AC 2012-4098: THE ROLE OF CLASSROOM ARTIFACTS IN DEVELOPMENTAL ENGINEERING

Diana Bairaktarova, Purdue University, West Lafayette

Diana Bairaktarova is a doctoral student in engineering education at Purdue University. She obtained her B.S. and M.S. in mechanical engineering from Technical University in Sofia, Bulgaria, and M.B.A. degree from Hamline School of Business, Minnesota. Bairaktarova has more than a decade of engineering design experience, working as a Module design, and MMIC Test Engineer. Her research interest is in the area of developmental engineering, creativity, engineering design, and STEM education, and engineering ethics. Bairaktarova is currently working on a research project to study the ways young children exhibit an interest in engineering in their classrooms.

Dr. Demetra Evangelou, Purdue University, West Lafayette

Demetra Evangelou, Ph.D., is an Assistant Professor in the School of Engineering Education at Purdue University. She obtained her B.A. in psychology from Northeastern Illinois University, and a M.Ed. and Ph.D. in education from University of Illinois, Urbana-Champaign. She is a member of Sigma Xi Science Honor Society. Evangelou was awarded an NSF CAREER grant in 2009 and a Presidential Early Career Award for Scientists and Engineers (PECASE) in 2011. Evangelou's current research focuses on engineering thinking, developmental factors in engineering pedagogy, technological literacy, and human-artifact interactions.

Dr. Aikaterini Bagiati, Massachusetts Institute of Technology

After graduating with a diploma in electrical and computers engineering and a master's degree in advanced digital communication systems from Aristotle University in Thessaloniki, Greece, Aikaterini (Katerina) Bagiati was at 2008 one of the first graduate students to join the pioneer School of Engineering Education at Purdue University. At 2011, she acquired her doctoral degree in engineering education, and is currently working as a postdoctoral researcher at the Massachusetts Institute of Technology (MIT). Bagiati's research interests reside in the areas of developmental engineering, STEM curriculum development, educational robotics and software, teacher training, art and engineering design.

Dr. Jennifer Dobbs-Oates, Purdue University

Jennifer Dobbs-Oates is a Clinical Assistant Professor in the Department of Human Development and Family Studies. Her research bridges the disciplines of psychology and education, focusing on the learning, and behavior of preschool-aged children. She is interested in how young children's pre-academic skills (including pre-literacy, pre-numeracy, and precursors of engineering thinking) are connected to their psychological functioning (including behavior and social-emotional development). In particular, she is interested in children who are at risk for negative outcomes due to poverty and early behavior problems.

The role of classroom artifacts in developmental engineering

Diana Bairaktarova
School of Engineering Education
Purdue University

Demetra Evangelou
School of Engineering Education
Purdue University

Aikaterini Bagiati
Massachusetts Institute of Technology

Jenifer Dobbs-Oates
Department of Human Development and Family Studies
Purdue University

Background

Initial research findings examining the developmental appropriateness of introducing engineering at an early age suggest that activities and content relevant to engineering are appropriate for young children [1, 2]. Objects in children's environment appear to be influential in the development of engineering thinking as they contribute to exploratory learning [3] which is long recognized as a developmentally appropriate practice in early childhood education [4, 5]. The present study investigates how children and teachers use artifacts in exploratory learning.

In this paper we present a study designed to investigate the engineering environment present in preschool classroom. The study builds on prior research related to young children's interactions with artifacts and possible implications to developmental engineering. We focus on questions related to the preschool classroom environment such as: 1) what artifacts appear to be the most common in classrooms, according to the teachers' responses? 2) How do children interact with the artifacts that exist in the classroom? 3) Do the teachers use the existing artifacts to plan organized activities? 4) Are there any differences based on the mission of the preschool programs?

Study setting

Our study participants are 38 children aged 4 to 5 years and 15 teachers from 6 sites with 15 preschool classrooms in the Midwest. Three of the sites are university-affiliated and serve a population of well-educated families of moderate-to-high socioeconomic status. The other three sites are Head Start programs serving families of low socioeconomic status. The selection of the two types of programs was intentional, as observing these different settings would allow us to answer our last research question. In each setting participating teachers were asked to fill out questionnaires regarding the presence of specific familiar and unfamiliar artifacts in their classrooms. The artifacts used in this study (Table 1) were carefully selected to meet certain criteria. In all cases, artifacts met the definition of being human-made, were relatively inexpensive and easy to transport, provided some opportunity for the children to act on them, and were easy to manipulate.

