Bringing Engineering Concepts into the Kindergarten Classroom

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Abstract

This paper focuses on the K in the K-12 pipeline for engineering education. It will describe the experiences of the partnership of an engineering professor and elementary teacher in bringing engineering activities into a kindergarten classroom. It will discuss how the activities were adapted for the kindergarten level and will provide suggestions on how to integrate them into a school district's required curriculum. Benefits for the kindergarten teacher as well as the engineering professor will also be discussed.

1. Introduction

Kindergarten is a transitional stage in a child's life. Their young minds are soaking in new ideas and learning every day. The kindergarten curriculum not only focuses on their social and emotional development, but it also emphasizes the importance of academics such as reading, math, science and problem solving. Bringing fun, hands-on activities into the classroom that demonstrate simple engineering concepts is an excellent opportunity to introduce these students to engineering at a young age and motivate their interest in learning. There are numerous resources available for teachers through websites such as pbskids.org and www.pbs.org/teachers for engineering activities. Teachers could use these resources in the classroom on their own; however, a partnership with engineering faculty or engineering student groups make it both exciting for the kindergarten students and more feasible for the teacher to fit such activities into the curriculum.

This past year, the partnership between a kindergarten teacher and engineering professor enabled bringing hands-on activities that demonstrate basic engineering concepts into a kindergarten classroom. By combining the school district's Everyday Mathematics curriculum with real-life engineering applications, the students received a deeper understanding of how math and science can relate to their everyday lives. The activities were adapted from Public Broadcasting Service (PBS) resources at www.pbs.org/teachers and modified to be appropriately challenging for the kindergarten level and to promote student engagement. The lessons encouraged the students to explore, question, predict and test their ideas through a hands-on, interactive focus. In each session, the students were enthusiastic, interested and eager to be involved.

In this paper, we will describe the activities used, how they were adapted for the kindergarten level and discuss what we learned regarding implementation strategies. We will summarize the results from basic survey questions answered by the kindergarteners following several of the activities. Suggestions for how these activities can be integrated into a school district's required curriculum will be discussed. Benefits for the kindergartener teacher as well as the engineering professor will also be highlighted.

2. Engineering Activities

The activities were selected based on several criteria: (1) ability to demonstrate basic engineering concepts, (2) hands-on, interactive focus to engage students, and (3) fit a unit theme already being taught in the mathematics, science or reading kindergarten curriculum. The teacher rotates through different unit themes in reading, math and science throughout the school year. The activities were implemented in the spring of 2010 in a classroom of 19 kindergarten students at Hoover Elementary School in North Mankato, MN. Each activity consisted of two parts, a large group discussion or story and a small group, hands-on portion. The students performed the hands-on activity in groups of 4 – 5 students as they rotated through the afternoon math stations. The integration into the math stations format used in the kindergarten curriculum will be described further in Section 4. A description of each of the engineering activities is provided below.

2.1 Floating Objects

Unit Theme: Water (Science)

Engineering Concepts:

- Buoyancy

The whimsical Baby Einstein book entitled "What Floats?" by Julie Aigner-Clark and illustrated by Nadeem Zaidi was used to get the students thinking about things that float versus those that sink. The book ends with the line "It's curious how a ship floats by as heavy as can be, while a pebble drops with a little plop and sinks beneath the sea." After reading this book and "Curious George, The Boat Show" to the class, the engineering professor led the students in a large group discussion thinking of other objects that float or sink.

The small group activity gave the students the opportunity to play in the water and experiment with an assortment of objects. They started out with two objects that were the same size, shape and color but had significantly different weights, a golf ball and a ping pong ball. The students voted on if each ball would float or sink and then tested their hypothesis. Then, they were given a small plastic bowl, instructed to place the golf ball inside the bowl and asked if it would now float or sink. Some of the students were surprised that the golf ball that previously sank would float when the bowl and ball combination were placed in the water. They were even more surprised when they were able to load as many as 10 golf balls into the bowl before it began to sink. The students also experimented with cans of food, small wooden boards, plastic containers and rocks. The basic principles of buoyancy were explained while the students enjoyed playing with the objects in the water tub.

