quite rare.

Table 1Artifacts Presented in the Three Conditions

Balance	Castanets	Notepad*
Bellows	Compass	Pencil*
Binoculars	Glow stick	Tape recorder
Blood pressure cuff	Lock box	
Camera	Newton's cradle	

^{*}Notepad and Pencil were not included in the final analysis for validity reasons. These artifacts were sometimes presented separately and sometimes combined and treated as a unit. Distinction with regard to their separate usage during coding and analysis did not appear to be accurate.

At the time of consent, parents completed a questionnaire that included demographic characteristics of the child and the presence or absence of certain artifacts in the home. Children's teachers also completed a questionnaire that included information about the presence or absence of certain artifacts in the classroom. The information gathered from these questionnaires confirmed that the artifacts chosen for this study varied substantially in terms of children's access to them. For instance, only two participating children had access to a bellows in either the home or the school setting. In contrast, most children had access to a camera in both the school and home environment, and only one child did not have access to a camera in either environment. These data confirmed that the artifacts did vary substantially in their familiarity to the children.

Child participants were randomly assigned to one of three conditions, namely the *sketch* condition (Figure 1), the *book* condition (Figure 2) or the *artifact* condition (Figure 3). By design, the random assignment was conducted in such a way that the number of children assigned to each group would be equal or nearly so.

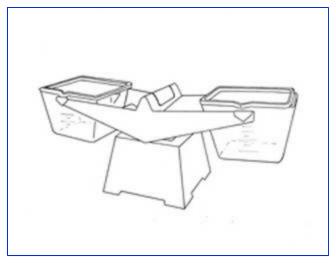


Figure 1. Sample of items presented in the sketch condition—Balance.

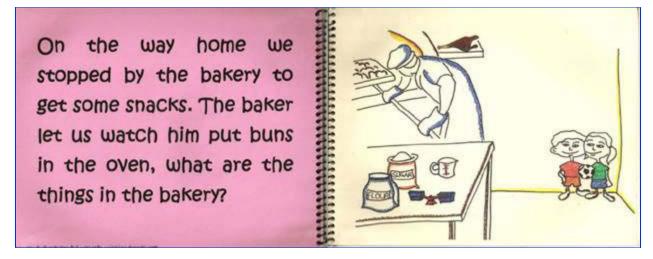


Figure 2. Sample of items presented in the book condition—Balance.

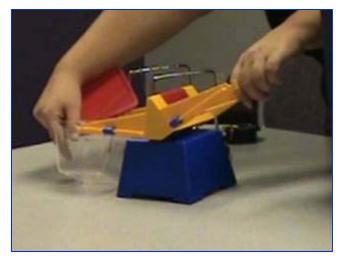


Figure 3. Sample of items presented in the artifacts condition—Balance.

Interviews were conducted in the preschool settings in enclosed spaces provided by the school

administration. Prior to video interviews, children were asked to fill out a digital questionnaire (using a laptop computer) regarding their interest in people and/or things (a child version of a Person-Thing Orientation scale; Habashi, Graziano, Evangelou, & Ngambeki, 2008), engineering-related behaviors and/or activities, and various professions. For every question, a prerecorded voice offered instructions to the child, asked a question accompanied by an image, and invited the child to respond by clicking on a button. When the child was asked to respond with Yes/No, the child would click on a $\sqrt{}$ or an X. When the child was asked to respond about likes or dislikes, the child would click on a smiling, a neutral, or a sad face icon. During this session, one researcher was present to assist the child with the use of laptop in case help was needed and also to manually note the child's responses for validity reasons.

Data from these questionnaires are not used in the present analyses. Upon completion of the digital questionnaire, children participated in the videotaped interview. Of the 35 interviews, 12 were from the artifact condition, 12 from the book condition, and 11 from the sketch condition.

