Session 3553

Practicing Teachers in a Graduate Engineering Course

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Introduction:

The National Commission on Mathematics and Science Teaching for the 21st Century stated that “Better mathematics and science teaching is therefore grounded, first of all, in improving the quality of teacher preparation and in making continuing professional education available for all teachers [1].”

The "constructivist" paradigm [2,3] 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.

At Iowa State University engineering faculty have worked collaboratively with teacher education faculty since 1996 to offer an undergraduate course entitled Toying with Technology[SM] to elementary and secondary education majors[4,5,6]. This course, which employs the constructivist method and seeks to improve teacher preparation, began with 15 preservice teachers in the first semester and has grown to about 100 preservice teachers per year in the undergraduate course and 20 inservice teachers in the graduate course. In addition about 1000 K-12 students per year experience a one to two hour workshop and others, who are in classes taught by teachers who have been in these courses in previous years, get a longer, more in-depth experience. The Toying With Technology[SM] Program maintains a web site at http://www.eng.iastate.edu/twt/. This technology literacy course provides students with an appreciation for the technological innovations that surround them. Studies have shown that students form many of their overall career and educational attitudes as early as elementary school[7]. Elementary (and even secondary) schoolteachers who have an appreciation for technology will likely convey that appreciation to their students. This will, in turn, broaden the horizons of these students regarding the opportunities they may have regarding careers in scientific and engineering disciplines.

The Graduate Summer Class:

For the past two summers (2002 will be the third) a similar course has been offered to practicing teachers for graduate credit. This graduate course is designed to explain the principles behind many of the technological innovations in wide use today. The students simulate garage door openers, remote controllers, elevators, and other devices. This is done through a collection of hands-on laboratory experiences based upon simple systems constructed out of LEGO®s that are controlled by small computers. In addition, several design experiments immerse the teachers in the world of engineering design, problem solving, and optimizing their "product" through calculated trade-offs. These laboratory experiences are designed to lead participants by hands-on experimentation through the use of technology in support of many everyday activities. The lab experiences are simple enough to isolate and illuminate the underlying basic principles and complex enough to represent real-world examples. Another engineering experience provides for the use of an expensive piece of equipment, not usually available to K-12 classrooms. A scanning electron microscope (SEM), accessible on the web, is included in this course. Creating lesson plans for its use is also a part of this graduate course[8]. A web site and database of SEM lessons for use in K-12 and college classrooms has been created and the practicing teachers contribute to this database during and after enrollment in the Toying With Technology℠ course.

The first LEGO®-based exercises in the course are highly structured and lead to less structured, more open-ended design problems throughout the semester. In the first exercise the students (whether they are preservice teachers, inservice teachers, or 4th graders) are given pictorial directions to build a car out of LEGO®s. They are given the following program employing Dave Baum's "Not Quite C" language (see the web site at http://www.enteract.com/~dbaum/nqc/).

Program 1

```
//prog1.nqc
//This program turns motors A and C on forward for 5 seconds
#include "vocab.nqh"

task main
{

//Tells motors A and C to go forward full speed, 5 seconds

OnFwd(OUT_A);
OnFwd(OUT_C);
Run_Time(500);                    //Moves 5 seconds
Off(OUT_A);
Off(OUT_C);

Run_Time(100);

//Tells motors A and C to go backward full speed, 5 seconds
OnRev(OUT_A plus OUT_C);  // We can start both motors at once
Run_Time(500);
Off(OUT_A plus OUT_C);
}
```

The students are asked to look at the program and construct an educated “guess” as to what the car will do once the program is downloaded to it. No instruction in programming is given during this course. The students are left to “construct” their own knowledge of programming experientially. After determining what the car will do and learning how to compile and download the program to test their educated guess, the students are challenged to do the following;

1. Modify prog1.nqc so your car goes forward and backward exactly 11 inches.

2. To figure out how long it takes the car to go 11 inches, you most likely used the “guess and check” method. We now want you to go 8 inches using the formula distance= rate x time. Using the formula will not give you the exact answer, but it will get you close.

3. Now modify your program so your car goes forward 8 inches and then makes a 90^{o} turn. There are two ways to turn the car, try to figure them both out.

