STEM Career Education in Middle School (STEM – CEMS)

INTRODUCTION

On the occasion of the 75th anniversary of the publication of the journal, American Scientist, 75 prominent scientists reported why each had chosen to become a scientist. Parents, teachers, mentors, and famous scientists inspired 35 of these men and women to choose science as a career. Thirty-three mentioned an interest in science from childhood, most in the precollege years. In his interview, scientist Michael S. Turner wondered who would inspire the next generation of scientists. His question and response help set the focus for the initiative described in this proposal. "Will we be able to find 100 American scientists to respond to this question on the 100th anniversary of American Scientist? - Not unless we start investing again in the education of our young people" (Press, 1988, p. 463).

REVIEW OF THE LITERATURE

The need for scientists and engineers to sustain American productivity in the 21st century was plainly and forcibly articulated by the 2007 report to Congress, *Rising Above the Gathering Storm* (Committee on Prospering in the Global Economy of the 21st Century, 2007). One of the principal recommendations of this report was to provide higher quality mathematics and science education in our nation's schools. Too few American students are entering the pipeline to the pursuit of university study of STEM subjects because U.S. schools fail to lay a good foundation in these subjects. Interest in mathematics and science as topics of study and as gateways to possible careers in these disciplines wanes when students experience poor science and mathematics teaching in elementary school and as students enter middle school (Hanson, 2008).

Continued study of mathematics and science beyond elementary school can have a huge career payoff. This message needs to be communicated to the middle school student population whose choices of high school courses may inadvertently close or make more difficult the pursuit of careers in the “hard sciences” or even in careers where the need for science is less apparent (for example, chef, artist, or beautician) (Smith, 1984). Primary grades students begin a study of science with enthusiasm; many high school students approach the study of science as an obligation – just one more required course. The critical years, then, for interventions to preserve a positive interest in science are the middle grades (White & Richardson, 1993).

One of the barriers to students’ consideration of science fields as a career choice may be their perception of who does science. Studies of students’ images of scientists reveal that too often students hold a masculine image of scientists, usually with eccentric attributes (Schibeci, 1986). Some research suggests that teaching behaviors, instructional strategies, and prolonged contact with a professional scientist can alter students’ perceptions of who does science for a career (Kahle, 1987; Alberts, 1994; Owens, 1998/99). If we hope to inspire our young people to embrace a career in science or engineering we must generate desirable attitudes and break the stereotypic image they have of those who do such exciting work (Flick, 1990). Smith and Erb (1986) recommend that teachers’ use of resource persons who use science in their careers within the middle school’s regular science program can improve students’ attitude toward science in general and toward women scientists in particular. With a curriculum already crowded with required topics to teach, the pressure of high-stakes tests, and little information about science career applications at their disposal, few teachers elect to incorporate career education in their science teaching on a regular basis. However, when asked about the importance of career education for middle school students, most teachers acknowledge its importance and prefer that it be taught in existing courses (Smith, 1982).

Assisting preservice and inservice teachers with information about STEM careers and how to incorporate it into their science teaching requires enhancing teachers' knowledge and adjusting the curriculum. So, teacher education is imperative. Teacher education is a life-long process, following the continuum from teacher preparation through induction through experienced to master teacher. Regular updates both in content and in pedagogical tools are needed to enhance their own learning and their students' achievement (Committee on Science and Mathematics Teacher Preparation, 2001).

PROJECT DESCRIPTION

Project STEM Career Education in Middle School (STEM-CEMS) provides a model of curriculum and instruction for middle school teachers, preservice teachers, and students that addresses the need for STEM career awareness embedded in standards-based STEM education. Lessons learned from this project and reports of project evaluation will inform members of the science education community interested in interventions to increase the pool of potential scientists and engineers from the middle school population to enter the higher education pipeline and the professional science community. The initial pilot of this project will commence in fall 2008 and will involve a learning community of preservice and inservice teachers, all students in one urban middle school grade band, professional scientists and engineers, university science education professors, and parents. Subsequent pilots will take place in a rural setting where students' awareness of science and engineering taking place in the locale may be lacking.

GOALS for STUDENTS

Project STEM-CEMS addresses the following goals for participating students.

1) Students will describe steps in scientific/engineering problem solving and apply these steps to solve a real world problem as measured by analysis of students' journals and classroom assessment protocols.

2) Students will describe the work of polymer scientists and engineers after interaction with professional scientists/engineers and a tour of the science/engineering workplace as measured by analysis of students' journals and focus group interviews.

3) Students will describe the interrelationship among STEM fields, especially the relationship between science and technology as measured by analysis of students' journals and focus group interviews.

4) Students' attitudes toward STEM and their interest in pursuing careers in these fields will shift to a positive direction as measured by pre- and post- responses on an attitude and preference survey.