Graduate research assistants were trained to conduct the interviews. The interviews were designed to be primarily open ended. Interviewers were trained to follow the children's lead, letting them dictate the topic of conversation in most cases. However, four key content areas were identified as key areas to focus on during the interview. For each item, if the child did not comment on any of the following topics, the interviewer asked about the topic:

- Identification: Do you know what this is? Do you know what this is called?
- Origin: I wonder where this came from. Do you know where I could find one? Do you know who makes it?
- Functionality: I wonder what I could do with that. Any ideas?
- Composition: Do you know what this is made of? What is this material?

During the artifact condition, half of the artifacts were laid out on a table at a time (because of space limitations). The children were permitted to interact with the artifacts in any order or combination. After the child completed interactions with the first set of artifacts, the other half of the artifacts were presented in the same way. The interactions in the sketch condition followed the same pattern, with half the sketches set out at a time. The book condition consisted of the interviewer reading the storybook to the child. Two artifacts were presented on each two-page spread. After reading the text on each page, the interviewer would ask the child about what was presented in the pictures.

Data Analysis

The present study reports on children's behavior as measured through a video coding system designed for the study. Upon completion of the data collection, a coding scheme was developed to be used during the video analysis of children's behavior. Two research assistants were trained for 2 months to code the video sessions. These coders had not been involved in the data collection process. InqScribe video analysis software was used for the video coding process. The coding included both an event coding approach, in which child behaviors were recorded as they happened (see <u>Appendix A</u> for a complete list of event codes) and a global coding approach, in which coders provided overall ratings of children's behaviors on 5-point Likert scales (see <u>Appendix B</u> for a complete list of global codes).

Following is a summary of the codes used in the present analyses. As part of the event coding, coders indicated when the children began "talking about, engaging with, and/or exploring" each artifact, and also when they ceased focusing on each artifact. These codes were used to determine

the total duration of engagement with each artifact. *Intended usage* was coded whenever the child used the artifact for its intended function, either through actions or words. For example, if the child held the camera up to his eye to take a picture, or if the child said "That's for taking pictures," *intended usage* would be coded. *Unintended usage* was coded whenever the child used the artifact in a novel way, something other than the function for which it was designed. For example, if the child held the compass to his wrist or said, "It's for telling time," *unintended usage* would be coded. Finally, coders rated the child's "overall interest, curiosity, and attentiveness directed to" each artifact on a 5-point scale.

Every video was independently coded by two separate coders, so two-way mixed effects intraclass correlations for average measures (Bartko, 1976) were used to measure reliability. A threshold of 0.7 was set by the research group as the critical value for reliability. Coded data that passed the 0.7 ICC threshold were included in the final analysis. Reliability for the duration codes used in these analyses ranged from .905 to .980. Reliability for the global interest codes in these analyses ranged from .721 to .914. Reliability for the frequency of intended and unintended usage in these analyses ranged from .701 to .966. Behaviors coded by each of the research assistants were then averaged for analysis.

Results

The results presented here address the question: *How do children's behaviors vary across the three conditions?* To answer that question, we used a series of MANOVA analyses. The dependent variables were the number of seconds that the child spent engaged with each different artifact. The multivariate test for this analysis was significant (Wilks' Lambda = .180, F = 3.624, p < .001). Main effects of condition were significant for Balance (F = 13.399, p < .001), Bellows (F = 5.286, p < .05), Blood pressure cuff (F = 6.170, p < .01), and Camera (F = 6.261, p < .01). In all four cases, Bonferroni comparisons indicated that the interaction time for each artifact was greater in the *tangible object condition* than in either the *book* or *sketch conditions*, which were not significantly different from one another. Estimated marginal means from the duration analysis are listed in Table 2.