4. Modify your program so that it makes a square. There is a repeat command which works as follows:

   repeat (n)   n= number of times you want the commands to repeat
   ```
   {
     the commands you want to repeat
   }
   ```

This set of exercises, starting with building the car and progressing through driving it in a square, will take an upper elementary team of two students less than one hour to complete. The time for completion goes up slightly for college age, preservice teachers and up quite a bit more for practicing teachers or faculty. Two factors that contribute to the time completion of tasks by students are the lack of recent experience with such devices and the desire to know “everything” about programming before solving the problem. Adults take more time to complete the tasks than younger kids who are not burdened with this problem. They are content to do (and learn) whatever piece is necessary to solve the problem at hand. Children are much less concerned with doing something wrong than are adults. Adults tend to be more concerned with getting the problem right than focusing on the problem solving that occurs during the tasks.

Subsequent exercises introduce sensors, digital and analog, to allow the car to interact with its environment. In two hours students are able to program their cars to follow a black line on a white background using an analog, reflective sensor and to avoid walls by tripping a digital, bump sensor.

Over time less structured exercises are introduced until students are handling projects such as ;

Wall Climber

Build an autonomous robot that can make its way out of a box with 6 inch high walls. The robot must fit within a 7-inch cube.

Rope Climber
Build an autonomous robot that climbs up a 1-yard rope and then climbs down.

Micromouse
Build an autonomous robot that will traverse an unknown maze from an outside door to a destination in the shortest possible time.

Candle Snuffing

Build an autonomous robot that locates and extinguishes the flame of a candle.

Cliff hanger

Build an autonomous robot that moves between two platforms that are the same height but at least five inches apart.

Botball

Build an autonomous robot that moves objects from the center of a field to the goal area.

Trailblazers
Build an autonomous robot that blazes through an unknown trail from a start position to a goal with a variety of obstacles.

In addition to the LEGO®-based experiments, the Toying With Technology℠ courses include engineering design and problem solving exercises that simulate the world of the practicing engineer for participant student teams. For example, student teams build a boat out of relatively inexpensive supplies such as Styrofoam, tongue depressors, etc. The teams learn Archimedes' Principle and predict how much weight their boat can hold and remain afloat. A competition is held to choose the best design with points assigned for cost (artificial costs are assigned to the materials used), weight held, coming closest to predicted weight held, and aesthetics. In addition to learning the science of calculating volume, mass, and buoyancy, the students learn engineering design, problem solving, and teamwork.

Besides the experiments, the class also includes a collection of hands-on demonstrations for the preK-12 classroom that shows the underlying engineering and science involved with the materials used in products. Tempering steel, ductile-to-brittle transition (exemplified in the Challenger or Titanic disasters), and many other materials properties are explored in entertaining, cost-effective demonstrations that are easily employed in a preK-12 classroom. A scanning electron microscope that is accessible on the Internet is made use of to develop experiments and lesson plans for the preK-12 classroom. The web site for the SEM project is at http://www.mse.iastate.edu/excel/.

Several of the practicing teachers who enrolled in this course are now partnered with the education students currently enrolled in the undergraduate course and provide an ongoing relationship among the practicing teacher, the pre-service teachers, the K-12 students, and the engineering and education faculty. In effect, the practicing teacher's classroom becomes the laboratory for the undergraduate Toying With Technology^{SM} course. Recent grants from the Department of Education and the National Science Foundation have provided funding to support the graduate course and the K-12 partner schools.

The teaching method in the graduate and undergraduate classes, as well as all workshops, employs the Constructivist method. There are no lectures. Programming and engineering design is learned by having the students "construct" their own knowledge in a hands-on, project-based environment.

Constructivism

The direction of education was dramatically shifted when Jean Piaget[9] developed a child-centered learning theory. Piaget proposed a 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. A Piagetian classroom must be filled with authentic activities to challenge students and to allow them to construct their own knowledge. Technology, specifically multimedia, offers students this vast array of such opportunities[10].

Constructivism is a relatively new theory in education that is growing in popularity. However, it is much easier to declare constructivism a major trend in the literacy aspect of education as opposed to actually defining it. It appears to be a simple concept: we construct our own meanings of the world in which we live[11]. Learners make sense of the world by incorporating new ideas and experiences into what knowledge they have already constructed. The potential for learning at many different levels is thought to increase as the environment becomes richer and more engaging[12]. Although a learner-centered classroom is not dependent upon computers and technology, they offer learners many different experiences than traditional classrooms.

Achieving the levels of constructivism, or constructing our own meanings, is not always easy. Learners have to have the opportunity to learn in a constructivist manner in order to be able to effectively tie new ideas into existing schema. Accepting the idea of learners constructing new understandings of their world makes accepting the present structure of education difficult. Educators must empower students to ask their own questions and seek their own answers, experience the world's richness, and challenge them to understand the world's complexities. According to Brooks[11], schools tend to operate in the exact opposite direction. The majority of school instruction is centered on the content and not on student learning. Even though many of the principles of constructivism offer promise in the development of successful learning environments, practical applications are often hard to incorporate into the common constraints of the school environment[12].