5) Students' perceptions of scientists and engineers will shift toward a less-stereotypical view as measured by pre- and post- *Draw a Scientist/Engineer* task.

GOALS for TEACHERS

Project STEM-CEMS addresses the following goals for participating teachers.

1) Teachers will describe steps in scientific/engineering problem solving and apply these steps to solve a real world problem as measured by analysis of their journal responses and performance assessment within a unit of instruction.

2) Teachers will increase their use of inquiry-based methods of teaching science and incorporate scientific/engineering problem solving in their curriculum as measured by their pre- and post- completion of surveys on teachers' belief and classroom instruction practices and by observation of science instruction.

3) Teachers will describe the interrelationship among STEM fields, especially the relationship between science and technology as measured by analysis of their journal responses and focus group interviews.

4) Teachers' perceptions of scientists and engineers will shift toward a less-stereotypical view as measured by pre- and post- *Draw a Scientist/Engineer* task.

5) Preservice teachers will gain experience from being involved in community of practice in which inquiry methods are utilized, discussed and refined.

ACTIVITIES

Note: Activities described will occur in the first pilot of the project and be repeated in the second pilot in a different demographic setting.

Professional Development Activities

Each semester (fall or spring) science, mathematics, and special education teachers from one grade level (for example, eighth grade) at participating middle schools in one district and preservice science teachers will form a learning community by participation in common professional development activities and co-teaching activities throughout ten weeks of the school term. Teachers will voluntarily agree to participate;

all research protocols, assessment instruments, and data collection procedures will follow the guidelines of the university's Institutional Review Board for the Protection of Human Subjects (application submitted on June 13; expedited review anticipated). Data collection procedures will assure anonymity and confidentiality of subjects and report of findings will be in aggregate.

Professional development (PD) activities will take place in an all-day session at which participants will experience a unit of instruction focused on state standards (Physical Science, Scientific Inquiry, Scientific Ways of Knowing, and Science and Technology) that they will teach in the middle school science classrooms. See below for specific references to the Ohio Academic Content Standards for Science.

Polymer science and engineering topics are the focus of the units of instruction that will be taught in this project for three reasons. Northeast Ohio, where the project will be implemented, is the site of numerous polymer research and processing firms making the topic somewhat familiar to the STEM-CEMS audience. Akron Global Polymer Academy (AGPA) personnel include a polymer scientist who has established many ties to the local school community. AGPA partnerships with researchers and industry in the region will assist in bringing a diverse array of career exposure to students in the project. Polymer science topics cannot be understood solely as "science" topics; every dimension of STEM (science, technology, engineering, and mathematics) is involved in a deep understanding of polymer science.

Professors from the University of Akron (UA) and personnel from the AGPA will facilitate the teachers' learning using selected lessons aligned to the districts' curriculum from the AGPA website (www.agpa.uakron.edu). Each of these lessons follows a learning cycle framework (Atkin & Karplus, 1962) and includes underlying content knowledge, safety protocols, materials needed, alignment to standards, and multiple assessment suggestions. For example, in an engineering problem solving lesson, students use polymeric materials to design, test, evaluate, redesign, test, and evaluate a prototype of an athletic helmet for use in a chosen activity (football, bike riding, etc). Mathematics teachers will discuss how the concepts and skills that they teach can enhance students' learning when the lessons are implemented in the classroom. Teachers of students with special learning needs will suggest adaptations that can be made to the curriculum and methods of instruction and assessment to meet the Individual Education Plan (IEP) of included students.

In addition, discussion of teaching, learning, careers, science research findings, and science/engineering problem solving will take place. Some PD discussions will take place via postings on the AGPA website, face-to-face sessions during teachers' common planning time, and after school sessions.

Ohio Academic Content Standards for Science Addressed
Science and Technology, Grades 6-8, Benchmark A
Science and Technology, Grades 6-8, Benchmark B
Scientific Inquiry, Grades 6-8, Benchmark A
Physical Science, Grades 6-8, Benchmark A
Scientific Ways of Knowing, Grades 6-8, Benchmark A
Scientific Ways of Knowing, Grades 6-8, Benchmark C

Classroom Teaching Activities

A small group of preservice teachers will be assigned to each science teacher and will observe, prepare, co-teach, and assess their instruction of science lessons experienced in the PD session. Mathematics teachers and special education teachers will support this science instruction as they prepare and implement their own curriculum and instruction. Because this project focuses on making students aware of career opportunities in science and engineering, a University of Akron polymer scientist, Dr. Carin Helfer, will be presenting polymer content knowledge, will be interacting with students throughout the science instructional periods, will coordinate visits to the school by scientists and engineers for Career Day, and will facilitate a field trip visit to the university's polymer research labs for all project students. The University of Akron science education professors, Katharine Owens and Nidaa Makki will be on-site to assist with all science lessons, to facilitate data collection, and to conduct project formative assessment. Project personnel will provide all materials needed to implement the selected lessons.