Purpose of the study

In this study we focus and interpret the data through descriptive statistical analysis using the Classroom Engineering Environment Measure (CEEM) to indicate the use of artifacts in the six schools studied. We also use a qualitative approach to describe the different types of interactions between children and the artifacts according to the teachers. Findings from this study could be useful in informing and guiding current efforts to create developmentally appropriate engineering relevant curricula.

Method

Data Collection

Participating teachers completed a written Classroom Engineering Environment Measure (CEEM) questionnaire (see Appendix 1). The first part of the questionnaire contained questions about the presence/availability of 18 specific artifacts in the classroom; how the children interacted with these artifacts; and whether these artifacts were part of carefully structured class activities targeting a particular learning goal. The set of artifacts was selected so that they varied in the expected familiarity of the artifact to preschool children. 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. The second part of the questionnaire contained both yes/no and open-ended questions regarding teachers' attitudes and beliefs about engineering, beliefs about children's early exposure to engineering concepts and content, and the modes teachers might use to expose children to engineering concepts.

Data analysis

Data that included Yes/No answers were analyzed quantitatively using SPSS software for descriptive statistics and teachers' answers to open-ended questions were analyzed qualitatively using the open coding method.

Findings

Findings regarding the existence of specific artifacts in the classroom (see Table 1) show that many items were common in the two types of schools. The most common artifacts present in the classrooms were phone, balance, and tape recorder, followed by camera, tongs, and bells.

	N	Mean
Phone	36	0.97
Balance	35	0.89
Tape recorder	32	0.88
Camera	36	0.78
Tongs	40	0.77
Bells	40	0.77
Holepunch	40	0.72
Stethoscope	27	0.67
Stapler	40	0.65
Binoculars	35	0.57
Flashlight	38	0.5
Blood pressure cuff	31	0.48
Pencil sharpener	35	0.46
Lock box	38	0.39
Compass	34	0.35
Egg-beater	40	0.35
Castanets	28	0.18
Pencil	34	0.12
Bellows sharpener	31	0.06
Shoehorn	34	0.06
Newton's cradle	40	0.05
Glowstick	32	0

Table 1. Artifacts present in the classroom

How do children interact with the most common artifacts according to the teachers?

Phone: is available in dramatic play for the children to pretend to make and receive calls. Children usually talk to each other in dramatic play; they act as though they are calling someone. Some children repeat conversations from home. Children also act out fire safety behaviors, pretending to call 911. Phones resembling both cell phones and land-line phones are used.

Balance: Children place counters on the balance. Children may fill the bins of the balance or just push them up and down. They fill both sides of the balance with objects and transfer them back and forth. In planned activities children use the balance to compare/contrast weight and graph findings. In spontaneous play they weigh different objects on their own such as shells, counting bears, magnets, and balls. Children also choose to play with the balance using it to weigh play food or taking it along as a basket.
Tape Recorder: Children listen to stories recorded on tapes. Tapes are available in the listening center for daily use. Some teachers also reported that children listen to the story of the week in a large group when a tape is available.

How do artifacts differ in the two programs?
Analysis shows that there are some differences in the presence of different artifacts between the University Lab classrooms and Head Start classrooms. The phone, the most common artifact present in both schools, was present in 100% of the University classrooms and 90.0% of the Head Start classroom.

Schools	No Phone Present	Phone Present	Total
Head Start	1(10%)	9 (90%)	10
Lab school	0	5 (100%)	5

A *Balance* is 100% present in Head Start classrooms while it is 80% present in the University classrooms.

Schools	No Balance Present	Balance Present	Total
Head Start	0	10 (100%)	10
Lab school	1	4 (80%)	5

A *Tape recorder* is present 100% of the time in Head Start classrooms and 80% in the University Lab classrooms.