In schools that do actively seek to adopt the constructivist method of thinking and learning, introducing technology can help enhance the learning process for students and teachers alike. Students in a technology-rich constructivist classroom are often observed helping each other, discussing what they are doing, and commenting on each other's work[13]. "Computers, video, and other technologies bent to a new pedagogical purpose engage children with the immediacy they are used to in their everyday lives.[14]" According to the Office of Technology Assessment[10] computer-based technology supports the constructivist community, allowing ways to access and process information. In addition, constructivist teachers create contexts for learning in which the students become actively engaged in the processes of their own findings and discoveries. 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[15]. Papert[16] defines constructionism as "an epistemological reversion to more concrete ways of knowing." Furthermore, Harel and Papert,[17] Kafai and Resnick,[18] and Martin[19] explain that constructionism also presents the idea that people actually construct new knowledge with particular effectiveness when they are actively engaged in constructing projects that are personally meaningful. Students often construct their own knowledge more effectively while building creations that are of exciting and of interest to them, which in turn encourages the students to learn. They actually learn how to analyze a problem that has no predetermined answer and come up with their own inventive solution to that problem. Students analyze what they see visually and either assimilate their observations into earlier mental models or change their mental model to accommodate new observations which were inconsistent with their earlier ideas. So, ultimately, constructionism refers to "giving children good things to do so that they can learn by doing much better than they could before."[20] The constructionist approach creates an environment in which students actually act like "real-world" scientists, engineers and inventors. This is turn provides students much closer contacts with the truly important ideas of engineering and science[17,18,19].

Conclusion:

The two main theories that drive this course are constructivism and constructionism. Both theories are centered on individuals creating their own learning while constructionism takes it one step further and employs that individuals actually construct something tangible that can be modified or worked on by themselves or others. People gain a certain sense of accomplishment when they have something physical to show for all of their hard work. The Toying with Technology[SM] class strives to provide a course from the undergraduate level to the graduate level that teaches both preservice teachers and inservice teachers (practicing teachers) how to introduce a different type of technology into their teaching. In addition, the class provides a unique quality of being able to give students an interdisciplinary experience, being able to work simultaneously within both the engineering and education arenas. Throughout their educational experiences, students are learning about engineering and just do not know it. Teachers many times do not call the concepts or projects that they are having their students complete engineering projects because teachers often do not have the vocabulary to do so. It is the hope of this course that we provide educators with the vocabulary to talk about engineering concepts and what engineers do with their students so that individuals may later choose the field of engineering in which to study. The Toying with Technology^{SM} course provides an atmosphere where preservice and inservice teachers can learn the concepts of engineering in a non-threatening environment so that they can provide the same experience for their own students.

Future plans for this course include the expansion of the Toying With Technology^{SM} Program throughout the State of Iowa and ultimately the dissemination of the program across the country. Workshops in collaboration with out-of-state universities are in the preliminary planning stages. Pedagogically the courses continue to evolve. The Toying with Technology^{SM} course is in a constant stage of development. New ideas are evaluated each semester in order to provide students with a greater understanding and appreciation for the field of engineering. A new software program that has recently been incorporated into the course is the interactive West Point Bridge Design software, which allows students the opportunity to design and test bridges to meet specified loading conditions. This software also had the honor of winning the prestigious Premier Courseware Award in 2000. In addition, various other engineering design and calculation problems are being developed to illuminate the engineering profession for K-12 teachers and students.

