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Partnering to Bring Engineering Concepts to Elementary Students*

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A partnership between Michigan Technological University (MTU) and the Western Upper Peninsula Center for Science, Mathematics and Environmental Education (http://www.wupcenter.mtu.edu) provides valuable learning experiences for K-12 students, teachers, and families throughout a five-county area, well beyond the limited staffing and budgets of typical rural school districts. Most of the programs are delivered with assistance from university students, both volunteer and paid, as well as university faculty and staff. Two programs developed through this partnership were established with NSF funding: (1) Family Science Nights where math, science, engineering, and technology (STEM) majors earn credit to develop and present lessons for K-12 students and their parents, and (2) paid internships for university STEM majors to teach after-school enrichment classes for K-12 students. The purpose of these two programs was to introduce K-12 students to engaging, hands-on activities in math, science and technology that utilized engineering applications, and provide an opportunity for STEM majors to work with K-12 students to determine if a teaching career is of interest to them. This paper will describe the benefits of the partnership that has been developed and provide a case study of the internship that was created for undergraduate STEM majors to teach after-school STEM enrichment classes to K-8 students.

Keywords: after school programs; hands-on activities; K-12 technology education; university/K-12 partnerships; engineering interns

INTRODUCTION

TECHNOLOGICAL LITERACY is crucial to America's future economic vitality. Yet the recent National Academy of Sciences (NAS) report *Rising above the Gathering Storm* describes both the shortage of employees skilled in math and science, and the growing shortage of qualified science and math teachers. Enrolment in engineering fields has steadily declined since 1983. Further exacerbating the problem is the continuing challenge of attracting women and minorities into the engineering field and the changing demographics of the U.S. population resulting in a shrinking percentage of white males—the traditional source of engineers relative to other demographic groups. Engineering careers represent good economic choices for women and minorities given their significantly higher starting salaries than other fields and their greater job security. Society will always need engineers to help solve important problems, such as controlling pollution, developing new medicines, designing fuel efficient automobiles, and developing other new technologies. The National Association of Colleges and Employers lists engineering-related degrees as five of the top ten degrees in demand at the bachelor's level; three of the top five degrees most in demand at the master's level; and are wholly targeted at the doctorate level. From 2000 to 2010, a 47% increase in jobs related to science, technology and engineering is expected compared with only a 15% increase in the total number of jobs in the U.S. (NSF S&E Indicators 2002).

The 1996 report by the International Technology Education Association (ITEA) *Technology for All Americans: A Rationale and Structure for the Study of Technology* [1] sets a goal of technological literacy—the ability to use, manage, assess, and understand technology—for all citizens. In a democracy, where citizens routinely make decisions regarding the environment, medical ethics, land use, and defense, it is important that all citizens are technologically literate to some degree. In today's society, technological literacy is confined mainly to those people who are directly working in technological fields such as engineering, manufacturing, science, and mathematics. The vast majority of American citizens have little or no comprehension of basic concepts upon which technology is based nor do they fully understand the technological issues that are a part of the daily news [2]. Traditional pre-college education in the U.S. has largely ignored technology as either a content area or course. Massachusetts is the first state in the nation to include 'engineering' in their K-12 curriculum frameworks which state, 'Science tries to understand the natural world. Based on the knowledge that scientists develop, the goal of engineering is to solve practical problems through the development or use of technology.' U.S. students rarely, if ever, take courses where they

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integrate these topics and skills, are exposed to the design process, or learn about how engineers and technologists use mathematical and scientific principles in the solution of society's problems [3–4].

A lack of instruction and understanding of technological issues will seriously hamper the ability of future citizens to keep pace with the ever-expanding role of technology in all facets of their lives [5]. In addition, because technology and engineering are incorporated into all aspects of American life, and because technology results from the integration of mathematics/science to solve problems faced by humanity, technology-oriented applications are ideally suited for use in motivating students to learn mathematics and science [6–7]. Engineering- and technology-oriented applications naturally incorporate authentic learning experiences, which are of demonstrated importance in the educational process [8–9]. In an effort to address technological illiteracy, the ITEA, along with other organizations, published *Standards for Technological Literacy: Content for the Study of Technology (Technology Content Standards)* as a catalyst for reform in the K-12 curriculum [10].