Schools	No Tape recorder Present	Tape recorder Present	Total
Heads Start	0	10 (100%)	10
Lab school	1	4 (80%)	5

Of Lab classrooms 4 (80%) had bells in the classroom. Of Head Start classrooms 7 (70 %) had bells in the classroom.

Schools	No Bells Present	Bells Present	Total
Head Start	3 (30%)	7 (70%)	10
Lab school	1 (20%)	4 (80%)	5

The above results show that the most commonly used artifacts tend to be present in both types of classrooms at similar rates. This is in regards to the presence of phone, balance, tape recorder, and bells. However, there are differences in comparing the presence of the camera, flashlight, and compass. The following statistics show these results.

Three (3) Lab schools (60%) had a camera in the classroom. All 10 Head Start (100.0%) had a camera in the classrooms.

Schools	No Camera Present	Camera Present	Total
Head Start	0	10 (100%)	10
Lab school	2 (40 %)	3 (60%)	5

A Flashlight is 70.0 % present in Head Start classrooms while is only almost half as often (40%) in the University Lab classrooms.

Schools	No Flashlight Present	Flashlight Present	Total
Head Start	3 (30%)	7 (70%)	10
Lab school	3 (60%)	2 (40%)	5

A compass is present only 20.0% in the University Lab classrooms, while 80.0 % of Head Starts classrooms had this artifact.

Schools	No Compass Present	Compass Present	Total
Head Start	2 (20%)	8 (80%)	10
Lab school	1 (80%)	4 (20%)	5

Which artifacts are used the most in planned activities?

Table 2 below shows the most used artifacts in planned activities are not necessarily the ones most commonly present in the classrooms. The analyses confirmed that castanets, staplers, pencil sharpeners, bells and flashlights are the artifacts teachers use most for planed classroom activities. Fifty percent of the teachers reported using binoculars, balances, and tongs in planned activities while phone and tape recorder, the most common artifacts in classroom presence were reported to be used less than 50% of the time in planned activity. Cameras and compasses were reported to be used 22% and 13%, respectively, by teachers in class time activity.

	N	Mean
Castanets	5	1
Stapler	8	0.88
Pencil sharpener	9	0.67
Bells	28	0.64
Flashlight	5	0.6
Egg-beater	9	0.56
Binoculars	20	0.55
Balance	31	0.55

Tongs	25	0.48
Tape recorder	26	0.46
Phone	36	0.36
Holepunch	17	0.24
Camera	23	0.22
Blood pressure cuff	11	0.18
Compass	8	0.13
Pencil	2	0
Shoehorn	0	
Glowstick	0	
Newton's cradle	0	
Lock box	0	
Bellows	0	

Table 2. Artifacts used for planned class activities

How do planned activities in Head Start programs are different from the Lab Schools?
Two of the teachers in Head Start reported using flashlights for planned activities comparing to one teacher in the Lab preschools. The use of this artifact in planned activities is used equally in both programs.

Schools	No Flashlight planned activity	Planned activity with Flashlight	Total
Head Start	8 (80%)	2 (20%)	10
Lab school	4 (80%)	1 (20%)	5

In two Lab classrooms the teachers used staplers for planned activities. Five teachers in Head Start (50%) used a stapler in a planned activity.

Schools	No Stapler planned activity	Planned activity with Stapler	Total
Head Start	5 (50%)	5 (50%)	10
Lab school	3 (60%)	2 (40%)	5

Bells are almost equally used in all classrooms, 60% for planned activities in the Lab School settings and 70 % for planned activities in the Head Start classrooms.

Schools	No Bells planned activity	Planned activity with Bells	Total
Head Start	3 (30%)	7 (70%)	10
Lab school	2 (40%)	3 (60%)	5

Planned activities with Tongs are used by the teachers in the Lab School classrooms by 60 % and not used for planned activities in Head Start classrooms at all.

