2006-795: ENGINEERING IN THE ELEMENTARY SCHOOL

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Having obtained a Bachelors of Science degree with a dual major in Psychology and Technology from Brigham Young University, Jared taught technology in three different public high schools. He worked for two major IT corporations and also spent a year as a consultant in the IT field before he chose to pursue a PhD from the University of Illinois Urbana-Champaign. At Illinois, he coordinated an online masters degree program, was a NSF sponsored technology trainee, and consulted with engineering faculty to improve their teaching and use of technology. His PhD is in Education with an emphasis in the psychology of learning and technology. He currently is a faculty member at Brigham Young University in the Technology Teacher Education program where he teaches heavily, serves as the Graduate Coordinator, and mentors numerous undergraduates in research projects. He is happily married, has 6 children, and loves to learn. His research interests are in technological literacy and engineering in the k-12 setting, teaching pedagogy that promotes higher order thinking skills, and creativity.

ENGINEERING and Technology IN THE ELEMENTARY SCHOOL

Introduction

Current trends and future projections of engineering in the United States indicate a need to better inform, teach, recruit and prepare our youth for the technological age in which we live. In the book *Technically Speaking, Why all Americans need to know more about technology*, the first recommendation made by the National Academy of Engineering and National Research Council was to further "encourage the integration and increased study of technology in the K-12 content, standards, curricula, instructional materials, and assessments" (2002, p. 105). The Academy also recently published, *Educating the Engineer of 2020,* which includes recommendations of "supporting efforts to improve math, science, and engineering education at the K-12 level" and "promoting public understanding of engineering and technological literacy" (National Academy of Engineering, 2005, p. 57)

Few states in America require engineering and technology competencies in their state curriculum, and even fewer require any such experiences at the elementary school. In the State of Utah, we have technology and engineering curriculum mandated by the Utah State Board of Education at the 7th – 9th grade levels, but there are no structured efforts to introduce elementary children beyond "science". At Brigham Young University, the faculty in Technology Teacher Education are dedicated to addressing these issues. Housed in a college of engineering and technology, our program introduces prospective technology education teachers to "real world" teaching in the classroom and hopes to expand technology and engineering in the K-12 curriculum. In order to accomplish this goal, we begin our students teaching in elementary schools, then middle schools, junior highs and finally high schools during their respective years in the program. This paper describes three years of experience in working with 6th grade students in Canyon Crest Elementary School, where our pre-service technology teachers partnered with, developed, and taught integrated technology and engineering units of instruction. We hope that by sharing our action research efforts that we might excite others about the vision and importance of integrating activities in the public schools that promote technological literacy and interest in engineering.

Year 1 – Computer engineering? -- More Like Multimedia Design

Determined that engineering and technology would be valuable to an elementary curriculum, in 2003 I set out to find a school that I could partner with. I was turned down by two schools before I found a Principal that was interested. As the Principal of Canyon Crest Elementary School and I began to discuss what it was I wanted, I naturally turned to defining technology and engineering. He listened politely, but suggested that their new iMac computer lab would be a great place to focus. Before accepting the role of teaching computers and information technologies, I made one more plug to teach other technical systems like manufacturing, transportation, construction, and design. I knew that a former teacher had used four modular "Engineering and Technology Curriculum" boxes on wheels to teach a more broad view of technology. I thought it would be a good idea to start with these boxes, but with further discussion it was obvious that the Principal felt it would be best to teach the children how to make multimedia presentations. This is a common challenge for those doing engineering outreach or technology education in the K-12 schools. When you approach people and tell them you would like to help infuse technology in the classroom, they immediately think of information technology (Dugger & Rose, 2002).

Even though we agreed to teach multimedia, I wanted to explore what kinds of activities were in the curriculum boxes. We took an extra field trip to the school to investigate them and found they had been sitting untouched for several years in a closet. The boxes were organized in themes of Engineering, Transportation, and Research and were targeted to teach a different technological system (Transportation, Communication, Power and Energy, Engineering.) The BYU students were surprised generally at the amount of information and activities packed into these carts. They liked the fact that they could be moved from one classroom to the next and liked the structure of the lessons around themes. The students also liked the fact that the activities were manipulative and hands on. The only concern they had was that no one was using them, and it seemed that they might be difficult to keep organized if young children were given free access to them.