THE PARTNERSHIP

Michigan Technological University is located in Houghton County in the western Upper Peninsula of Michigan (see Fig. 1). To better appreciate the partnership formed between MTU and local school districts, it is helpful to understand the geographic and economic setting.

The State of Michigan is composed of the Upper and Lower Peninsulas, joined by the five-mile long Mackinac Bridge. The Lower Peninsula is well-populated and industrialized, with the automobile industry dominating. In contrast, the Upper Peninsula (U.P.) with almost one-third of the state's land area (16 452 square miles or 42 610 km^2)—about the size of Denmark—has a mere 3% of the state's population (328 000 people). Distances in the Upper Peninsula are great, spanning 320 miles east to west (515 km) and 125 mi (200 km) north to south. The distances become even more challenging during the U.P.'s six months of winter. The largest city in the U.P. has 19 661 residents—most towns have far fewer. Because of its remoteness and great distance from potential markets, the UP has a very small industrial base, with forestry and paper production playing a significant role in the region's economy. At the turn of the previous century, this area produced the majority of the nation's copper. In 1885, Michigan Technological University was founded as the Michigan School of Mines to support the copper mining industry's need for engineering talent. It was renamed Michigan Technological University in 1964.

The poverty rate in the western Upper Peninsula is greater than average for Michigan. A majority of school districts are in communities where the poverty rate is greater than 20%. The per capita income of this region is 27% lower than the average per capita for Michigan. The largest school district in the region, Calumet Public Schools, is located in the poorest community in the state of Michigan where the median household income in 2003 was $15 550 compared with state median household income of $43 451. The L'Anse and Baraga school districts in Baraga County serve a community with a significant Native American population (12% of the population as a whole for Baraga County) as part of the Keweenaw Bay Indian Community. In Gogebic County, the Watersmeet School District also has a significant Native American population with the Lac Vieux Desert Band of Lake Superior Chippewa.

Initially, two intermediate school districts (ISDs), the Copper Country Intermediate School District and the Gogebic–Ontonagon Intermediate School District, had responsibility for serving the math and science needs of the 20 school districts in the five western counties of Michigan's Upper Peninsula, spanning roughly 12 000 square miles. These two ISDs had no science and math specialists on staff, resulting in very limited science and math programming for K-12 students and teachers.

After several years of collaboration on individual programs, MTU and the two ISDs formalized

Fig 1. Upper peninsula of Michigan.

their partnership in the creation of the Western Upper Peninsula Center for Science, Mathematics and Environmental Education in 2001. The mission of the new Center is to 'enhance the teaching and learning of K-12 science, mathematics and environmental stewardship in the twenty school districts and communities in the five counties of the western UP.' The partnership is physically real in that the Center has two offices—just five miles apart—in order to best bridge the university to area school districts. One office is located at the Copper Country Intermediate School District and a second office is located on the campus of Michigan Technological University. Both offices are integral to ensuring that communication lines are strong between the Center and the school districts, as well as between the Center and university administration, faculty, staff and students. The benefits of partnership are a win–win for all.

BENEFITS DERIVED FROM THE PARTNERSHIP

There are many benefits to be derived in fostering a partnership between a university and local school districts. Some of the benefits realized by the Michigan Tech partnership with the Western U. P. Center are outlined in the following paragraphs.

University faculty share expertise in delivering teacher professional development

Through this partnership, university faculty share their expertise at teacher professional development workshops and research internships for teachers. University faculty are especially valuable in enhancing the mathematics, science, and engineering content knowledge of elementary, middle and high school teachers. For example, faculty in the Department of Civil and Environmental Engineering Department share expertise in wastewater treatment, air quality monitoring, measuring the potential effects of global warming, tracking local weather patterns via satellite imagery, conducting research on the Great Lakes, and helping K-12 teachers integrate engineering design challenges into their math and science classes. Faculty in the Department of Physics have established summer research internship for teachers.