2.2 Levers

Unit Theme: Pan Balance (Mathematics)

Engineering Concepts:

- Simple machines
- Levers and fulcrums

Source:

- "Level Investigation" by Sid the Science Kid (http://www.pbs.org/parents/sid/activities.html?leverinvestigation)

In this activity, the small group portion was conducted first in the classroom. Following completion of the afternoon math stations, the entire class took a field trip outside to the playground for the large group part of the activity. The small group activity consisted of a crate filled with heavy books, a board 6 – 8 ft long and 12 – 16 in wide as the lever, and a small step stool placed underneath the board as the fulcrum. The large group activity required a door for demonstration purposes and a plastic spoon and several marshmallows for each student.

The small group activity was started by placing the crate filled with heavy books on the ground and giving each student the opportunity to try to lift the crate. Then the crate was placed on the end of the lever with the fulcrum positioned in the middle. Each student was again given the opportunity to push on the lever and feel how much easier it was to lift the crate. The students experimented with moving the fulcrum to different positions and the effect it had on the force required to push down on the lever and lift the crate. During the activity, the engineering professor discussed levers, fulcrums and how simple machines can be used to make tasks, such as lifting a heavy object, easier.

After each group had rotated through the lever investigation station, the class put on their coats and headed outside to the playground. On the way out, they stopped at the double doors exiting the school building and the engineering professor used the doors and a student volunteer to demonstrate a lever in action. The students saw how it is easier to open a door if you push or pull on it farther away from the hinges. This was a great opportunity to connect something they do multiple times a day to the engineering concept behind it. Outside, the students were each given a plastic spoon and several marshmallows. Using the spoon as a lever and their thumb and index finger grasping positioned on the spoon as the fulcrum, the students launched their marshmallows into the air. They experimented with how moving their fulcrum up and down the spoon handle affected how far the marshmallow was launched.

2.3 Sand Castles

Unit Theme: Ocean Animals (Reading)

Engineering Concepts:

- Cohesion and mixing materials to increase strength
- Structurally sound foundations for building

Source:

- "Day at the Beach" with Curious George (http://pbskids.org/curiousgeorge/games/day_at_beach/day_at_beach.html)

The book "Curious George Goes to the Beach" by H.A. Rey and Margaret Rey was used to introduce the Sand Castle activity. The engineering professor read the book to the class during circle time and then called on volunteers to discuss their explorations at the beach and previous experiences in building sand castles. The children were excited to talk about their experiences of playing in the sand box and at the beach.

The materials required for the small group activity included several large, shallow tubs of moist sand (approximately two students per tub) and sand shovels, cups and other molds. A large tarp spread out underneath the station area was helpful to capture the sand spillage and facilitate easy cleanup of the classroom following the activity. At the start of each small group rotation, the engineering professor used two smaller tubs, one with dry sand and the other with very wet sand, to demonstrate the importance of the right mixture of sand and water to get the proper consistency for building sand castles. Cohesion between the sand and water and how it increases the strength of the mixture was discussed.

The students used various sizes of cups and molds to build their own sand castles within the tub. As they played in the sand, the engineering professor discussed structurally sound foundations for building sand castles. Through demonstration followed by testing it on their own, the students learned about the need for a level building site and the importance of using larger molds for the bottom of their sand castle and smaller molds for the top.

2.4 Tower of Coins

Unit Theme: Money (Mathematics)

Engineering Concepts:

- Forces
- Friction
- Inertia

Source:

- "Tower of Coins" by *Zoom* (www.pbs.org/teachers/connect/resources/2692/preview/)

Most kindergartener's are already familiar with the fun science stories of The Magic School Bus by Joanna Cole. This activity was introduced by the engineering professor reading "The Magic School Bus Plays Ball" by Joanna Cole and illustrated by Bruce Degen to the class. In this story, teacher Ms. Frizzle and her class take a Magic School Bus ride into a non-friction world. Through a baseball game played on a field without friction, the story explains forces and inertia. Since the students were already familiar with the characters in the Magic School Bus series, the story provided a fun and imaginative way to introduce these engineering concepts to the class.