Schools	No Tongs planned activity	Planned activity with Tongs	Total
Head Start	10 (100%)	0	10
Lab school	2 (40%)	3 (60%)	5

What do teachers think about engineering in the early child classroom?
According to the Classroom Engineering Environment Measure (CEEM) questionnaire, none of the 15 teachers have an engineering background. When asked what engineering is, they described it as the science of creating something. A sample of the teachers' responses follows:

> *"Engineering is figuring out how and why things work";"it is development of machines and ideas; designing and operating structures"; "making things/structures work"; "figuring out and exploring the way things work and how they can work better"; "making/developing product/solution based on clients' needs/wants"* [6].

Almost all teachers think engineering is important to be introduced to young children because engineering encourages teamwork, problem solving, and thinking outside of the box.

> *"Engineering incorporates a lot of what makes the world work, problem solving, making predictions, measuring outcomes, etc"; "To understand the world around them, preschoolers should get a basic knowledge of how things work";" children need to know how things work and understand why an object is used for something";"they can learn how to design things and make things work"* [6].

Teachers also think that introducing engineering at that early age can spark an interest. The teachers in all Lab schools and Head Start think engineering is important with exception of only one teacher from Head Start school who thought engineering is not important to be introduced to young children because "*sometimes the contexts are not age appropriate*"[6].

When teachers were asked if they identify and describe the characteristics of natural materials to children, 20% of the teachers from Head Start schools responded positively while 80% of the teachers of the Lab schools responded in the affirmative. Teachers talk about natural materials during group time. The materials used are often materials for observing/investigating and for the purpose of helping children enrich their vocabulary. Teachers discuss with children where a material comes from, how it is used, what the physical parameters are, and how it feels. A few examples of how the teachers teach children about natural materials:

> "*Wood working- make things; coal- investigate how it is used for fuel"; "cloth- used for clothing and drawing, etc"; "we get wool from sheep and it keeps us warm"; "toys are made from materials; clothing- discuss how our clothes came to be, or blankets";" wood- houses, boats (giving tree)"; "if natural materials come up in discussion we discuss its uses and talk about where things come from- napkin, forks"*[6].

In response to the question "Do you identify and describe the characteristics of human-made materials?" again 20% of the teachers from Head Start schools responded positively compared to 60% positive responses from the teachers of the Lab schools. Teachers describe human-made materials only if the material is being used in classroom and the child has questions. Teachers

discuss how human made materials are used when children ask about, for example, drinking cups and how it is important to not throw them away as it is not good for the environment. Teachers have discussed styrofoam and its use and how to reuse and recycle items.

When teachers were asked if they identify and describe how tools and materials can be used to create simple structures, 80% of the Lab school teachers said yes. They describe this topic mostly through open exploration and teacher-directed activities such as art/creative activities and discussions of how the children can be builders and crafters. In Head Start schools, 50% of the teachers identify and describe how tools and materials can be used to create simple structures. Some examples include: children make multiple objects out of paper; children use toothpicks to make food sculptures. Teachers introduce daily or weekly use of scissors- for demonstrations to children or assisting them in activities; rulers- have demonstrated how to measure objects; paper is always in use and available in the classroom.

> *"We create using these materials". "We measure objects with rulers". "We use scissors to cut things out and tape to put things up/together"* [6].

In response to the question "Do you identify and describe the characteristics of simple machines?" 20% of the teachers from Head Start schools responded positively in comparison to 80% positive responses of the teachers of the Lab schools. In Head Start schools teachers identify and describe the characteristics of simple machines mostly through modeling and open exploration.

> *"We have gears throughout the semester and talk about how one makes the others go". "We allow for real life experiences, hands on, using daily, etc. use in vocabulary and use in daily life"*[6].

In the Lab schools some of the examples of discussing simple machines are:

> *"The children build ramps for their cars in blocks. Some of the manipulatives are gears". "When building in the block areas we talk about ramps and build different heights of ramps". "We had a tub of gears and when you put them on the board and turn the handle, they all worked together"*[6].