Literature Cited

1. National Commission on Mathematics and Science Teaching for the 21st Century (2000). *Before It's Too Late.* Jessup, MD: Education Publications Center.
2. Duffy, T. & Jonassen, D., *Constructivism and technology of Instruction: A conversation*. 1992.
3. Lane, C. & Cassidy, S., The role of technology in the systemic reform of education and training. *ED Journal, 8*(6), 1-22, 1994.
4. Genalo, L. J., Gallagher, M., Golder, J., “An Engineering Linkage to K-12 Teachers,” Proceedings of the ASEE Annual Conference, on CD - Session # 3453, June, 2001.
5. Genalo, L. J., Wright C. T., Wright K. B., “Toying with Technology in Elementary Education,” Proceedings of the Frontiers in Education Annual Conference, on CD - Session # S4H, November, 1998.
6. Genalo, L. J., Wright C. T., Jr., Wright K. B., Collier, C. L., “Toying with Technology: Mobile Robots and High School Interns,” Proceedings of the ASEE Annual Conference, on CD - Session # 1692, June, 1997.
7. Schwartz, W., “Preparing Middle School Students for a Career,” ERIC Clearinghouse on Urban Education (UD), http://icdl.uncg.edu/ft/083099-01.html, 1996.
8. Chumbley, L.S., Meyer, M., Fredrickson, K., and Laabs, F. C., "Computer Networked Scanning Electron Microscope For Teaching, Research, and Industry Applications," Micro. Res. Tech., 32:330-336, 1995.
9. Piaget, J., The Science of Education amd the Psychology of the Child. NY: Grossman, 1970.
10. Office of Technology Assessment, Teachers and Technology: Making the Connection. (Report NO. OTA-HER-616). Washington D.C.: U.S. Government Printing Office, 1990.
11. Brooks, J, & Brooks, M., In Search of Understanding: The case for Constructivist Classrooms, Alexandria, VA: Association for Supervision and Curriculum Development, 1993.
12. Rieber, L.P., Computer-Based Microworlds: A Bridge Between Constructivism and Direct Instruction. (ERIC Document Reproduction Service No. ED 335007), 1991.
13. Means, B. & Olson, K., Technology’s Role within Constructivist Classrooms, Menlo Park, CA: SRI International. (ERIC Document Reproduction Service No. ED 383283), 1995.

14. Strommen, Erik F.; Lincoln, Bruce. Constructivism, Technology, and the Future of Classroom Learning. Education and Urban Society; v24 n4 p466-76 Aug 1992.
15. Papert, S., 'Introduction.' In I. Harel (Ed.), *Constructionist learning.* Boston: MIT, 1990.
16. Papert, S., The Children's Machine. Rethinking School in the Age of the Computer, HarperCollins, 1993.
17. Harel, I. And Papert, S., Constructionism:Research Reports and Essays, Blex Corp., 1991.
18. Kafai, Y. and Resnick, M., "Constructionism in Practice. Designing, Thinking, and Learning in a Digital World," Lawrence Erlbaum Associates, 1996.
19. Martin, F., "Kids Learning Engineering Science using LEGO and the Programmable Brick," in the proceedings of AERA 1996 Annual Meeting, April, 1996.
20. Papert, S., Mindstorms: Children, Computers, and Powerful Ideas. New York: Basic Books, 1980.

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Course overview. Instrumentation and control engineers are highly sought after in a range of industries including oil and gas, petrochemicals, chemical engineering, manufacturing, research, transport and infrastructure.Â Your Advanced Practice module is assessed by an individual written reflective report (3,000 words) together with a study or workplace log, where appropriate, and through a poster presentation.Â As a graduate you can expect to be employed in a range of sectors including industries involved with oil and gas, petrochemicals, chemical engineering, manufacturing, research, transport and infrastructure. Information for international applicants. Qualifications. Courses in teacher education range in duration and cost. The specific program and university will affect how long the program is and how much tuition will cost. Programs range in duration from a few weeks to a few years.Â A graduate of the course could go on to be a teaching assistant in an elementary school or a lead teacher in a middle school geography class. Another career choice that this program offers is teaching English as a second language.Â COLTT engages participants in learning about teaching practices and technologies, challenging the way they think about both. COLTT engages participants in learning about teaching practices and technologies, challenging the way they think about both. - Courses. English. Subsequently he established the Postgraduate Certicate in Academic Practice at Queen Mary and has developed strategy in areas such as learning and teaching, skills and employability. He is a key reference point on supervision of doctoral students in science and engineering, and advises universities and research institutes across the UK.Â She has a wide knowledge of current practice in teaching, learning and assessment resulting from previous involvement in a variety of national initiatives including the Higher Education Academy. Carol Arlett is the Manager for the Engineering Subject Centre and oversees the Centreâ€™s range of activities that aim to provide subject-specific support for engineering academics. She has a particular interest in employer engagement and skills devel-opment. Construction Engineering and Management Graduate Student Handbook. Zachry Department of Civil and Environmental Engineering. Last updated: June 1, 2020.Â CVEN 644 Project Risk Management is a prerequisite for this course when CVEN 644 is available in a previous semester and a co-requisite for this course when CVEN 644 is available in the same semester as CVEN 689 is taken. Not every course on this list is taught every year. The courses above are typically taught in the semester. indicated. Use the Texas A&M â€œHowdyâ€ web based system to identify which courses will be offered in. which semesters. 9.