

Successful methods for introducing engineering into the first grade classroom

Sue Ann Kearns, Catherine Rogers, Judy Barsosky, Merredith Portsmore, Chris Rogers,
Tufts University / Lincoln Public Schools

Abstract

Children in early elementary school are natural engineers – building and taking apart anything they can get their hands on. Introducing engineering into the classroom at this early age takes advantage of their interest to excite and engage them in math, science, and technology learning. Moreover, it plants the seed for an interest in engineering and can start to combat some of the gender issues associated with engineering. Several members of Tufts University's Center For Engineering Educational Outreach (CEEEO) have worked for the past few years at the first grade level to bring engineering into the classroom. Using LEGO materials, CEEEO members have collaborated with teachers to create a collection of activities that introduce first graders to forces, frictions, the engineering design process, as well as reinforce math and reading concepts. Activities range from building walls and chairs to discuss forces -- to creating ramp climbing cars to discuss gear ratios and torque -- to producing a LEGO based movie of Dr. Seuss' *The Lorax*.. This paper will describe the process of creating the activities as well as support required to implement engineering activities at the first grade level.

Introduction

The primary goal of Tufts University's Center for Engineering Educational Outreach (CEEEO) is to bring engineering into the K-12 classroom. Constantly building and taking things apart to gain a better understanding of how they work, children are natural engineers. By bringing engineering into the classroom, these natural instincts can be capitalized on to excite children about math and science and interest them in a future careers in science , math , and engineering. Engineering also provides a way to integrate subjects and to show students the real world applications of the subjects they are learning. It lends itself to the development of personally meaningful projects that the students can relate to and hence are more likely to find motivating and engaging.^{1,2} At the state level in Massachusetts the importance of engineering is supported by the State Board of Education's recent adoption of new science standards that make engineering a part of the required state curriculum.³

The CEEEO, located in Medford, Massachusetts, works with several area schools and teachers to bring engineering into the classroom. Looking specifically at the first grade teachers we have worked with in a suburban school in Eastern Massachusetts is of particular interest because

engineering is often only associated with higher grades. The first grade teachers we have been working with generally have advanced degrees in education with little or now background in math, science, or engineering. While very receptive to the prospect of providing new opportunities for their students, they weren't quite sure what engineering was or what it had to offer initially. This paper will look at the materials and process that helped both the teachers and the students understand engineering

Materials

To make engineering a hands-on experience in first grade classrooms it was necessary to have materials that the students could construct a number of different types of projects with. While different household and classroom items could be used to demonstrate various topics, it was far easier for classroom implementation and management to have a kit of materials for groups of 2 students to work with. A set of Lego materials was selected for use in the first grade environment. The kit, entitled, Motorized Simple Machines (9645), contains over 200 pieces and retails for around \$100.⁴ Generally targeted at older students, initial testing showed that the majority of first grade students could easily use the kits.

Lego kits were chosen for their quality, durability, and range of "real world" pieces. The Motorized Simple Machine kit, developed by Lego DACTA, contain a motor, gears, pulleys, cams, axles, and various building pieces like bricks and beams. The kits can easily be expanded using existing classroom Lego pieces or inexpensive buckets of LEGO elements from a toy store.

Teacher Training

With materials in hand the first step was to train the teachers, this was initially accomplished through summer workshops. The summer workshops held for one or two weeks typically had the first grade teachers attending with other K-8 teachers. All workshop attendees would spend time working on challenges that examined engineering, math and physics. Challenges included building a car that would travel the furthest when started from the top of a ramp, a crank that would raise a weight, and a model of a working airport. From these challenges, teachers explored friction, conservation of energy, gear ratios, torque, and engineering systems. Teachers left the first summer workshop with a better understanding of physics concepts and engineering but without a solid plan on how they could incorporate these concepts into their classroom. A number of the first grade teachers implemented a selection of projects over the course of the year in their class but were still unsure of exactly how engineering and the materials fit into their curriculum. Many expressed that they felt much of what they had learned in the workshop was too advanced for their students and they were unsure of how to scale it to the first grade level.