At first glance, the unit theme for this activity may seem disconnected to forces, friction and inertia. The students had been learning about money over the past month. This engineering

activity integrated into the money theme by giving the students a fun, hands-on activity using coins. During the small group activity, each student was given a stack of 12 coins of the same size. Pennies, nickels, dimes and quarters were used for the different stacks. The students were asked to count how much money they had in their stack and as a group determine which student had the most money. They were also asked how many of their coins would they need to trade in for a $1 bill.

The small group activity was started using a ball at rest and rolling in a straight line to explain the basic concept of inertia and forces. Friction was demonstrated by the rolling ball eventually coming to a stop. A small box (filled with coins) on an inclined surface was used to further illustrate friction and its kindergarten level explanation as a "sticky" force. The engineering professor then demonstrated with one of the stacks of coins how pushing on the bottom coin slowly causes the whole stack to move together due to friction and how hitting the bottom coin quickly overcomes friction and causes just the bottom coin to shoot out and the stack to stay at rest. The students then experimented with their stack of coins. First they moved their stack of coins together by slowly pushing on the bottom coin. Then, they tried to get the bottom coin to shoot out and the rest of the coins to remain in the stack by hitting the bottom coin quickly with a flat utensil (e.g., metal spatula or butter knife). The activity took some practice for them to learn the right speed and force to use with the utensil and develop the skill to hit only the bottom coin. However, once they achieved it, they had fun with their new "magic trick".

2.5 Wind Power Car

Unit Theme: Weather (Reading, Science)

Engineering Concepts:

- Forces, friction and inertia
- Wind power

Sources:

- "Blow It Away" by *FETCH! with Ruff Ruffman* (www.pbs.org/parents/fetch/activities/act/act-blowitaway.html)
- "Balancing Balls on Air" by *Zoom* (pbskids.org/zoom/activities/phenom/balancingballsonair.html)

We started the activity with a large group demonstration. Volunteers were called on from the class to participate in the demonstration of a ping pong ball floating in the stream of moving air from an electric blower. The volunteers tipped the blower hose at different angles and the class was amazed at how the ball remained suspended in air. During the demonstration, the engineering professor discussed forces and the power of wind with the class.

Following the demonstration, the students completed the wind power car activity in small groups. They each built a small car using a 4x6-inch index card as the car body, drinking straws for axels, and LifeSavers® mint candies as wheels with mini marshmallows as stoppers to keep the wheels from falling off. They built sails using popsicle sticks and a choice of aluminum foil, plastic bags or small paper cups and added load to their cars using string with paper clips attached to the end.

Discussion points used in conversation with the small group during the activity included kindergarten level explanations of inertia, forces, friction and wind power. Basic demonstration of the car remaining at rest until the force of the wind acts upon it, the force of the wind needing to be stronger than the friction to get the car to move, and friction resisting the motion of the car and causing it to slowly stop if the wind stops where used to illustrate these concepts. The students were asked to talk about other things that the wind moves (e.g., tree branches, ocean waves, sailboats, kites, flags). A pinwheel was used in the conclusion of the small group activity to discuss how wind power can be collected and stored using wind mills.