Improving success rates on grant applications

Being able to demonstrate strong partnerships is often the key to a successful grant proposal. University faculty are able to share their grant-writing expertise; and the grant funds received benefit both the university and greatly enhance the K-12 math and science education programs of area school districts. For example, the Center was selected by the U.S. Environmental Protection Agency's (EPA) to conduct a one-week Ecology of the Great Lakes teacher workshop aboard the EPA's Great Lakes research vessel, *Lake Guardian*, during summer 2002 because of their strong partnership with Michigan Tech University. Twenty Michigan teachers had the incredible opportunity to live and work side-by-side with Michigan Tech faculty research engineers and scientists aboard the *Lake Guardian* as it traveled throughout the western half of Lake Superior. Participating teachers were totally inspired by their experience in the research vessel and have produced many new math and science curriculum units as a result. Another teacher institute on Isle Royale National Park, funded by the Michigan Department of Education and sponsored by the Center and MTU, resulted in a new elementary children's book describing the ecology of Isle Royale.

In 1999, Michigan Tech faculty collaborated with the Western U.P. Center to submit a successful grant proposal for a three-year National Science Foundation G-K12 Fellowship project that placed thirty graduate students into elementary and secondary schools to assist teachers for ten hours per week for the entire school year. Some of the projects conducted by these graduate students included training teachers on-the-job in technology applications, designing a K-8 forestry curriculum, developing hands-on K-6 science labs, and developing a high school unit on Geographic Information Systems.

Another collaborative grant proposal to the National Science Foundation resulted in the creation of two very useful programs—a master of education degree program at Michigan Tech that allows science teachers to earn a Master of Applied Science through engineering applications, and an after-school science program for the twenty elementary schools in the Center's service area taught by science and engineering undergraduate students at Michigan Tech. The after-school program allows these STEM majors to gain hands-on teaching experience to find out if a teaching career is for them. This program is described in detail in a later section of this paper.

Scientific research and curriculum development for K-12 students and teachers

University faculty can also provide opportunities for K-12 teachers and students to become involved in scientific and environmental research projects. In 1998, when the issue of frog deformities exploded onto the national screen due to large numbers of deformed frogs being found in the states of Minnesota and Wisconsin, scientists in the Upper Peninsula of Michigan naturally wondered if these high numbers of deformities extended into Michigan. To find out, Center staff teamed up with a faculty member from Michigan Tech and successfully submitted a grant to the Michigan Department of Natural Resources to conduct teacher training in the use of middle and high school students to conduct frog deformity surveys. This collaboration resulted in the collec-

tion of data that found Upper Michigan's rate of frog deformity approximately 1%, well within natural rates. The Center has also received grants from the Michigan Department of Environmental Quality to provide teacher professional development in stream monitoring, in collaboration with MTU faculty.

Most recently, the Center led a 3-year effort with a $188 000 grant from the Michigan Department of Environmental Quality to produce three Michigan Environmental Education Curriculum units on Ecosystems and Biodiversity (gr. 4–6), Water Quality (gr. 6–8) and Energy Resources (gr. 7–9). This effort combined the content expertise of MTU faculty from the Departments of Civil and Environmental Engineering and Geological Sciences and Engineering, and the School of Forest Resources and Environmental Sciences, with the classroom teaching expertise of elementary/middle school teachers, working together on curriculum development teams.

University students increase the center's ability to deliver programs

University students greatly increase the center's ability to deliver programs to K-12 students in the five-county service area. Since 1998, the number of individuals reached annually by Center programs has increased from 5518 to 18 700 due in large part to the more than 350 Michigan Tech University students who have assisted in conducting Center programs over the last few years. University students help deliver Family Science Nights and after-school STEM enrichment classes, coach LEGO MindStorm and Robotics teams of elementary, middle school and high school students, conduct a Science Exploration Festival and assist with judging for the gr. 4–9 students participating at the annual Science Fair, help lead forest field trips, conduct family physics nights, conduct classroom presentations around specific themes, such as the Great Lakes, and assist schools with stream monitoring programs. University students benefit by improving their presentation and communication skills, receiving university credit, being paid, or simply reaping the rewards of community service and enhancing their resume.