High teacher turnover in subsequent years yielded a number of classrooms that had the necessary materials but whose teachers had no idea how to use them. At this point we implemented monthly meetings as well as regular classroom visits and assistance to help with projects. Monthly meetings helped to create a dialog between the teachers and us as to what projects had been attempted and how they had been successful. The meeting also facilitated communication between teachers, especially those who taught the same grade, and helped to build resources for

ideas and assistance. When time permitted, mini projects were introduced at the meetings to help teachers review topics like gears or to introduce them to new concepts or building techniques.

The in-class assistance that accompanied regular classroom visits was strongly received by many of the teachers. However, in some cases it seemed that the person from the CEEO assisting was viewed more as a specialist who would implement the activity and run the activity. Many of the teachers who had a CEEO assistant hadn't attended a workshop and felt that they weren't prepared to lead the class. It was initially difficult to find a balance between specialist and assistant. However, over the course of the year most classrooms were able to find a balance. The key to the balance was in clear communication and careful planning of the activity for the following activities. CEEO members would help in brainstorming new activities, outlining skills and materials that should be presented, and demonstrating or explaining physics or engineering concepts that would be needed for a new activity. With this careful preparation, teachers seemed to be more confident in presenting and running activities.

The past two years have yielded a more collaborative relationship between teachers and CEEO assistants with the two working together to identify a sequence of activities and skills that the students should engage in and learn over the year. One of the intended products of that collaboration is comprehensive documentation of the first grade activities that can assist new first grade teachers in the school. In addition, the activities are being added to the CEEO's growing web database of activities for broader dissemination.⁶

In the classroom

The goal of Lego based engineering activities is to give students an understanding of basic engineering concepts, the engineering design process, and hands-on experiences that will facilitate later learning. Students enter first grade with different levels of experience with Lego building materials and few, if any, have used them as a learning tool. The first few sessions of Lego engineering activities are dedicated to giving all students a chance to gain experience and explore the pieces. We have found that taking the time to get all students to similar level of expertise helps to facilitate later activities. Pieces are introduced by their "proper" name and where they appear in real world constructions is discussed (Figure 1). Students are very interested in the idea of performing tasks and challenges that are similar to those of real engineers.

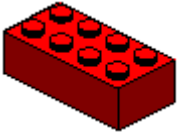
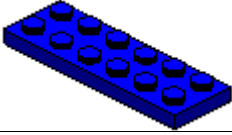
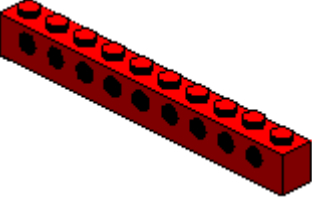



	BRICK – seen in school walls, house foundations...
	PLATE – seen on roof tops, floors, doors...
	BEAM – seen in the barns, in houses without walls, at the gym (balance beams)...
	TIRES – seen on cars, trucks, motorcycles, bikes...
	HUBS – seen on tires and pulleys...
	Axle – seen on cars, bikes, trucks, playground equipment

Figure 1: Sample of pieces initially presented to students.

Students typically work in groups of 2 students per kit. We have found that larger groups work poorly in first grade where sharing and compromise are being learned. The time reserved for engineering activities varies depending on the teacher. Typically, anywhere from 1 hour a week to 1 1/2 hours twice a month is reserved for Lego engineering activities. While more time is preferable, much can still be done in biweekly meetings. Though it is beneficial if those meetings are sequential so that continuity is maintained..

Initial activities work to developing students' ability and understanding of sturdy structures (Figure 2). Discussions focus on what keeps a wall from falling over or a chair from falling down. Very basic concepts of force are presented to the students by evaluating what happens to their constructions in different situations. Nearly all projects require sturdy structures so it is important for students to learn how to build them and how they work. The activities in Figure 2 continue to evolve as our understanding of students' use of the Lego pieces improves and we are better able to create activities that help them understand forces and support.

