K12 Engineering Education Field Experience

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Abstract

Engineering faculty have offered an engineering literacy course entitled Toying With Technology^{SM} to elementary and secondary education majors for eight years. Studies have shown that students form many of their overall career and educational attitudes as early as elementary school. Schoolteachers who have an appreciation for technology will likely convey that appreciation to their students. This will, in turn, broaden the horizons of their students regarding the opportunities they may have regarding careers in scientific and engineering disciplines. This appreciation is achieved through various engineering activities, many of which involve LEGO© robotics. Providing field experiences for future teachers so they can practice teaching the engineering-based activities they've learned is crucial in their development as confident teachers.

This paper will describe one semester's extended field experience with a local 6th grade classroom and the companion 6th grade extended learning program (ELP) students. Hands-on, problem solving experiences are necessary in order to develop skills such as troubleshooting, innovation, and experimentation, which are national science, mathematics, and technology standards for 6th graders. Constructivist-based methodology is employed to create goals, expected outcomes, and the logistics for the field experience. The 6th graders use computers to follow step-by-step instructions, program their creations, and operate their systems. The students in the Toying With Technology^{SM} course serve as classroom facilitators for the engineering activities used to attain the goals and achieve the outcomes desired. Assessment of the success of the program is through multiple measures. These include: a written feedback from the 6th graders with answers to specific questions as well as any comments, observations and feedback by the TWT student facilitators during problem solving and design projects, interpretations of the results by the TWT class facilitator, and interviews with the collaborating in-service teachers.

Introduction/Need

"At the heart of our modern technological society lies an unacknowledged paradox. Although the United States is increasingly defined by and dependent on technology and is adopting new technologies at a breathtaking pace, its citizens are not equipped to make well-considered decisions or to think critically about technology. As a society, we are not even fully aware of, or conversant with, the technologies we use every day. In short, we are not 'technologically literate.'"[1]

Now more than ever, the United States needs a skilled, technologically literate workforce whose members can address problems with time-tested solutions as well as creative problem solving. Increasing the pool of workers with strong problem-solving skills requires that students have experiences in quality science and mathematics problem-solving environments. Numerous studies[2-7] have shown the need for more hands-on, project-oriented, (engineering) exercises for K-12 students. Engineering offers an effective context for these problem situations. By "engineering context" we do not mean to replace existing math and science curriculum in schools, but to enhance the curriculum by infusing engineering as a learning tool. For example, when students are learning how to multiply fractions, they could be asked to do this with paper and pencil and learn the rules of fraction multiplication by rote. Instead, with engineering context, they can be asked to design a gearbox that would propel a small robotic car up an incline. To do this several gears with differing gear ratios would be meshed and their gear ratios (fractions) would have to be multiplied to arrive at the machine's overall gear ratio. Providing teachers the training necessary to make use of such engineering contexts is crucial to the success of curricular improvement.[8]

The need for technologically capable K-12 teachers is well documented.[9-13] There is a similarly strong demand for engineers.[14,15] Taken together these projections suggest a strong need for high quality, standards-based science and mathematics learning environments for K-12 students. During congressional hearings on "Improving Math & Science Education So That No Child Is Left Behind," the Subcommittee asked the following question of Philip M. Sadler, the director of the Science Education Department at the Harvard-Smithsonian Center for Astrophysics. Dr. Sadler has had experience in running numerous partnerships aimed at improving math and science education from the higher education perspective. "*Scientists, engineers, and mathematicians are relatively new players in the world of K-12 education and their participation is often ad-hoc and unstructured. How has the work of your Center benefited from the structured, long-term inclusion of these individuals and how can we encourage more practitioners of science, mathematics and engineering to get involved in K-12 program?"* Dr. Sadler responded. "*I like to characterize how scientists and engineers have contributed in two ways. First, many have acted as consultants, providing expertise that requires little change in perspective from their scientific research. Second, and by far, the largest impact has come from individual scientists who have committed themselves to education. They have become educators. This has meant following the same approach they would use in delving into a new field of science. They have studied the problems hard, read the research literature in the field, gone to conferences to hear about the latest experiments and innovations, partnered with educational researchers and classroom teachers to plan and pursue programs. They insist on careful experimentation and evaluation of impact."*[16]

In *How People Learn*,[17] a publication sponsored by the Commission on Behavioral and Social Sciences and Education and the National Research Council, the authors emphasize the emergence of a new science of learning that is based in the growing body of research on human learning. The authors point out that "Overall, the new science of learning is beginning to provide knowledge to improve significantly people's abilities to become active learners who seek to understand complex subject matter and are better prepared to transfer what they have learned to new problems and settings."

The Toying With Technology℠ Program

Many existing K-12 engineering context-based educational experiences have been devised in engineering colleges, but few are aligned with national science and mathematics standards and integrated into an age-appropriate curriculum and few are geared toward systemic change through education of preservice and inservice teachers. Two web sites that list engineering context materials are NSF's http://www.nsf.gov/sbe/srs/seind00/access/chapter3 and ASEE's http://www.asee.org/K-8smet_ed/default.cfm.

An example field experience, described later in this paper, is taken from the Toying With Technology℠ (TWT) Program at Iowa State.[18-23] It will demonstrate how we bring engineering context to standards based K-12 science and mathematics curricula and to relate this work to teacher education. The TWT program includes teacher education courses at the undergraduate and graduate levels (offered in the summer to accommodate inservice teachers), workshops for teachers and faculty, and experiential classroom partnerships with K-12 schools. Existing engineering materials, such as those developed by Seymour Papert at MIT,[24] Ellen Frye at Dartmouth,[25] Martha Cyr formerly while at Tufts,[26] and Richard Drushel at Case Western,[27] to name just a few, are adapted for use in the TWT Program and its partner schools. Other materials that are developed are based on constructivist principles espoused by Papert.[24]

Constructivism & Constructionism

The "constructivist" paradigm [28,29] asserts that learning occurs through a process in which the student plays an active role in constructing the set of conceptual structures that constitute his or her own knowledge base. Some specific examples of the successful application of technology grounded in constructivist theory are evident in projects in the Carter Lawrence School (Tennessee), Clearview Elementary School (California), Ralph Bunche School (New York) and the Apple Classroom of Tomorrow (ACOT) studies. Jean Piaget[30] developed a child-centered, developmental theory of learning. According to his theory, children construct knowledge about their world through their active involvement in experiences that are meaningful for them in order to provide an ideal learning environment.

Seymour Papert, who invented the LOGO language, tied constructivist classroom principles to children's robotics exercises with LEGO®s. Papert, who worked with Piaget and continues to be a leader in this field, coined the term "constructionism" to refer to constructivist practices applied to a learning environment in which the students are constructing objects.[31] Papert[24] defines constructionism as "an epistemological reversion to more concrete ways of knowing." Various studies[32-34] report on the efficacy of the active learner who is engaged in the construction of a project.

Field Experience

Introduction/Logistics

Twenty-four Toying with Technology^{SM} students were assigned an elementary classroom where they would spend four weeks working with children and helping them complete technology based activities. The majority of the class was assigned to a 6th grade classroom split up into two different sections; regular and ELP (Extended Learning Program). The activities that were to be completed include the basic Lego car programming (see reference 23), building and testing an egg drop creation, and if time allowed, challenge sheets which had students think creatively to build a structure and complete certain tasks. Since constructivism is being practiced in this class and its related outreach programs, the TWT students were assigned to pairs of 6th graders to work cooperatively with, and guide them along with helpful hints or suggestions, but not give away correct solutions to the problems. This is an admittedly "facilitator rich" experience as there was one TWT students for each pair of 6th graders. One of the main goals of this experience is for the elementary students to problem solve, and to become more familiar with technology and computer applications in the classroom. For four weeks the TWT students spent each Tuesday and Thursday for two hours (the regular TWT class meetings) with the 6th graders facilitating exercises similar to ones they first experienced as students themselves earlier in the semester.

Expected outcomes

The 6th graders were expected to work with their classmate and their "ISU buddy" to problem solve and find solutions to the tasks that were presented to them. They were given a desired goal and it was their job to use their groups' combined knowledge to find a way to reach the goal. For the egg drop activity, the goal was to successfully move a raw egg from the top of the table to the floor without breaking it. The materials supplied were only those found in one LEGO© Mindstorms kit. The students at this point were already familiar with the basic programming of the LEGO© Mindstorms RCX since they had done the robotic car projects. They applied this knowledge and creative, team-based problem solving to complete the project. The egg drop activity has been matched to certain desired standards to be achieved. Although Iowa does not use national, or even statewide, standards, the activities in the egg drop problem are matched to national standards in Table 1 for readers' uniformity. Individual school districts in Iowa maintain their own district-wide standards. These standards vary greatly and are being reviewed at the district and state levels in light of the No Child Left Behind legislation and its impact on each district. Since the TWT program deals with many districts, it adheres to the national standards and "customizes" activities for each district. In some cases the TWT program has been unable to work with certain grade levels in certain districts because the local standards didn't fit the activities to be undertaken. An example of an egg drop design is shown in Figure 1.

Table 1: National Standards and the Egg Drop

Standards		Engineering Context Activity – Egg Drop					
Standards Used	Domain/topic/benchmark	Conceptualize design	Assess suitability	Construct	Test	Reconstruct	Final Test
NSES	A. Science as Inquiry · abilities necessary to do scientific inquiry	**X**	**X**	**X**	**X**	**X**	**X**
NSES	B Physical Science · motions and forces	**X**	**X**			**X**	
NSES	E. Science and Technology · abilities of technological design · understandings about science and technology	**X**	**X**	**X**	**X**	**X**	**X**
NCTM	problem solving · solve problems in math and other contexts	**X**	**X**			**X**	
NCTM	problem solving · apply/adapt a variety of appropriate strategies	**X**	**X**			**X**	
STL	Standard 11: Students will develop abilities to apply the design process.	**X**	**X**	**X**	**X**	**X**	**X**
STL	Standard 13: Students will develop abilities to assess the impact of products and systems.		**X**	**X**	**X**	**X**	**X**

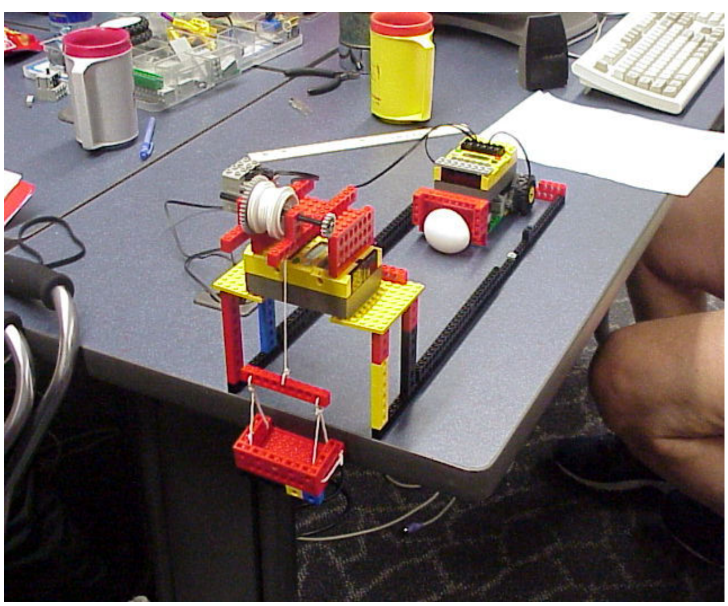

Figure 1: An Egg Drop Design

Results

The students were successful at completing the task for the most part. Even if their egg did break, many students were eager to discuss what they thought went wrong, and how they could fix it to make it better. This was exciting to see because they were learning, even if the end result was not perfect. The results were pleasing, and it appeared that the goals were met through this experience. According to the 6th graders feedback, the majority of the students felt that it was a worthwhile experience and they learned a lot about how to program cars to attain certain outcomes. Many of them said that their favorite part was the egg drop activity, and also that they learned new information about light sensors, bump sensors, and thresholds. When asked to state three things they learned they didn't know before, Ezra said, "I learned about thresholds, that light sensors are very helpful, and that every day complicated things are really just bigger versions of the stuff I did with the brick." They felt that their ISU buddy was helpful, and gave them suggestions when they were stuck. The TWT students also gave feedback that this was a positive learning experience for them. On a scale of 1-10 with 10 being the highest, the average rating of the classroom experience was a 9.17. Comments on the experience suggest that they felt the 6th graders learned a lot and that the TWT students also learned a great deal. They commented that in order to teach the information to the 6th graders, they had to know the information better then they did when working with it as students. One TWT student stated, "The whole thing was awesome because it gave us experience with using engineering in a classroom."

It was a fun and challenging experience and it was enjoyed because it gave the TWT students great practice with using engineering in a classroom, which is a goal of the TWT class as a whole. The 6th grade classroom teacher and the ELP teacher thought this was a great experience for their students. They liked how their students were allowed time to figure things out on their own, before a TWT student would give them instruction. They both said it was a worthwhile project and they would enjoy having TWT students work with their classes again. Overall, the classroom experience was successful for the 6th grade students and the TWT students. The student supervisor of the TWT students enjoyed watching the 6th grade students engage in the problems that were presented, use various methods to try to accomplish their goals, and enjoy the results when their creations worked the way they wanted them to. The positive feedbacks from both groups of students showed that the goals of the program were met, and implementing technology into the classroom is an important part of an educator's curriculum in today's society.

Conclusion

Each semester the Toying With Technology℠ course is offered to about 20 – 30 future K-12 teachers. The field experience described here, or one similar to it, has become a regular and important portion of the class. As mentioned earlier, providing teachers the training necessary to make use of such engineering contexts is crucial to the success of curricular improvement.[8] This field experience is helping this course provide such practical training for future teachers.

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