Conclusions

To successfully introduce engineering in the early years, we must first understand what constitutes appropriate content and pedagogy for the children of this age. "Teacher preparation can then follow suit based on that understanding" [7]. A simple and teacher-friendly strategy to introduce engineering to the early childhood curriculum would be to start by showing teachers how curricula and tools they are already familiar with can promote engineering learning. Despite the fact that a variety of artifacts appear to be present both in the Lab and the Head Start schools, teachers do not seem to be taking full advantage of them in order to introduce engineering to their students. The use of artifacts has an established history in early childhood education. The very nature of artifacts as the results of engineering ingenuity and labor [8], provides an opportunity for the teachers to introduce engineering to the children in a way that is "concrete, accessible and relevant." [5] However, this opportunity appears to be almost completely ignored. In the rare cases that such an attempt is mentioned, it is described as moving through some very literal paths, such as "*I am discussing engineering if I see a gear*" [6] or "*through building*" [6] and these attempts are mostly identified in the University-based Lab

schools where engineering is particularly salient as the University is well-known as one of the top ten engineering schools in the nation.

We hope that this research may inspire early engineering curriculum developers and preschool teachers to promote engineering-related outcomes using everyday classroom materials. Furthermore, having acquired an understanding of the landscape describing the existence of various artifacts in early childhood classrooms, we hope that this study may function as starting point towards reevaluating the use of popular and unpopular or even completely unfamiliar artifacts. It may be appropriate to consider shifting the existing use of artifacts in preschool classroom to achieve a developmentally appropriate introduction to early engineering.

Bibliography:

[1] Brophy, S. and D. Evangelou (2007). "Precursors to engineering thinking (PET)." *In Proceedings of the Annual Conference of the American Society of Engineering Education.* Washington DC: ASEE.

[2] Bagiati, A**.** (2011). *Early engineering: A developmentally appropriate curriculum for young children. (Doctoral Dissertation)* Purdue University.

[3] Bagiati A. and D. Evangelou (2011). Starting young- A developmentally appropriate curriculum for early education. Proceedings *of the Research in Engineering Education Symposium 2011, Madrid, Spain, October 4-7, 2011*.

[4] Evangelou, D. (2010). Guest Editorial. *Early Childhood Research and Practice, 12.* http://ecrp.uiuc.edu/v12n2/evangelou.html [Last reviewed 01/09/12].

[5] Evangelou, D., Dobbs-Oates, J., Bagiati, A., Liang, S., and J.Y. Choi (2010). Talking about artifacts: Preschool children's explorations with sketches, stories, and tangible objects. *Early Childhood Research and Practice*, Vol.12 (2).

[6] Teachers responses to Classroom Engineering Environment Measure (CEEM) questionnaire.

[7] Bagiati, A., Liang, S., Choi, J. Y., Dobbs-Oates, J., Evangelou, D. Predicting Preschoolers Interest in Engineering Using the DECA Scale. *Society for Research in Child Development Biennial Meeting*, Montreal, Canada, 2011.

[8] Petroski, Henry. (1992). The evolution of artifacts. *American Scientist, 80*(5), 416-420.

APPENDIX 1

Classroom Engineering Environment Measure (CEEM) questionnaire

Do you have a background in engineering?

Yes ☐ No ☐

1. If yes, describe your engineering background.

2. Describe what you understand engineering to be.

3. Do you think it is important for children at this age to learn about engineering?

Yes ☐ No ☐

4. Why or why not?

5. Do you participate in the following activities with the children in your classroom?

i. Do you identify and describe the characteristics of natural materials (for example, silk, wood, etc.)?

Yes ☐ No ☐

If yes, describe how or give an example:

ii. Do you identify and describe the characteristics of human made materials (for example, Styrofoam, polyester, etc.)?

Yes ☐ No ☐

If yes, describe how or give an example:

iii. Do you identify and describe some uses of natural materials (for example, silk, wood, etc.)?

Yes ☐ No ☐

If yes, describe how or give an example:

iv. Do you identify and describe some uses of human made materials (for example, Styrofoam, polyester, etc.)?

Yes ☐ No ☐

If yes, describe how or give an example:

v. Do you identify and describe how tools and materials (for example, scissors, toothpicks, rulers, tape, paper) can be used to create simple structures?

Yes ☐ No ☐

If yes, describe how or give an example:

vi. Do you identify and describe the characteristics of simple machines (for example, gears, levers, ramps)?

Yes ☐ No ☐

If yes, describe how or give an example: