AC 2011-42: INTRODUCING YOUNG CHILDREN TO ENGINEERING THROUGH EARLY STEM LITERACY

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Introducing Young Children to Engineering through Early STEM Literacy: Method and Preliminary Assessments

Introduction

Engineering education (and outreach) at the youngest ages is largely predicated on hands-on activities using manipulatives such as *Legos*™ that promote innovation and creativity [1, 2], two cornerstones of any engineer. Even with these activities integrated into selected curriculums, on average less than 10% of instructional time is spent teaching science in the early grades and even less addressing engineering [3, 4]. One explanation may be that there is significant emphasis on language and literacy skills in these early years and there are limited engineering-related texts written for this age group. The impact that engineering literature may have on engineering learning is therefore not well studied. Two very informative reports on this topic are: (1) the *Engineering is Elementary* report detailing assessing elementary students' understanding of engineering and technology concepts [5] and Taylor and Smith's recent examination of writing assessments geared toward elementary level children [6]. These reports describe large scale assessments approaches tailored mainly toward hands on activities. The key is not simply to test for comprehension but to examine the science, technology, engineering, and mathematics (STEM) thinking of each student. This study examines the development of an engineering text targeting early elementary grade levels and performs an early assessment of the potential impact of the literature on engineering thinking. The literature developed in this project may complement the *Engineering is Elementary* curriculum such that formal integration of the literature may enhance early childhood learning.

Science can be described as an enterprise that builds and organizes knowledge in the form of testable explanations and predications about the world [7-8]. Engineering can be described as part investigative scientist and part creative inventor with the goal of solving practical problems. Engineering is not synonymous with science but uniquely distinct yet synergistically entwined with overlapping epistemologies. While there are many non-fiction science based picture books that can complement a science based hands-on activity for young children, there are virtually no books introducing young children to the world of engineering. Also, there are many studies that explore the connection between learning *science* through literacy and learning through activity-based, hands-on experiences and the references sited here are just a small collection of representative articles [8-14]. These studies suggest that in order for children to understand the scientific world, they need to use both the hands-on and literary elements of scientific activity; the two elements interact and influence each other significantly [8-14]. The objective of this study is to assess how literature influences children's thinking about *engineering* and observe through illustrative data the connection children make between science and engineering.

In particular, this study targets 3rd grade students approximately 8-9 years of age participating in a summer school program at two different school districts in the West Texas region. There are 22 students in each classroom. The literacy level of this age group and grade level can be classified as transitional readers; they are able to read unknown text with some independence but benefit from a story introduction given by a teacher [15]. They are able to use meaning, grammatical and letter cues to complete sentences and recognize a large number of frequently used words on sight and use pictures in a limited way while reading [15]. Examining this developmental reading level will enable a link between how engineering literature is presented and how children process the information. The research conducted here may enable the creation of improved books targeting this specific developmental level for which there are severally limited engineering books available currently.

The idea that engineering learning could be promoted through literature is supported by the theoretical perspectives of situated cognition and distributed cognition [16, 17]. Brown et al [16] explain that from a situated cognition perspective, engineering activities can be described as socio-cultural such that a person's cognition is enmeshed with a situation and activity in a community of practice. In other words, *concepts* are formed by both *culture* and *activity*, and the meaningfulness of learning is constrained by all three conditions [16, 17]. In this way, the literature needs to present an engineering concept in the framework of a culture (i.e., characters in a story) ensnarled in an activity (i.e., venturing through the story's plot).

Methods

With over 15 years of combined engineering experience, the authors developed and published an engaging, interactive children's book Engineering Elephants [18] which introduces the engineering profession as well as fundamental Science, Technology, Engineering, and Mathematics (STEM) concepts to young children. This was a necessary first step for this study as there are very few engineering based children's books suitable for this grade level. The *Engineering is Elementary* series introduces children to different engineering careers. However, Engineering Elephants is different in its approach which is a whimsical, highly-imaginary picture book with rhyming lyrics. Engineering Elephants teaches children about relevant topics such as nanotechnology, renewable energy, and prosthetics by engaging them through an interactive journey of an elephant and his questioning of the world around him. The authors worked with early childhood literacy experts, science museums, and local school districts to strategically develop the text. The text was composed using the language of science (i.e., asking questions) and introduces vocabulary relevant to science and math using a narrative text structure and lyrical pattern children are familiar with. The feedback from parents, teachers, and children indicates that children love the opportunity to scream 'No!' on every other page as well as the rhyming pattern. Kids like the rhyming-lyrical text because they can guess what comes next. A very important component of a children's book is the story board presentation. We selected an illustrator, Ms. Holly Steward, who specializes in water color artwork with bright colors and simplistic images to convey meaningful concepts in an elementary fashion. Ms. Steward is also a Kindergarten teacher with valuable insight into the perceptions of early elementary readers.