Activity	Description	Lego Building Techniques
The “Flick” Wall	Build a wall that can withstand the 1 finger, 2 finger, & 3 finger flick test	Overlapping bricks
The Marshmallow Box	Build a box that will keep a small bag of marshmallows from being squished by a heavy book placed on top	Building corners, using beams and connector pegs
The Falling House	Build a house that can be dropped from the table and not break	Building corners, reinforcing beams
A Chair for Mr. Bear	Build a chair that will keep a floppy stuffed animal from falling in all areas	Using beams and connector pegs, Using axles and bushings

Figure 2 : A selection of activities to start first graders with

All activities are presented to the class as an engineering challenge that each group needs to design a solution for. If the problem has specific constraints or requirements those are discussed in depth as well. The chair, in “A Chair For Mr. Bear” for example, must be large enough to accommodate the stuffed animal being used. After the students have completed the challenge the class forms a circle and shares their designs. Each group presents their design , how it accomplished the challenge presented, and how they “engineered” their solution. (Figure 3). The teacher will guide their presentation with inquiries as to which piece provides key support and which piece would cause the design to fall apart if removed. Students also highlight which part of the construction was difficult to make and what interesting building techniques they used. Groups that worked well and exchanged and integrated ideas are highlighted to promote teamwork and sharing. The majority of the activities have been designed with additional extension challenges that can be given to students who finish quickly. A lid that can open or close can be added to “ The Marshmallow Box” and Mr. Bear can have a cup holder added to his chair in “A Chair for Mr. Bear”.



Figure 3 : A student chair for Mr. Bear, complete with cup holder.

The activities transition from sturdy structures to motion using gears and pulleys. Teachers demonstrate how pulleys and gears work to the class and ask the class to make observations (Figure 4). “What happens when I have a big gear/pulley and a little gear/pulley? What happens when I turn the little one? The big one?” The majority of first grade students are easily able to determine that when a large gear and a small gear are meshed together turning the larger one will make the smaller gear turn very quickly and that turning the small gear makes the big gear turn very slowly. They are able to translate that to applications and recommend which gear be turned if a snail car was being constructed or a speedy train. They spend time engaged in activities learning to connect pulleys and mesh gears before continuing on to applications of their new knowledge and skills (Figure 5). These projects, as the earlier ones are presented and shared as a class.

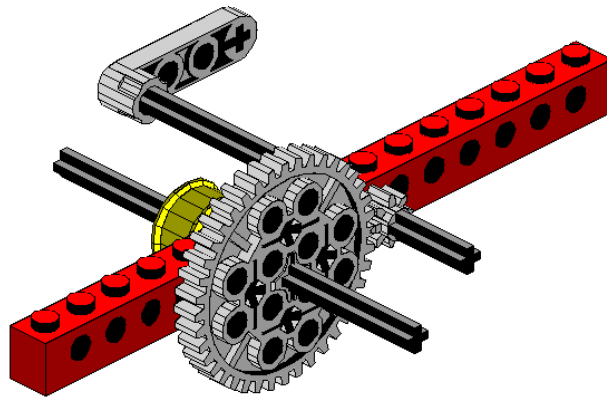


Figure 4: A sample setup used to demonstrate gears to students

The first application of gear and pulley knowledge is to build a car complete with a motor. This activity is connected with sturdy structures as their car must be able to survive a drop from the knee of the teacher. This helps students to keep their knowledge of sturdy structure fresh and to help avoid the frustration of building a car where the motor always falls off. Students gain experience attaching and positioning their motors. Once they have a sturdy working car they can begin to explore friction and torque through the snow plow, steep cookie sheet and lunar rover activities. The lunar rover is also linked with the science curriculum which explores the moon and the related NASA missions.

Activity	Description	Lego Building Techniques
The Pulley Wall*	Connect as many pulley as you can together on a wall so that when you turn one axle they all turn	Learning to use pulleys, bushings
The Gear Wall*	Connect as many gears as you can on together on a wall so that when you turn one axle they all turn	Learning to use gears, creating spacing for gears using plates, using bushings
The Drop Car	Build a car that can withstand a drop from the knee	Attaching motors, Building a sturdy structure for a motor, using axles and wheels
The Snowplow	Build a vehicle that can move “snow” (Styrofoam peanuts)	Using motors, connector pegs and bushings
The Lunar Rover	Build a vehicle that can traverse the hilly, sandy moon terrain	Gear/Pulley Ratios, Tire Selection
Steep Cookie Sheet	Build a vehicle that can climb up the Mt. Cookie (a slippery inclined cookie sheet)	Gear/Pulley Ratios, Tire Selection

**The gear and pulley wall can be combined into one wall where one student specializes in adding pulleys and another in gears.*

Figure 5 : Gear and Pulley Activities – Introduction to Friction and Torque

In the months of time in the school year that remains, students work on activities that let them apply their knowledge and skills to integrated activities. As students study the farm and how it works, they create a map of a Lego farm they will build and decide what vehicles and structures are needed. Mapping and spatial skills are exercised as students must draw birds eye views of the farm and build their vehicle or structure to fit in the space allotted for it. The designing and building of the farm reinforces the concepts that they study . From a building perspective, students are often able to translate concepts they applied to their vehicle designs to add moving doors , gates, and windmills to the farm with minimal instruction or assistance.