Culminating Activities

The culminating activities will be an in-school Career Day, field trip to The University of Akron's College of Polymer Science and Polymer Engineering, and Polymer Family Night for participating students, their parents and siblings, district personnel, and interested community members.

Career Day: Small group assemblies will take place during the school day near the end of the semester. Presenters (scientists and engineers from industrial/academic settings) will describe the dimensions of their careers, what academic preparation is needed, what rewards are derived, and how middle school students might prepare to seek their career.

Field trip: Each participating student will take a tour of the research facilities of the college. A typical field trip includes a brief formal presentation about the college's work, then in small groups visitors are escorted through several research labs where researchers explain/demonstrate products/processes under investigation. For example, in one lab visitors typically see an example of an adhesive that imitates the sticky feet of the gecko.

Polymer Family Night: This event will occur every semester for the families of participating students. AGPA has experience sponsoring these events in the northeast Ohio area. Typically this event occurs in the school's gym and includes inquiry stations where students facilitate attendees' experiences with polymeric materials, refreshments, door prizes, and a short presentation by a polymer scientist or engineer. Since Barberton (our first pilot site) is home to many research, development, and manufacturing facilities we plan to ask representatives of these entities to set up a display and answer questions about their work.

PROJECT EVALUATION

Project personnel have engaged the talents of an external evaluator to provide oversight of project's activities, to assist in data analysis, and to provide a report to the funder regarding achievement of project goals. Project goals for students and teachers include a brief listing of data sources. In more detail –

<u>Performance assessment within instructional activities (students)</u>: the lessons to be implemented in the classrooms require that students solve problems much like those addressed by a scientist or engineer. Therefore, traditional forms of assessment (i.e. pencil and paper tests) would be inappropriate to ascertain students' learning.

<u>Journal entries (students)</u>: sample questions that will be used include

1. Think about your last trip to the mall. Describe an occupation of someone who works there. How does this person use science or engineering in his or her work?

2. Describe the most interesting thing you saw on your tour of the polymer science research labs.
3. Name a scientist whose work you have heard about. What did this person discover?

Focus group interview questions (students): sample questions that will be used include

Pre-project

1. Will you take more science classes than are required by your school when you go to high school?
2. Describe your thoughts on science.
3. Have you considered a possible career as a scientist or engineer? Why, or why not?

Post-project

1. Will you take more science classes than are required when you go to high school?
2. Describe your thoughts on science.
3. Now that you have completed this project, are you considering a career as a scientist or engineer?

Attitude towards science, careers in science, normality of scientists (students): Both as a pretest and a post-test, consenting students will complete the *Test of Science-Related Attitudes (TOSRA)* (Fraser, 1978). Data collected from this survey will provide information about changes in students' attitudes over time. Data will be reported in aggregate.

Draw-A-Scientist (teachers and students): To ascertain students' image of scientists and any change over time on their perceptions after participation in Project STEM-CEMS, students will make drawings of scientists, including physical characteristics, tools used, setting, and descriptive words (Chambers, 1983). These drawings will be made before any project activities are conducted and after all activities wrap up. Scoring of these drawings will follow guidelines from Finson, Beaver, and Cramond (1995).

Observation of science instruction (teachers): Project personnel and the external evaluator will observe the implementation of science/engineering problem-solving lessons in the classrooms of participating teachers. Field notes of these observations will be recorded and summarized.

<u>Surveys (teachers)</u>: the following three quantitative surveys will be administered to participating teachers as pre- and post- assessments

1) Beliefs about Teaching Science and Mathematics (Riggs & Enochs, 1990) – a five-scale survey inquiring about how teachers perceive students' learning of mathematics and science and their role in students' success in these disciplines.

2) Classroom Learning Environment Survey (modified from Taylor, Fraser, & White, 1994) – a five-scale survey inquiring about attributes of classroom practice and environment.

3) Survey of Practices and Standards of Instruction – a survey that probes the frequency of use, importance, and a teacher's preparedness to teach science and mathematics.

<u>Focus Group Questions (teachers)</u>: sample questions that will be used include

1) What have you learned about STEM fields and careers by participating in this project?
2) How do you perceive that this project has impacted your students' learning? Your students' knowledge of careers?