Engineering Elephants is an award winning finalist in the Children's Non-Fiction category of the "Best Books 2010" Awards, sponsored by USA Book News [17] and within its first year of circulation, we have found that the story appeals to a multi-age level audience. For Pre-K through 2nd grade students, the bright yet simplistic water color illustrations coupled with repetitive interactive questions captivate and engage the child (see Fig. 1). By 3rd and 4th grade the text is simplistic enough for the student to independently read and the book can also be used as a corner-stone for the further development of math and science concepts introduced.

While our initial intent was for Engineering Elephants [18] to be shared by parents with their children (i.e., specifically targeting 2-7 year olds), we have found it plays a significant role when directly integrated into a classroom. A school district in West Texas designed elementary summer school curricula using Engineering Elephants [18] as the centerpiece. Because of the multifaceted concepts presented in the book, Engineering Elephants [18] served as a jumping off point for educators to create literacy rich curricula centered on their core STEM requirements. In particular, 3rd-5th grade summer school students (i.e., ranging in age from 8-12 years) in Slaton Independent School District (ISD) (Slaton, Texas) showed an estimated 80 % improvement on their practice Texas Assessment of Knowledge and Skills (TAKS) science tests after having Engineering Elephants [18] integrated into their summer school curriculum [23].

Figure 1: Excerpts from Engineering Elephants that illustrate the interactive, engaging presentation of engineering concepts tailored to young ages.

While we exposed a variety of age groups and grade levels to this story, this study focuses on findings limited to the 3rd grade level (i.e., transitional readers). Three groups of students from two different school districts in West Texas (for a total of 6 groups of students) were used for this pilot program. The students were all from similar demographic and socioeconomic profiles and use the same common science curriculum (C-SCOPE) which is implemented in almost every public elementary school in the state of Texas. One school is 42.3% Hispanic, 49% White, and 7.8% Black and the other is 53.9% Hispanic, 32.7% White, and 13.3% Black. There were only two students in the entire group who had been exposed to engineering through a parent or relative and their work is not presented here. The purpose of this activity was not only to evaluate the impact on engineering learning but also to enhance students' creativity while spurring their excitement about engineering. For this reason, our analysis was based on illustrative data because drawings are commonly used to interpret qualitative knowledge gains for science and quantify creativity [20-21]. Similarly, this data may also shed light on engineering thinking. This is a preliminary, qualitative analysis to better understand the impact of this type of text on engineering learning.

Because young children learn science through literacy in combination with visual construction of scientific concepts, examination of illustrations and drawings can used as a form of learning assessment [18]. When young children interact with science literature through reading and writing, they make meaning in a range of modes of communication including visual images [20-21]. As early as kindergarten, the National Science Education Standards (NRC 1996) [22] recommend developing a child's observational skills and abilities to notice and describe patterns in data. Vareles [6] states that "although early-elementary-grade children may not be ready to develop sophisticated ways of thinking and talking about some science topics, we believe they must be given the opportunities to engage in observing and experimenting and in developing ways to understand and explain what is going on in the world." According to Kress [21], "children actively experiment with the representational sources of word and image, and with the ways in which they can be combined. Their drawings are not just illustrations of a verbal art, not just 'creative embellishment'; they are part of a 'multimodally' conceived text, a semiotic interplay in which each mode, the verbal and the visual, is given a defined and equal role to play." When children compose pictures, they employ visual-design features to express understandings. They use color, size, shape, and position of objects to express important concepts and to depict action and perspective [9-10].

Each group of students was asked to draw what they would design if they were an engineer and explain their picture with corresponding text.

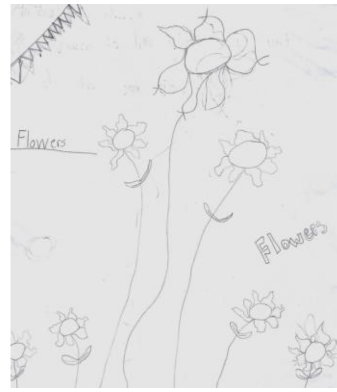
- The first group (identified as Group 1) had *not* been exposed to engineering through reading and discussion of <u>Engineering Elephants</u> or through any other means within the classroom setting.
- The second group (identified as Group 2) had been exposed *only* through the reading and class discussion of <u>Engineering Elephants</u>.
- The final group of students (identified as Group 3) participated in a program which included reading and discussion of <u>Engineering Elephants</u> *in combination* with hands-on experiments and field trips.

Results

Figures 2-4 show representative illustrations from all groups.