Table 2
Estimated Marginal Means of Children's Duration of Interaction, Measured in Seconds, for Those Artifacts with Significant Main Effects*

	Tangible Object Condition	Book Condition	Sketch Condition
Balance	216 ^a	43 ^b	35 ^b
Bellows	107 ^a	42 ^b	49 ^b
Blood pressure cuff	117 ^a	47 ^b	48 ^b
Camera	75 ^a	40 ^b	43 ^b

^{*}Different superscripts indicate conditions that have significantly different durations of interaction from one another (p < .05).

Next, a MANOVA was conducted in which the dependent variables were the interest that the children showed in each artifact, as measured by the global codes. The multivariate test for this analysis was significant (Wilks' Lambda = .230, F = 3.388, p < .001). Main effects were significant for five artifacts: Balance (F = 4.021, p < .05), Bellows (F = 7.260, p < .01), Blood pressure cuff (F = 3.547, p < .05), Glow stick (F = 5.428, p < .01), and Newton's cradle (F = 3.793, p < .05). Bonferroni comparisons indicated that children's interest varied across the conditions in a number of different ways. For the Balance, children displayed more interest in the *artifact condition* than in

the *book condition*. For the Bellows, children displayed more interest in the *artifact condition* than in either the *book* or the *sketch condition*. For the Blood pressure cuff and Newton's cradle, children displayed more interest in the *sketch condition* than in the *book condition*. For the Glow stick, children displayed more interest during the *book condition* than in the *sketch condition*. Estimated marginal means from the interest analysis are listed in Table 3.

Table 3
Estimated Marginal Means of Children's Interest toward Artifacts, Measured Using a 1-5 Scale, Only for Those Artifacts with Significant Main Effects*

	Tangible Object Condition	Book Condition	Sketch Condition
Balance	3.5 ^a	2.3 ^b	2.8 ^{a,b}
Bellows	3.5 ^a	2.1 ^b	2.1 ^b
Blood pressure cuff	3.3 ^{a,b}	2.7 ^a	3.8 ^b
Glow stick	3.1 ^{a,b}	3.7 ^a	2.2 ^b
Newton's cradle	2.8 ^{a,b}	2.2 ^a	3.1 ^b

^{*}Different superscripts indicate conditions for which the measure of children's interest is significantly different from one another (p < .05).

The next aspect of children's behavior that was examined was the frequency with which children provided responses—either verbally or with gestures—indicating intended or unintended uses of the artifacts. In this paper, the term *intended usage* indicates that the artifact was used in the way that it would most probably be used by an adult, whereas *unintended usage* indicates that the child came up with a novel idea regarding the artifact's functionality. A MANOVA was conducted in which the dependent variables were the number of times that children indicated intended usages, or unintended usages, for each of the artifacts. The multivariate test for this analysis was significant (Wilks' Lambda = .050, F = 2.039, p < .05). Significant main effects were found for the frequencies of intended usages for Balance (F = 14.464, p < .001), Bellows (F = 10.459, p < .001), Castanets (F = 5.523, p < .05), and Newton's cradle (F = 7.364, p < .01). No significant effects emerged for the frequencies of unintended usages. For each of the four artifacts with significant effects, Bonferroni comparisons revealed that children demonstrated or mentioned intended usages of the artifacts more often in the *tangible object condition* than in either the *book* or *sketch condition*. Estimated marginal means for the intended usage analysis are presented in Table 4.

Table 4
Estimated Marginal Means of Frequencies of Children's Demonstration of Intended
Usage for Each Artifact with a Significant Main Effect*

	Artifact Condition	Book Condition	Sketch Condition
Balance	3.1 ^a	0.5 ^b	0.4 ^b
Bellows	2.0 ^a	0.1 ^b	0.1 ^b
Castanets	1.0 ^a	0.0 ^b	0.1 ^b
Newton's cradle	1.1 ^a	0.1 ^b	0.2 ^b

^{*}Different superscripts indicate conditions for which the frequency of children's demonstration of intended usage is significantly different from one another (p < .05).

Discussion

Children behaved differently in the three conditions in terms of the duration of their interactions,

the interest displayed in artifacts, and frequency of inferences about typical and novel uses.

Duration of Interaction

For all artifacts, children in the tangible object condition seemed to spend longer periods of time with the artifacts (and/or talking about them) than did the children in the sketch or book conditions. For some artifacts, the duration of interaction with the tangible object was 2 to 3 times longer than duration of discussion about the same artifact in the book or sketch conditions. Given that exploratory learning is under consideration in this paper, longer duration of interaction may indicate greater possibility for learning to occur.

When comparing the book and sketch conditions, no significant difference between the two appears with regard to duration of discussion about the artifact. It is possible that books and illustrations might be perceived, by young children, as more alike than different. The two sources share the symbolic aspect, and from a perceptual perspective, both operate on the 2-dimensional plane. It would therefore be worth researching whether varying the types of illustrations and books would result in different outcomes. Exploring whether the quality and style of the illustrations are associated with behavior variations might be a factor worth considering in subsequent studies. While informational text and accompanying illustrations are increasingly used to introduce children to nonfictional ideas (Duke, 2007), questions remain about the meaning-making capacity of young children (Pike et al., 2010). Exposing children to a combination of textual, pictorial, and real-object exploratory opportunities might be an optimal way of introducing new ideas because these learning modes are separate and distinct yet could all complement children's development in a classroom. Additional explanations for the lack of difference between children's responses to book and sketch might be the fact that some of the artifacts were not familiar to the children, making it difficult for them to associate a pictorial representation with a real artifact and construct inferences about them (DeLoache & Marzolf, 1992).

Interest Displayed in Specific Artifacts

Examining children's demonstration of interest toward specific artifacts, as perceived by the two coders, did not produce any consistent pattern of results. Interest demonstrated in each artifact may be partly dependent on characteristics of the artifacts themselves. Further exploration with an even larger assortment of artifacts could help us understand children's patterns of interest across the various modes of learning explored in this study. Interest may also be dependent on the quality and style of illustrations used in the book and sketch conditions or on aspects of story and context presented in the book condition. Clearly, additional research is needed to understand the potential importance of such variations.

Inferences about Usage

With regard to children's inferences about an artifact's usage, results show that of the three conditions, the tangible object condition was the one that led to significantly more instances of intended and unintended usage demonstration. Informal observations of the interviews suggest that children's demonstration of intended usages often did not occur as demonstration of prior knowledge but rather as a result of the children's interaction with and exploration of the artifact. As in the duration analysis, this finding may indicate that interaction with the real artifact provides greater opportunity for enhanced exploratory learning compared to interaction with sketch or book representations of the artifact. Examining the same results from an engineering perspective, instances in which children are coming up with intended, but not previously known, functions for

an artifact can be interpreted as demonstrations of knowledge synthesis, problem solving, and causal and teleological inferences—all of which are fundamental engineering skills.

Limitations of the Study

This study investigated children's exploration in three different conditions aiming to understand how young children approach tangible objects differently and how such explorations might encourage the introduction of engineering in early childhood education.

The small number of participants prevents us from being able to generalize our findings without additional research. Even though our sample was drawn from two diverse populations, a university-based laboratory preschool and Head Start preschool, other types of preschool settings were not included in the current study.

Our across-groups comparison allowed us to investigate the differences in the exploratory approaches, but a within-child comparison, where every child participated in each of the conditions, would have given us more insight into individual differences that might be confounding some of our results. Some of these limitations we plan on addressing in future studies.

Conclusion

Our findings support the notion of artifacts as developmentally significant in promoting cognition through exploration. The underlying developmental sequence of understanding form, function, and labeling, as part of a longer trajectory, suggests that promoting the use of artifacts for curricular purposes can rely on children's natural propensity for exploration. Incorporation of tangible objects into the curriculum would probably be most beneficial if the artifacts are part of a structure that focuses the children's exploration on salient features and pertinent questions around the objects. Such guided activities could also be used to promote children's knowledge about design and engineering because they can act as loci for meaningful classroom interaction and exploration.