PROJECT PERSONNEL

Name	Responsibility	Percentage of Time	Qualifications
Ms. Jane Beese	External Evaluator • Collect and analyze assessment data • On-site observations of project activities • Generating formative and	5%	Ed.D. in Educational Leadership; three years experience in evaluation; over 10 years experience as an administrator; and over 20 years experience as a

	summative reports		teacher K-12.
Dr. Carin Helfer, Akron Global Polymer Academy	Polymer Scientist and Project Co-Director • PD and classroom instruction • Coordinate field trips, career days, family nights • Oversee ordering materials Classroom visits	20%	PhD in Polymer Science; five years industry experience as a chemical engineer; seven years experience as a research scientist; three years as scientist in residence at AGPA
Dr. Nidaa Makki	Science Educator and Senior Personnel • Supervise preservice classroom instruction	10%	PhD in Curriculum & Instruction (emphasis in science education); physics teaching experience; project coordinator – Operation Physics
Dr. Katharine Owens, College of Education and Akron Global Polymer Academy	Science Educator and Project Director • PD and classroom instruction • Supervise classroom instruction • Budget oversight • Project evaluation	20%	Ed.D. in Curriculum and Instruction; M.Ed. in Science Education; over 20 years experience as a middle school science and mathematics teacher; over 20 years experience as a PD trainer and project coordinator of federal and state grants

MANAGEMENT PLAN: TIMELINE

Note: First pilot of project STEM-CEMS takes place in Barberton City School District, an urban setting. Barberton is located in Summit County, Ohio. The median household income of Barberton's families is situated about $10,000 below that of other households in the state. Only about 10% of the city's adults have a college degree. The district serves about 1,000 students in its two middle schools, which are rated as needing improvement by the Ohio Department of Education.

Second pilot of project STEM-CEMS takes place at Cloverleaf Middle School in Medina County, Ohio, a rural setting made up of several small towns. Cloverleaf Middle School serves approximately 600 students; more than one-fifth are economically disadvantaged (more than $10,000 below the state average). The district is rated effective by Ohio Department of Education.

Fall/Spring Term	Activity	Assessment
Weeks 1-3	Selection of preservice teacher participants Formation of learning community of inservice and preservice teachers Professional development program Experience unit of instruction to be taught to science/math classes	Pre-project survey completion; pre-project draw a scientist task; performance assessment of unit of instruction
Week 4	Presentation to all classes by professional scientist	Students' journal entries and drawings
Weeks 5 - 8	Classroom instruction by learning community of teachers	Students' journal entries, focus group interviews, performance assessment within instruction
Week 9	Career Day – visits to classrooms by scientists and engineers	Students' and teachers' journal entries
Week 10	Field trips to the research labs at The University of Akron	Students' and teachers' journal entries
Week 11	Polymer Family Night	Students' focus group interview; exit survey
Week 12	Compilation of assessment data	Preliminary report as formative assessment of project

An annual report will be compiled, both for project evaluation and to inform the STEM education community. Dissemination activities will include publication in scholarly, peer-reviewed journals and conference presentations at local, state and national venues.

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STEM-CEMS

BUDGET JUSTIFICATION

Training Stipends
18 teachers per semester * $500/teacher * 4 semesters **$36,000**

Indirect Costs
8% * $107, 449 **$8,596**

Contractual: External Evaluator
Jane Beese has been hired to conduct evaluation of this project and to produce the reports as described in the narrative section. **$14,000**

Other
Field Trips
Buses (per semester)
6 field trips (100 students per trip) * 2 buses * 3 hours @ $45/hr. per trip
6 * 2 * 135 = $1620 * 4 semesters **$6,480**

Substitute Teachers (per semester)
Substitute teachers needed for classrooms while teachers are on field trips
6 - half days with 3 substitute teachers @$50/half day
6 * 3 * $50 = $900 * 4 semesters **$3,600**

Honorarium (per semester)
Speakers at Career Days will each be given a gift card valued at $100
6 speakers * $100 = $600 * 4 semesters = $2400 **$2,400**

TOTAL OTHER **$12, 480**

Travel

Mileage: Funds are requested for local travel for project personnel to and from school sites (Rate = $.505/mile)

Per semester: 25 miles round trip * $.505/mile * 15 trips * 3 project personnel = $568

Total for four semesters **$2,273**

2 Trips to Washington, DC for Director & Co-Director to attend a meeting **$2050**
Hotel @ $200/night * 2 nights * 2 people = $800
Round Trip Airfare = $300 8 2 people = $600
Ground transportation & parking = $100 * 2 people = $200

Per Diem @ $75/day * 3 days * 2 people = $450

TOTAL TRAVEL	**$4323**

SUPPLIES
Polymer Family Nights (one per semester)
Costs include materials for inquiry stations, door prizes, publicity, and hospitality
$5000 per semester * 4 = $20,000
Supplies for Classroom Implementation (12 classes per semester)
Costs include materials for hands-on activities and consumables
$1000 per class * 12 classes = $12,000 * 4 semesters = $48,000
Duplication ($25/year * 2 years = $50)

TOTAL SUPPLIES	**$68,050**
TOTAL DIRECT COSTS	**$98,853**
INDIRECT COSTS	**$8,596**
TRAINING STIPENDS	**$36,000**
TOTAL COSTS	**$143,449**