Enhanced university course offerings

Each year, about two dozen Michigan Tech graduate and undergraduate students enroll in the semester-long, two-credit Department of Education course titled Communicating Science that prepares them to design and present fun, hands-on STEM lessons for elementary students and their parents at family science nights which are offered at all 20 elementary schools in the five-county area. Family science nights have become a popular event that both parents and elementary students look forward to each year, and earned the highest priority ranking from teachers and school administrators in 2003 Needs Assessment.

Comments from parents completing evaluations after attending a family science night include,

> 'The kids really look forward to it and its fun!'
>
> 'We all learn something. The (MTU) students are great with the kids!'
>
> 'It fosters the importance of education in the family. Science is the bedrock of the future. Plan several (family science nights) per year.'
>
> 'It was educational and fun.'
>
> 'It gets kids excited about science.'
>
> 'Family Science teaches kids how to apply science to daily life,' says a first-grade parent.

The Communicating Science course is taught by Center staff. MTU students come from a wide array of science and engineering departments across campus; less than 5% are education majors. Each student develops two 40-minute lessons that are each presented twice at three science nights. By delivering the same lesson more than once, university students have the opportunity to incorporate the instructor's suggestions for enhancing the effectiveness of both the lesson and its delivery.

> 'Presenting at family science nights has increased my confidence as a presenter, and taught me to think on my feet,' explains a civil engineering student.
>
> 'Communicating Science has been, by a wide margin, the most useful class I have taken at Michigan Tech. I know that Dynamics and Mechanics of Materials are necessary for my major, but they are not the skills that will help you get hired or sell a product,' reflects Mechanical Engineering junior.
>
> 'I learned a lot from this class. I never thought that I would actually enjoy teaching, but I had a good time presenting to the kids. I feel that if I had taken this class earlier in my college career, I would have strongly considered changing my major, but since I am graduating in four days it is a little late! The experiences that I had can be used towards my engineering career. I also have a new respect for teachers that have to teach everyday, because it is not that easy a job,' explains a Mechanical Engineering senior.
>
> 'Communicating Science was a wonderful course. The presentation/teaching experiences will help to contribute positively to my academic and professional career,' observes a Biomedical Engineering senior.

The teaching and presentation skills gained by university students will help them to stand apart when they enter the job search market. A 1998 *Wall Street Journal* article noted that the number one skill sought by employers was 'ability to communicate.' These family science night presenters and after-school instructors will have plenty of evidence to share with potential employers.

A CASE STUDY—AFTER SCHOOL STEM ENRICHMENT PROGRAM FOR K-12 STUDENTS

The Bachelor of Science in Engineering (BSE) program at Michigan Tech has been around since

the early 1970s. We have recently restructured our BSE program to allow students flexibility in pursuing their interests outside of engineering. The BSE program is fully accredited by ABET and consists of courses in four areas: (1) General Education core, (2) Math and science core, (3) Engineering core, and (4) an Engineering Emphasis area. The engineering emphasis area provides students with upper-division coursework in a single discipline and enables them to pursue graduate studies within that discipline if they desire. As part of the new BSE program requirements, students are also required to complete either a minor or certification in an area generally outside of engineering itself. By one option, students in this program are able to pursue teacher certification along with their BSE and complete all degree/certification requirements within a four-year period of study. When teacher-candidates complete the program, they are certified to teach in Technology and Design. Most candidates have a teaching minor in mathematics and may also have a minor in either physics or chemistry, depending on their emphasis area.

In an effort to recruit students into the BSE program combining engineering with teacher certification, an internship program was implemented through the Western U.P. Center for undergraduate engineering students at Michigan Tech. Through this program, approximately fifteen engineering students each semester for three years were selected to conduct a variety of after-school STEM enrichment programs in area schools. The after-school classes were conducted weekly in 4- or 6-week sessions, meeting for 90 minutes per class. Michigan Tech students were assigned to teach at two schools per week and had classes of 15–20 students. The MTU students conducted fun hands-on activities and experiments that were part of lessons developed by the Western U.P. Center staff. Table 1 lists the variety of After-School STEM Enrichment Classes conducted by Michigan Tech student interns during the 2001–02 academic year.