3. Survey Results

For the last three activities, a multiple-choice survey was handed out to the class to assess if the students enjoyed the activity and what they learned. It was challenging to design a survey that would be understandable and meaningful for the kindergarten level. In some cases, the multiple choice answer options consisted of pictures or sketches. For example, the "did you have fun today" question had choices of a happy, indifferent or sad face. In other questions, the choice of answer was a list of words that would already be familiar to kindergarteners plus the new engineering words they learned during the activity. The teacher asked students with advanced reading skills to read the question out loud to the class. The teacher then read through all the answer choices and helped the students point to each word as she read it. They were told to circle the one word that they thought was the correct answer. The process of going through the survey gave the students an opportunity to apply what they were learning in reading on sounding out words along with allowing us to assess if they could remember the new engineering words they learned in the activity. In several questions, they were asked to write down a one-word answer to a question rather than circling a multiple-choice answer. This gave them practice in matching letters with the sounds in a word and working on their writing of those letters.

Table 1. Survey Results

	Format of Choices	Correct Happy Face[1]	Partially Correct Indifferent Face[1]	Incorrect Sad Face[1] No Answer
SAND CASTLE ACTIVITY				
1. Did you have fun today building sand castles?	pictures	14	2	1
2. What happens if you mix too much water into the sand?	pictures	10		7
3. What happens if you use dry sand?	pictures	10		7
4. Which sand castle has the best foundation?	pictures	16		1
5. Which mold should you use when building the bottom of your sand castle?	pictures	13		4
6. Which mold should you use when building the top of your sand castle?	pictures	12		5
TOWER OF COINS ACTIVITY				
1. Did you have fun today playing with the tower of coins?	pictures	18		
2. Circle the two new words you learned about today in our engineering activity.	words	12	5	1
3. What stops a ball from rolling forever?	words	14		4
4. How can you make an object that is at rest start to move?	short answer	11		7
WIND POWER CAR ACTIVITY				
1. Did you have fun making a car today?	pictures	19		
2. What force was used to make the car move?	words	17		2
3. What force between the wheels and the table resisted the car moving?	words	12		7
[1]The multiple choice answer options for question 1 were a happy face, indifferent face and sad face.				

The results of the surveys confirmed what we saw in the faces of the students during the activities. They were enthusiastic, interested and eager to be involved. In almost all cases, they circled the happy face as the answer for having fun in the activity. The percentage of correct answers on the questions to assess what they learned was encouraging. For the most part, the students picked up the basic engineering concepts being taught. They were learning new words such as inertia and fulcrum and retaining this knowledge. In subsequent sessions, the teacher would start by asking the class if they remembered what they learned during the last engineering activity. Not only did they remember the activity, but were also able to recall the basic concepts and new engineering words they had learned 2 – 3 weeks earlier. The retention of this knowledge was encouraging for both the teacher and the engineering professor.

4. Integration into Kindergarten Curriculum and Implementation Strategy

Kindergarten teachers are responsible for meeting the school district's educational requirements for the kindergarten level. The curriculum emphasizes the importance of academics such as reading, math, science and problem solving and also focuses on the students' social and emotional development. They are given some flexibility in trying new methods and ideas along with using the established best practices in kindergarten education. Thus, the teachers have to make conscious decisions regarding what curriculum choices and activities work well for their students while meeting the school district's educational requirements.

Hoover Elementary School is part of Independent School District (ISD) 77. The district uses *Everyday Mathematics* for its math curriculum and *2005 Macmillan-McGraw Hill Science* for science. Both of these focus on real-life problem solving and everyday experiences in their curriculum. The reading curriculum, *2006 Macmillan-McGraw Hill Treasures*, is also based on themes that are relevant to their everyday lives. The topics for the engineering activities were selected to integrate with the unit themes currently being covered in the mathematics, science and reading curriculums.

The partnership between an engineering professor and kindergarten teacher made it feasible to integrate the engineering activities into the curriculum with only a minimal interruption of the normal routine. The *Everyday Mathematics* curriculum was typically covered during the afternoon through whole-group instruction followed by small group, partner or individual activities. Stations were regularly used to give each student the opportunity to work in a variety of different groups settings while learning, applying and completing new skills. These station activities balanced teacher-directed instruction with opportunities for open-ended, hands-on explorations, long-term projects and on-going practice of skills. The students rotated through approximately four stations in small groups of 4 – 5 students with each station lasting approximately 10 minutes. The stations were based on the *Everyday Mathematics* curriculum along with integration of science, reading and problem solving.