Figure 6 :A first grade Lego farm model

Reading is integrated with engineering through the illustration of a book using the LEGO materials. Projects vary from teacher to teacher based on time, however this past year during a unit on pond and the environment study one class read Dr. Seuss's *The Lorax*. The class then built various scenes from the book complete with working vehicles and structures. The scenes were put together and a movie was filmed as each of the student read a portion of the story aloud. Students were very engaged in re-reading the book and learning new words so that they were sure to build their part of the story correctly.

Evaluation

Teachers have been reporting a number of observations based on the introduction of engineering activities into the classroom. There has been a very high level of excitement among both genders for the activities. Improvement in problem solving skills as well as a heightened interest in engineering and building by both boys and girls have been observed. Understanding of the need to plan, to compromise with others, and to communicate ideas has also been mentioned. More quantitative evaluation of the impact on math and science knowledge and gender differences is currently under development.

In discussions with teachers, activities like the farm and *The Lorax*, that integrate engineering activities tightly with existing curriculum pieces or reading and writing are often given as favorite activities. They seem more comfortable with activities that relate to subjects they enjoy teaching or have more experience with. The teachers are starting to take a more active role in seeking instruction on new topics and designing the methods that will be most helpful to them. Requests have been made for documentation as well as grade specific workshop sessions that allow time for them to collectively plan for the year.

Conclusions and Further Directions

The introduction of engineering into the first grade classroom has been a process for all involved. Finding the right balance and way to present engineering concepts to first grade teachers and students took a significant amount of time. However, the benefits are clearly seen as one first grade girl examines the vehicle of another student and announces correctly “Your wheels are way too close to beams. You have too much friction it won’t move.” Excitement continues to grow among teachers and students opening up more and more possibilities for projects and activities.

Other projects that have been piloted in one or two first grade classrooms will hopefully be able to be disseminated on a larger scale. One class used the Lego RCX , a programmable Lego brick, and various sensors to monitor the temperature and humidity of the incubator where their duck eggs were house. Another has used the RCX for further automation of vehicles, where a bus for example stops to gather children at each house along the road

Acknowledgements

The authors would like to thank the LEGO Corp., NASA, and the many teachers and students that have been involved with this project.

Bibliography

1. Dewey, John. Experience and Education. 1963. New York: Collier Books.
2. Resnick, M., Martin, F., Sargent, R., and Silverman, B. (1996). Programmable Bricks: Toys to Think With. IBM Systems Journal, vol. 35, no. 3-4. pp. 443-452.
3. Greenberge, Scott S. (2000, December 21). State Pushes Engineering. The Boston Globe, B-6
4. URL: <http://www.pldstore.com>; Pitsco Lego DACTA Online Store.
5. URL: <http://ldaps.ivv.nasa.gov>; Lego Data Acquisition and Prototyping System
6. URL: <http://www.ceeo.tufts.edu/curriculum>: CEEO Engineering Curriculum/Activities site

Chris Rogers

Chris Rogers is an associate professor of Mechanical Engineering at Tufts University. He spends much of his time either playing with LEGO bricks, causing trouble at recess, or looking at the behavior of particles in a turbulent airflow.

Sue Ann Kearns

Sue Ann Kearns is a first grade teacher in the Lincoln Public Schools in Lincoln, MA. She makes amazing Lego cars, ducks, and snow plows.

Catherine Rogers

Cathy Rogers is a former teacher and parent volunteer in the first though fourth grade classes in Lincoln, MA. She has a world famous LEGO bus.

Judy Barsosky

Judy Barsosky is a first grade teacher in the Lincoln Public Schools in Lincoln, MA. She makes a killer gear wall and does a tremendous reading of The Lorax.

Merredith Portsmore

Merredith Portsmore is currently the Education & Technology Program Manager at the CEEO and is constantly developing and teaching engineering concepts through the web and LEGO bricks.