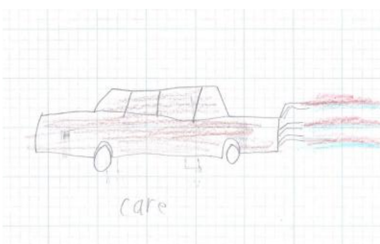
A

B



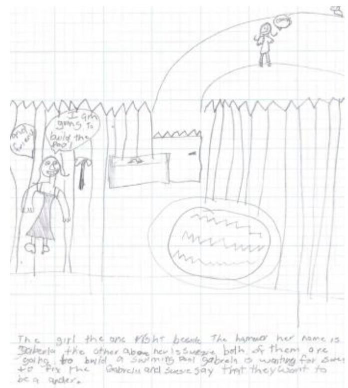
C

Figure 2: Engineering illustration by student not exposed to Engineering Elephants. A. Text reads “*Me Driving a Train in the Daytime*”, B: Text reads “*I’m putting coal in the back of the train*”, C: Text reads “*Flowers—An engineer is like someone who grows something*”



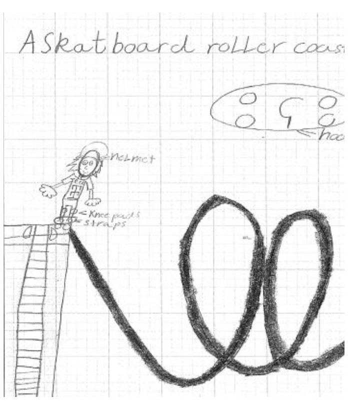
A

B



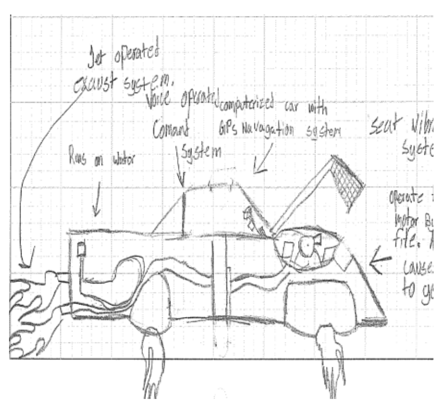
C

Figure 3: Engineering illustration by student exposed to Engineering Elephants through class reading and discussion. A. Text reads “*Engineers make cars and rockets*”, 3B: Text reads “*A firework becoming a rainbow*”, C: Text reads “*The girl the one right beside the hammer her name is gabrela the other above her is suesie, both of them are going to build a swimming pool gabrela is waiting for suesie grabrela and Susie say that they want to be an angr (engineer).*”



A

B



C

Figure 4: Engineering illustration by student exposed to Engineering Elephants through class reading and discussion as well as summer school program with hands-on activities. A. Text reads "*A skatboard roller coaster*" B: Text reads "*Environment Trash picker upper*" C: Text reads "*Jet operated exaust system. Valve operated computerized car with GPS navigation system. Command system. Runs on water. Seat vibration system. Operate the motor by putting fire and causes car to go up.*"

Discussion

The children's drawings show the advanced ways that they think about ideas. When asked to draw what they would design when they were an engineer, the students did not hesitate to immediately picture themselves in this role. Two of the students who had never been exposed to Engineering Elephants or in any type of classroom instruction (Figs. 2 A and B) held the common belief [10] that engineers drive trains or work on trains. The student who drew the flowers (Fig. 2C) appears to be unable to make any connection to engineering at all, which is also very typical of this grade level.

The students that had read Engineering Elephants in class and participated in class discussion about engineering showed elevated knowledge in their drawings with direct correlations to topics covered in the book. For example, Fig. 3A shows a car and a rocket, and Fig. 3B shows a firework becoming a rainbow. Engineering Elephants uses a car to introduce drag, a rocket to teach about solid and liquid fuels, and fireworks to explain combustion. It is encouraging that the students are obviously learning through this text because their drawings show they have begun to develop concrete ideas about engineering.

The final group of students had several interactions with Engineering Elephants including hands-on activities and field trips that tied directly to the book. It is very clear that these students are not only making connections with the topics discussed in Engineering Elephants but are also creating new ideas of their own. It is exciting to see these children start to allow their mind to advance past what is currently possible and their creativity has been stoked by the inspiring literature and complementary activities. For example, instead of a roller coaster, a skateboard roller coaster (Fig. 4A)! Instead of a typical car, a water-driven, jet-operated, car with vibrating seats (Fig. 4C). These kids are ready to advance the field of engineering!

Conclusions

The purpose behind the development and use of Engineering Elephants is not mastery of all engineering concepts, but to introduce children to the idea of engineering and problem solving and encourage them to begin to imagine all of the things that they could potentially create. Results from integrating Engineering Elephants into 3rd grade classrooms show that engineering literature inspires heightened levels of creativity and instilled a concrete sense for what engineers can do. When the book is complemented with hands on activities and field trips, the level of detail and thinking interpreted from the illustrative data is further increased. These results show the need for engineering based literature that complements current scientific curriculum such that the stories can more easily be integrated into every classroom and foster early enthusiasm for engineering.

Acknowledgements
The authors are grateful for the participation and contributions of the many administrators, teachers and students in Canyon Independent School District (ISD) and Slaton ISD, Texas. We are also thankful for support and collaboration with Dr. Dean Fontenot, the Director of the Texas Science, Technology, Engineering and Math Center (T-STEM) center housed at Texas Tech University for facilitating the incorporation of this study into Slaton ISD.

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