In summary, we propose that artifacts provide an easy, accessible, and relevant way for young children to explore the engineered world around them. Tangible objects as well as representations of the artifacts in books and sketches are all viable means for exposing children to the products of engineering, but exploration of the actual artifacts themselves appears to accord advantages in terms of the duration of children's exploration and the extent to which they notice artifacts' typical functionality. This study is a very early attempt at exploring engineering-relevant learning for young children. Future directions in this area should include explorations with other artifact sets as well as the creation of more formalized engineering-relevant learning activities.

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Appendix A Event Codes Used for Coding Video Sessions in Each Condition

Codes	Definitions		
Book and Sketch Event Co	Book and Sketch Event Codes		
Object Initiation	The point at which the child begins talking about, engaging with, and/or exploring an artifact(s) Specify which artifacts(s).		
Talks/demonstrates intended way (specify)	The child talks about/uses the artifact in its intended way (e.g., uses the pencil to write on notepad, uses the camera to take a picture, etc.).		
Talks/demonstrates unintended way (specify)	The child talks about/uses the artifact in an unintended way (e.g., uses the compass as a watch, uses the tape recorder as a walkie-talkie or phone, etc.).		
Artifact Event Codes			
Object initiation (single, NONE, primary/secondary, shared/equal)	The point at which the child begins talking about, engaging with, and/or exploring an artifact (s) Specify which artifact(s). Two or more artifacts: Primary/secondary —specify if one appears to be the primary and the other the secondary		

	OR Equal —Specify if the artifacts appear to be equal.	
	Examples of two or more artifacts coded: 1: balance; 2: tape recorder OR Eq: lock box and pen.	
Uses object in intended way (specify)	The child uses the artifact in its intended way (e.g., uses the pencil to write on notepad, uses the camera to take a picture, etc.).	
	Specify how the child uses the artifact.	
Uses object in unintended (specify)	The child uses the artifact in an unintended way (e.g., uses the compass as a watch, uses the tape recorder as a walkie-talkie or phone, etc.).	
	Specify how the child uses the artifact.	
Puts down object or ceases action	The child stops whatever action he/she has been engaged in.	

Appendix B Global Codes Scales

Code's Title	Code's Description	
Child's overall interest in artifact(s) (coded once for every artifact)	Child's overall interest, curiosity, and attentiveness directed to the artifact; the extent of time he or she spends exploring, playing with, and asking questions about the artifact; overall level of interaction and engagement with the artifact.	
	N/A 1 2 3 4 5 /_ / / / / / Low High	
Goal Orientation	Goal orientation of child's actions; the extent to which the child's exploration of artifacts appears intentional, deliberate, and/or purposeful as opposed to appearing random, unguided, shallow, haphazard, and/or superficial.	
	1 2 3 4 5	
	Low Goal High Goal Orientation Orientation	
Engagement with Interviewer	Child's overall level of engagement, interaction, and collaboration with interviewer; the extent to which the child seeks interaction with the interviewer as opposed to remaining relatively independent, self-reliant, and/or uninvolved with the artifact.	
	1 2 3 4 5	
	Low High Engagement Engagement	
Avoidance toward artifact(s)	Child's overall avoidance toward exploring the artifacts; the extent to which the child appears cautious, reluctant, wary, evasive, and/or reticent about	

	exploring the artifacts as opposed to appearing eager, willing, and/or unreserved.	
	1 2 3 4 5	
	Low High Avoidance Avoidance	
Negativity toward Interviewer	Child's overall level of negativity toward interviewer; the extent to which the child is cooperative/uncooperative, polite/impolite, courteous/discourteous, friendly/unfriendly in his or her interaction with the interviewer.	
	1 2 3 4 5	
	Low High Negativity Negativity	