Although not all topics in these after-school classes were directly related to engineering, they were designed to provide young children the opportunity to have fun 'doing' science, engage in inquiry-based learning, and provide real world applications of science concepts The activities that the children participated in were gathered from many resources [12–17] Many innovative activities had been developed by Michigan Tech students enrolled in the 2-credit Communicating Science class and 'field-tested' at Family Science Nights. Detailed lesson plans and supplies for each after-school lesson are pre-assembled enabling the Michigan Tech students to focus primarily on their teaching.

Table 1. After-school STEM enrichment classes conducted by science and engineering student interns (2001–02 academic year)

Title	Grade levels	Number of students served
Amazing animals	1–3	166
Forest fun	1–3	108
Science explorers I	1–3	156
Science explorers II	4–6	172
Outdoor investigations	4–6	95
Chemistry for kids	4–6	75
Alternative energy LEGOs	4–6	90

After-school sessions available for 2005–06 school year

For Grades 1–3:

- *Under our feet*: erosion, rocks vs. minerals, mining and recycling, sand/soil, and fossils
- *Amazing animals*: wiggly worm experiments, animal adaptations, insect investigations
- *Insect friends*: explore body parts, major insect groups, adaptations and ecology.
- *Science explorers I*: characteristics of objects, sound, forces, flight, simple machines
- *Forest fun*: explore trees, wildlife, insects, and ecological relationships outdoors (fall/spring)
- *Fractions are fun I*: explore how fractions represent a portion of a whole, use equivalent fractions, compare and order fractions, and add and subtract fractions

For Grades 4–6:

- *Chemistry for kids*: explore chemical reaction all around us and properties of common chemicals. Use chemistry to solve crimes and to make ice cream and silly putty
- *Alternative energy LEGOs*: design and build vehicles powered by solar, water and wind energy
- *Engineering challenges*: construct bridges, towers, tunnels, and other structures
- *Microscopic explorations*: use microscopes to investigate good and bad bacteria, and microbiology in our lives
- *Fractions are fun II*: explore how fractions are used in games of chance, convert fractions to decimals, multiply and divide fractions, and express fractions as percents
- *Human body*: explore your senses, make models, and investigate the systems in the body
- *Science explorers II*: electricity, air pressure, physical/chemical properties of water, simple machines
- *Outdoor investigations*: conduct experiments and gather data about birds, spiders, frogs, and more

For Grades 7–8

- *Plants and photosynthesis*: explore how plants grow, make food, produce flowers and seeds
- *Energy and resources*: explores environmental sustainability by examining how much energy and resources we use, and potential global consequences

Since the program's inception in the 2001–02 school year, it has expanded to include many

Table 2. Science explorer program for Grades 1–3

Week	Activities
1	Why planes fly: Ping pong puffer [11], controlled flight, in a spin
2	Observations and comparisons: Science in a bag [12], mystery powders, What makes paste? [13]
3	Characteristics of objects: Magnetic attraction, magnetic strength [14], separating mixtures, sifting sand and beans
4	Sound: Vibration, frequency and pitch, slinky sound waves [14], straw oboes [15], spoon bell [14], clucking chicken [14], school box guitar [11]
5	Forces: Balancing stick [11], balloon on a string [11], forces and motion [11]
6	Engineering Forces: Tug-push-twist-o'war [15], straw shapes [15], spaghetti towers

Table 3. Science explorer program for Grades 4–6

Week	Activities
1	Structures and strength: Straw shapes [15], spaghetti towers, gum drop bridges
2	Package engineering and design: Columns [15], egg drop, mail-a-pringle
3	Electricity: Hot [14], conductor [14], electromagnet [14]
4	Air pressure: How can you feel the weight and pressure of air? [16], How hard can air push? [16], How can we measure atmospheric pressure? [16], How can air pressure help airplanes fly? [16]
5	Water properties: Water olympics, under pressure [15], How can you make a soap motorboat? [16]
6	Simple machines: Ramps and cars [11], simple machines

more classes and now includes middle schools. Of the various after-school sessions offered, Science explorers, Alternative energy LEGOs, and Engineering challenges contain the most significant engineering 'flavor.' Outlines for the science explorer I and II sessions are shown in Tables 2 and 3.