On five occasions this past spring, an engineering activity related to the lessons or units they were focusing on was used as one of the stations. The large-group instruction time for that day was used to read a book or perform a demonstration related to the engineering concept the students would be learning about. This strategy of implementation fit the engineering activity into the normal classroom routine. Since the afternoon stations were followed by free time, it

worked well to pull any extra time required for the engineering station out of the free time allotment. The students were so eager to have extra time to play with the engineering activity, that the station was also kept set-up and supervised during the remaining free time.

With each session, we learned more about how to effectively implement the activities through large group story time or demonstration followed by small group, hands-on activities. Throughout the process, we also gained experience on the logistics of implementing each activity at a kindergarten level. Field notes were kept regarding these logistics and will be used to improve future implementations. For example, the most effective group size was determined to be 3 – 4 students. When the small groups consisted of 5 students, it was significantly more challenging to keep everyone in the group paying attention to the discussion of the engineering concepts and calming taking turns with the hands-on component. We also experience some challenges in groups focusing on their current station. They were so eager to participate in the engineering activity that is was distracting them from the learning taking place at their current station. Thus, the students had the opportunity to work on their skills in patience and focusing on the task at hand while they waited their group's turn to rotate into the engineering station.

This initial experience of bringing engineering concepts into a kindergarten classroom was based on implementation in one classroom through the partnership of an engineering professor and kindergarten teacher. A broader group of students could be reached by expanding future implementations to include all kindergarten classrooms in a school or even across the district. Suggestions for this type of larger scale implementation would be to draw on the resources of college student organizations at the university such as the America Society of Mechanical Engineering (ASME), American Society of Civil Engineer (ASCE) or Society of Women Engineers (SWE). An engineering faculty member could organize and coordinate the engineering activities and draw upon these student organizations for volunteers to effectively bring the activities into multiple classrooms and multiple schools in the district. This would have the added benefit of providing an opportunity for these college students to volunteer and serve the community using their chosen major. It would give them the opportunity to share their passion for engineering and instill those concepts into future engineers.

5. Benefits for Kindergarten Teacher and Engineering Professor

Benefits for the engineering professor included both professional development and involvement in community service. The professional development plan for tenure and promotion at Minnesota State University, Mankato outlines five key areas in which faculty members are expected to grow and contribute. Community service falls within one of these areas and is recognized by the university as a valuable contribution. The engineering professor enjoyed having this opportunity to use her knowledge and training to motivate young students to consider engineering. The excitement of the kindergarten students as they worked on the various activities was rewarding and encouraging. The professor also used this experience to sharpen her skills in adapting engineering concepts to be understandable by people with various levels of background knowledge. In this case, the kindergarten students provided an extreme case in adapting concepts to basic explanations that are fun, easy to understand and connected to everyday life. Engineering concepts seen at this basic level is a valuable viewpoint to have even when developing lectures for engineering courses at the university. Furthermore, developing

professional connections with elementary education is beneficial for engineering departments and universities as they focus on the K-12 pipeline for future engineering students.

Benefits for the kindergarten teacher included learning about engineering applications and how to integrate them into various areas of the kindergarten curriculum, developing collaboration with engineering faculty, and experiencing the excitement of the students as they participated in the hands-on activities. Opportunities to bring parent and professional volunteers from the community into the classroom are beneficial for both the teacher and the students. The power of collaboration through a program like this allows that partnership to extend from professor to teacher, teacher to student, student to professors alike. It creates a new community of explorers that take what they are learning in the classroom and applying it in new and challenging ways. It was exciting for the teacher to see the students work, explore, and investigate together to learn new concepts. It creates an inviting atmosphere where students, teachers, and professors are excited about what they are learning and how they are learning it.

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