After evaluating the modular technology curriculum, the students went into the iMac lab to determine what resources were available to help us meet our goals and objectives of teaching multimedia design. A lesson plan was developed as a class the next day and BYU students spent two additional classes preparing to teach. Since there was only time for one day of teaching in the elementary school, half of the BYU students became experts in PowerPoint, and the other half became experts in iMovie. Teaching pairs were created with each person having a different expertise. These pairs were assigned to make sure they were comfortable and competent in teaching the curriculum to each other before they taught it to the elementary students. Students taught the children to capture and edit video and place it in a powerpoint in just two days with 50 minutes per visit (See Figure 1).

Though I would recommend more time for teaching, this first year's activity was a great success. There were a total of 22 students from the 6th grade and 20 BYU students – all of whom benefited. As the 6th graders left they kept asking if they could save the presentations to show their friends later. Smiles were on their faces, and excitement was in the air. As for the BYU students, here are a few of their comments:

Figure 1: Year 1 Multimedia design

STU 1- My favorite part of the whole trip was seeing the kids faces light up when they understood how to insert a title, or how to make a movie.

STU 2 - When we went to the elementary school to teach the 6th graders, I had no idea what intelligence level the kids would be at. I had envisioned what I was like as a sixth grader, barely knowing what a computer was, let alone how to use one. Instead I found that the kids were extremely quick to catch on to what we were teaching. They were excited to learn all they could and explore even more ways to do things when we taught them. After a few minutes of instructions, about half the kids were turned loose to use the programs on their own. I was really surprised at how well they were able to operate everything quickly and confidently.

As I reflected on the experience I felt it was rewarding to see both college students and 6th grade children engaged in the teaching and learning process. All involved increased in their understanding of information technology and multimedia design, but I looked forward to the next opportunity to bring a more traditional engineering perspective to the classroom. I wanted my students to bring something to Canyon Crest Elementary that they could not do on their own concerning technology and engineering.

Year 2 – Mars Rover Engineering

The next year rolled around and I began teaching my introductory technology teaching class once again. I had written a mini curriculum grant to acquire a Lego MindStorm kit for the year and had begun toying with the idea of having my class teach something to do with engineering robotics. When I contacted Canyon Crest Elementary, they enjoyed the previous year so much that they said they would love to have us back, but couldn't bear to have any of their 6th grader's miss out this time. *(Instead of working only with one class, as we did the previous year, we agreed to teach all three 6th grade classes; which meant we would be working with approximately 90 children!)* The 6th grade teachers loved the idea of designing and building robots so I turned the project over to my students to determine the specific objectives and develop the curriculum.

The students worked closely with the International Technology Association Standards (ITEA, 2000), state standards, and teachers' lesson plans. We wanted to ensure that we taught a meaningful core rather than just a lot of "cool" activities. Space exploration and the NASA Mars Rover project became the theme of our activity. NASA's Jet Propulsion Laboratory (JPL) was particularly helpful in providing resources and ideas about what might be available. BYU students split up into three different instructional teams where 5-6 BYU students worked on curriculum for Space Exploration, Deployment Design, or Rover Engineering. Once inside the elementary school, the 6th graders were grouped by their classroom teacher and rotated from class to class every 25-30 minutes during the four-day event.

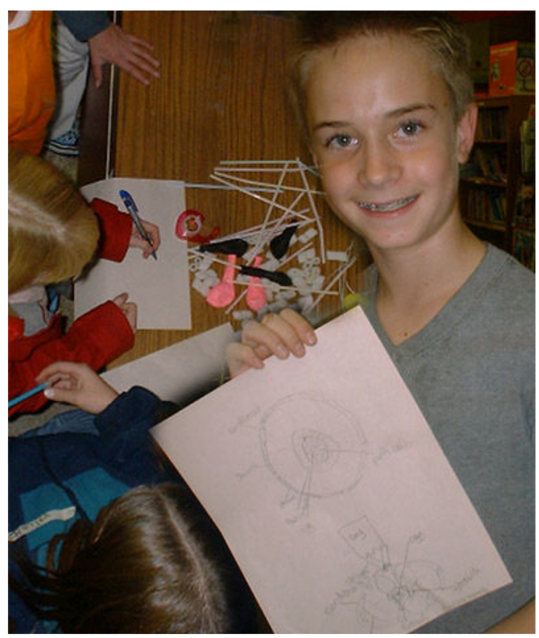

Figure 2: Deployment Design

Space Exploration – During the four days of instruction, students were exposed to the solar system, planets, time, and space travel. Instructional material included movies, worksheets, and games. One activity was to make a poem with the beginning letters of each planet (M,V, E, M, J, S, U, N, and P). Another took the children outside where each of them became a planet that orbits our sun. They separated themselves proportionately across the school yard. (I thought Pluto would never stop running ☺). Finally, the BYU students researched the planets and created a game show that had the whole corner of the school rocking with excitement.

Deployment Design – In this rotation, students designed a prototype device that would protect their "Mars Rover" as it would land on the surface of Mars like the NASA engineers were doing. We began by watching a 3D animation movie from JPL that depicted how this would take place. Afterwards, students teamed up in twos and sketched possible solutions to the design problem (See Figure 2). Presenting their ideas to one another helped them identify and chose the best solution. Having decided on a solution, the children showed it to a BYU student who issued them a bag of common resources to use for building their device. Building the prototype was a highlight of the activity. Once they had their prototype built, they had to test it. In order to pass the test, their deployment device had to protect an egg as it fell from a height of 20 feet onto the surface of the lunchroom floor. The 6th graders had a blast with this activity.

Rover Engineering – This third section of instruction allowed students to design and program an actual prototype of the "Mars Rover" out of LEGO Robolab kits. I ended up having to purchase 5 more in addition to the one I received from my grant, so we had a total of six kits for the 6th graders to use. BYU students taught the kids how to prototype, program, troubleshoot, input data from light and touch sensors, and how to use and control motors. Laptops were brought for convenience from BYU. The children worked in design teams, and a challenge was presented at the end of the 4 days to see which teams could build the best robot to navigate a course with natural obstacles.

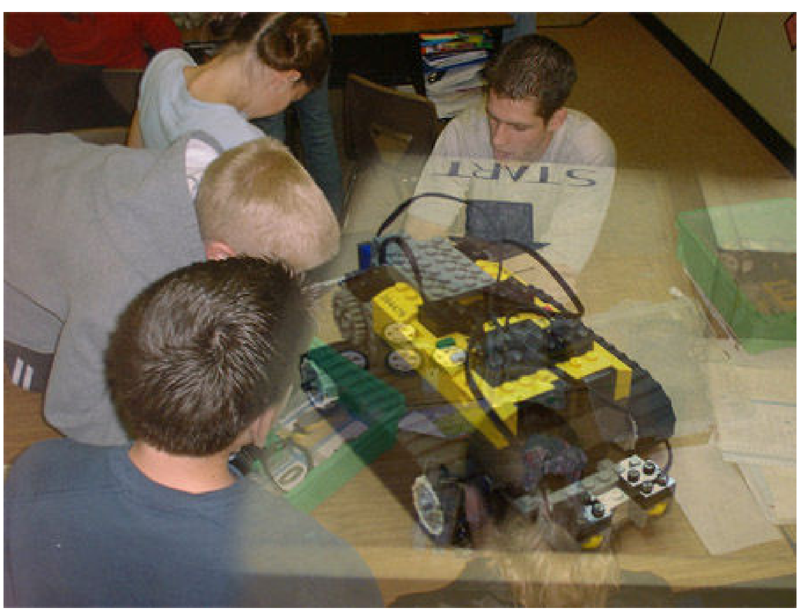

Figure 3: Rover Engineering

The experience this year was a very successful once again for both BYU students and the 6th grade children. The 6th graders were so excited to be learning technology in a hands on approach they sent some Christmas cards to our class. One 6th grader wrote, " I enjoyed everything, but I especially liked making the rover, because you could make it turn right or left, and a lot of other cool things." Another child thanked us for putting aside our time to teach them and claimed, "We had so much fun!

I liked all the activities we did, learning about space, egg drop, and the space rovers!" Not only did the 6th graders think it was a success, but I did too. I felt we were especially successful because BYU students were able to bring in engineering concepts and expose the 6th grade teachers and children to things they would not have had a chance to otherwise. For further information you can visit a website created for this experience at www.et.byu.edu/tte/tte101.

Year 3 – Innovations of China

Similar contacts were made and planning occurred for the third year of our outreach efforts. This year seemed it might be challenging because we would only have two days in the elementary classroom (due to scheduling conflicts) and two new teachers greeted us in the 6th grade classrooms. Time did turn out to be an issue, but the two new, energetic young teachers stepped right in where the others had left off and were great to work with. The theme we chose this year was based on the Social Studies curriculum. We called it Chinese Innovations. BYU students once again brainstormed and researched curriculum ties with the Utah state core and Standards for Technological Literacy (ITEA, 2000). After presentations and a couple hours of deliberation, it was determined that we would split again into three groups and teach about the technology of paper, rocket engineering, and news broadcasting. We would frame it all in the historical context of China's contributions to these areas.

News Broadcasting – In this section the children were to research a technology in the history of the Chinese culture and create a short 1-2 minute infomercial on it. Kids began by dividing up into teams, researching the topic, creating a script, using the camera equipment to capture the story, transferring it to the computer, editing the footage, and premiering it to their peers in class. In each of the three classes were six to eight teams of three to four children working on each video. Of all the BYU groups, this unit struggled to accomplish all that was required. The BYU students had expected the 6th graders to already have a script made when they came to class, but this didn't happen. Most overcame this challenge however, and all but one team produced a nice finished video.

Paper Technology – Children gained knowledge about how paper was made in China, and how calligraphy, stamping, and poetry have served as communications technologies that have impacted their society. As mentioned earlier, the Standards and Benchmarks for Technological Literacy were used as a guide for developing all lesson plans. For example, in this section the ITEA Standard of "Students will develop an understanding of the characteristics and scope of technology" was the focus for the lesson plan. Benchmarks this activity met included "Things that are found in nature differ from things that are human-made in how they are produced and used," "Tools, materials and skills are used to make things and carry out tasks," and "creative thinking and economic and cultural influences shape technological development" (ITEA, 2000). For the lesson, students briefly studied some characters of the Chinese language and practiced drawing them. Next they got into groups and manufactured their own paper, practiced calligraphy, and wrote a poem on the parchment paper they made. They finished by stamping it with a "royal" seal.

Rocketry and Life in Zero G's – During this rotation, students had the opportunity to learn about the differences between jet and rocket engines and how the characteristics of space make engineering transportation technologies particularly tricky. The principle of "Action-

Reaction" was demonstrated by a creative activity where students tried to unscrew an air hatch and move an anchored object in a simulated weightless space station environment. The big hit however, was designing, building, and launching paper rockets into different orbits of the planets located throughout the gymnasium (See Figure 4). Trajectories and pressure had to be checked and those that landed on the planets received a "sweet" reward of their choice.

Figure 4: Rocketry

When we finished our teaching, several of the students asked me if we could go to the 7th grade next year and teach them again. The 6th grade teachers said "no-way" they wanted to confirm that we were coming back. The BYU students had a wonderful learning experience teaching technology and we received letters of appreciation from one elementary class exclaiming their enjoyment. A few of the elementary Kids comments included:

> Child 1 - Thank you so much for coming to our school. I haven't had that much fun in ages!
>
> Child 2 - I really like space and want to become an astrophysicist but if that fails, I would like to become a quantum mechanic. I wish I had the cords for my camera or the program on the computer to make a movie like that. I thought that way of making paper was so smart and conservative…
>
> Child 3 - Thank you so much for coming to our school and making our afternoon so much fun! I enjoyed every moment of it! Making rockets was very fun. It was very fun and educational at the same time. I absolutely loved it…

Findings

Though the benefits of our efforts have not been formally measured, there are some initial results that can be shared from our experience. I have framed the discussion here around the question of readiness. "Are elementary age kids ready, and is there a benefit to bringing engineering and technology curriculum into the classroom?" First, looking at technological literacy, it appears that students are capable of thinking about and are interested in developing these skills. Considering the benchmarks in the standards for technological literacy (2000, ITEA, p.14), it seems that students in grades 6 have a well developed understanding of the concepts expected of those up through and including for the most part their grade level. For instance, standard one states "Students will develop and understanding of the characteristics and scope of technology." The benchmarks for this standard are:

Grades K-2:

a) The natural world and human-made world are different.
b) All people use tools and techniques to help them do things.

Grades 3-5:

c) Things that are found in nature differ from things that are human-made in how they are produced and used.
d) Tools, materials, and skills are used to make things and carry out tasks.
e) Creative thinking and economic and cultural influences shape technological development.

Grades 6-8:

f) New products and systems can be developed to solve problems or to help do things that could not be done without the help of technology.
g) The development of technology is a human activity and is the result of individual or collective needs and the ability to be creative.
h) Technology is closely linked to creativity, which has resulted in innovation.
i) Corporations can often create demand for a product by bringing it onto the market and advertising it.

Children in the sixth grade show varying levels of competence in these areas, but as evidenced through the children's dialogue, answers they have given, and observations we have made it seems that they are able to engage in all these areas and are interested in being taught more about them.

Besides general technological literacy principles and understandings, another important perspective to consider is the children's apparent ability to understand key engineering concepts. The concepts associated with the engineering problem-solving cycle which include: (Frey, 1997, p11)

- Look at the problem carefully
- Redefine it to eliminate bias
- Identify constraints and set specifications for solutions
- Brainstorm alternative solutions
- Analyze the alternatives
- Select the best potential solution and test it
- Look at the original problem statement and decide whether or not you have solved the problem

Though these concepts can be handled by this age group, they are little less familiar to most of the children. They have had very little experience thinking in an engineering design way, but can handle it. Finally, concepts like optimization, robust design, safety, material properties, and precision are engineering ideas that appear to be foreign to most kids. It takes more effort to teach the students why these are important to them and their everyday life. This is like trying to get the students to look through an engineer's glasses. This can be difficult for some students because Its they don't have exposure to this kind of thinking in their every day life.

Not only do students at this age group have the aptitude to study technology and engineering, but there is a huge interest. As I write this paper I am in the middle of our fourth year of partnering with elementary schools. I have chosen to work with 2nd graders this year to determine the readiness of the younger children to understand technology and engineering concepts. So far, we have found that these younger kids, just like the older ones have a hard time sitting in their chair because they are so excited to learn about the concepts we are introducing, but the older kids are much more ready to comprehend difficult concepts. With this in mind, I believe it is very valuable to bring these topics into the classrooms. The outcomes will include increasing interested in technology and engineering careers; a society better prepared to make well-informed decisions on matters that affect or are affected by technology; a democratic society with individuals who could help make technological choices, and a more abundant supply of technologically savvy workers for jobs in today's workplaces. (NAE & NRC, 2002)

Recommendations

If you are interested in conducting an experience like this with your students, there are several things that you might want to consider. First, start early. Approach different school administrators well in advance (1yr) and inquire if they would be open to some collaboration. Second, become familiar with the state requirements for the age group you are thinking of working with. Third, be sensitive to the teachers' teachinng methods. After you get the approval from the principal, follow up with the teachers and ask to have a meeting with them to see who might be best to work with. Observe their classrooms and their pedagogical approaches. Fourth, if you will be taking class time, try to do this early in the year. End of the year testing is a real issue and teachers and administrators are more sensitive to loosing time the later it gets in the year. Fifth, consider collaborating with your technology education teacher preparation program, or if your University doesn't have one, than the science education pre-service teachers. Sixth, pilot test your delivery. See if the content makes sense and is age appropriate before you take it in front of the entire class. Finally, have fun. Engineering and technology is about hands-on and minds-on experiences. Make it fun for the kids and they wont be able to get enough of it.

Conclusion

Teaching technological literacy to our children is a national imperative, and one that needs to begin in the elementary schools. "Throughout the elementary years, technology education should be designed to help pupils learn and achieve the educational goals of the total elementary curriculum. " (ITEA, 1996) Unfortunately there are only a few states that have mandated technology curriculum at all, let alone mandated it at this early age. It is our hope that if more engineering educators become involved in partnering with the public education system, and showing teachers the possibilities and value of an integrated technology and engineering curriculum, that we can have a significant influence for change. We need to help create a vision of what could and should be taught to help our nation prepare future generations to be technologically literate.

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