PROGRAM EVALUATION

The internship program was evaluated on several levels. Michigan Tech engineering students who participated in the program were surveyed both pre- and post-experience; K-6 students' enjoyment of the classes was surveyed at the end of the six-week session; and school principals who served as the interns' in-school supervisor were also surveyed.

University student intern surveys

Statistical analysis of pre-/post-experience surveys for the engineering students who taught the after-school sessions showed an increase in their confidence, their interest in a teaching career, and their perception of the importance of teaching. The gains in attitudes towards each of these three factors were statistically significant ($p < 0.005$). Representative comments from open-ended survey questions are:

> 'Overall, it was an incredibly rewarding experience that didn't feel like work. Being able to go out to area schools and interact with the teachers and students was a great privilege, which I really enjoyed! Furthermore, this experience has allowed me to consider the possibility of becoming a teacher after having worked in the chemical engineering industry, which is something I would have never considered had I not participated in this opportunity.'
>
> 'I have very much enjoyed this teaching experience and look forward to teaching another group of students in the winter. It gave me such a warm feeling inside to see the joy on the children's faces when they would complete the activity.'
>
> 'I learned that being a teacher might be something that I would like to pursue sometime in the future. I learned how to break science concepts down into simple, easy ideas that young children could more easily grasp.'
>
> 'Participating in this program is by far the most exciting job I have ever had. Everyday that I presented a lesson to a class I learned something new. I thank you for this opportunity and I just hope that this class has benefited the students I have taught as much as it has helped me.'

K-6 student surveys

The elementary students who participated in the after-school classes were surveyed and the following results were obtained for the Forest fun (gr. 1–3), Outdoor investigations (gr. 4–6), Science explorers I, and Science explorers II programs.

Forest fun: Grades 1–3

- 65% would have liked the program to last longer
- 80% wanted to take another class the following year
- 74% reported liking science more than they had before the program

Outdoor investigations: Grades 4–6

- 91% would have liked the program to last longer
- 100% wanted to take another class the following year
- >75% of activities were well liked

Science explorers I: Grades 1–3

- 100% would have liked the program to last longer
- 93% wanted to take another class the following year
- 96% reported liking science more than they had before the program

Science explorers II: Grades 4–6

- 91% would have liked the program to last longer
- 93% wanted to take another class the following year
- 67% reported liking science more than they had before the program

Surveys of K-12 school administrators

K-12 school administrators served as the on-site supervisors for the MTU student instructors. They were asked to rate their observations of the after-school science program and the university student instructors. Questions were scored on a 10-point scale and included items relative to the performance of the Michigan Tech students as a teacher and role model, the use of effective teaching techniques in the sessions, and the age-appropriateness of activities and concepts taught. Average scores on the supervisor ratings were virtually all 10s with the lowest items being the use of 'effective teaching techniques' (8.9) and the use of 'effective classroom management techniques' (8.2). Supervisors overwhelmingly viewed the program as a valuable opportunity for students to enhance their knowledge of science (9.8), their attitudes towards science (10.0), and their ability to interact with science role models.

CONCLUSIONS

Michigan Tech University has successfully established a partnership with area school districts through the Western Upper Peninsula Center for Science, Mathematics and Environmental Education. This partnership has greatly increased STEM teaching and learning opportunities for university students, and K-12 students and teachers, as well as enhanced funding for both the university and school districts.

The two most successful collaborations have been the delivery of family science nights and after-school STEM enrichment classes for K-6 students delivered by MTU science and engineering students. The focus of the after-school classes is on improving children's attitudes towards and understanding of science and engineering. A secondary focus of the internship program was to interest engineering students in the possibility of a teaching career. Surveys completed by the university student interns, the K-6 students, and the school supervisors indicate that the internship program is achieving its goals. Furthermore, whether or not engineering students ultimately decide to pursue a teaching career, they are all much more enthusiastic and confident about teaching lay audiences–an opportunity they'll likely have in any career.

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