After the Funding: Sustaining an NSF GK-12 Outreach Initiative

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Abstract

The National Science Foundation funded Authentic Teaching Alliance (ATA) (DGE-0086415) began in 2001 as a collaborative program between the College of Engineering (CoE) and the K20 Center for Educational and Community Renewal (CECR) at the University of Oklahoma (OU). In the past four years, 22 graduate and 17 undergraduate Fellows worked directly with 19 science and mathematics teachers, in 11 secondary schools, impacting over 2,578 students. Fellows and teachers collaborated in developing, designing, implementing, teaching, and assessing over 100 authentic learning, inquiry-based activities, 41 of which are available on the ATA website[1] for public use. ATA activities are related to an issue or topic pertinent to the students' community and used as a vehicle to teach science and mathematics. These activities are incorporated into lessons, laboratory exercises, individual and group projects, and field experiences in order to: 1) emphasize authentic and community-based experiences; 2) encourage creative problem-solving skills; 3) develop interest in life-long learning; and 4) prepare students for advanced education. ATA activities are designed to fit the teachers' and students' needs based on curriculum requirements, national and state standards, course content, and students' abilities and interests.

The goal of "authentic" teaching is to enable students to directly experience the relevancy of their education to "real-world" problems, as well as experience a direct link between their education, their community and themselves. Rather than didactically focusing on memorization of factual information, *authentic learning* requires educators to design and facilitate learning experiences that *engage students* in personal construction of new knowledge; promote disciplined inquiry; and help the students see the value of the learned material beyond the classroom.

As this grant draws to a close, the key goal is sustaining this type of outreach to science and mathematics classrooms. One means of sustainability can be achieved through curricular programs at the higher education level. In

collaboration, the Colleges of Engineering and Education, along with the Graduate College, have proposed a minor in education for engineering undergraduates and a dual STEM-education degree for graduates. Through this curriculum, college and university STEM students will gain the pedagogical knowledge, teaching experience, and professional skills necessary to become successful educators at levels ranging from elementary through graduate school and on into the professional workplace. In addition, this curriculum will provide the essential core education leading to alternative certification to be a STEM teacher, thereby possibly increasing the number of potential future K-12 science and mathematics teachers. This curriculum will be open to all STEM students across campus. The curriculum will require students to spend one semester (for course credit) in secondary STEM classrooms implementing authentic activities they design. *Thus, this curriculum provides the primary pathway for advanced STEM undergraduates and graduate students to maintain involvement in ATA K-12 outreach activities in classrooms beyond NSF support*. The details of the curriculum and its associated courses, as well as survey results indicating interest in the program of engineering students will be presented.

Introduction

The Authentic Teaching Alliance (ATA) (DGE-0086415) began in 2001 as a collaborative program between the College of Engineering (CoE) and the K20 Center for Educational and Community Renewal (CECR) at the University of Oklahoma (OU). In the past three years of ATA, 22 graduate and 17 undergraduate Fellows worked directly with 19 science and mathematics teachers, in 11 secondary schools, impacting over 2578 students. Fellows and teachers collaborated in developing, designing, implementing, teaching, and assessing over 100 authentic learning, inquiry-based activities, 41 of which are available on the ATA website[1] for public use. ATA activities are related to an issue or topic pertinent to the students' community and used as a vehicle to teach science and mathematics. These activities are incorporated into lessons, laboratory exercises, individual and group projects, and field experiences in order to: 1) emphasize authentic and community-based experiences; 2) encourage creative problem-solving skills; 3) develop interest in life-long learning; and 4) prepare students for advanced education. ATA activities are designed to fit the teachers' and students' needs based on curriculum requirements, national and state standards, course content, and students' abilities and interests.

The goal of *authentic teaching* is to enable students to experience both the relevance of their education to real problems and direct links among their education, their community and themselves, thereby allowing them to participate as effective citizens in an information society. Rather than didactically focusing on memorization of factual information, which often has little value outside of the school setting, *authentic learning requires that educators design and facilitate learning experiences that: engage students in personal construction of new knowledge; result in students conducting disciplined inquiry; and have value beyond the classroom*[2, 3, 4, 5]. Construction of new knowledge involves students producing original work, while disciplined inquiry requires students to use their prior knowledge to understand a topic at a deeper level. The concept *value beyond the classrooms* means that students effectively apply their knowledge in their everyday lives. The effectiveness of authentic teaching has been demonstrated[6, 7, 8]; most notably a study of over 1,500 secondary schools found that students taught authentically consistently outperformed students taught using more conventional methods[9].

Two examples of authentic learning activities developed under ATA are: 1) Urban Algebra I students learning to use logarithms by measuring sound levels throughout their school and homes and comparing these levels with OSHA noise regulations. Many found they listened to their car radios at levels damaging to their infant's hearing, inspiring them to lower the volume. 2) Rural high school chemistry and biology students used their farm ponds as laboratories to study the affect of water quality on pond ecosystems. Many, realizing the importance of proper fertilizer and runoff management practices, had their parents follow improved practices on their farms.

In addition, ATA designed an advanced-level, 3-credit, general engineering course *Incorporating Authentic Science and Mathematics Activities into the Secondary School* to instruct Fellows on: 1) educational theory, concepts, and assessment congruent with authentic learning; 2) the design, implementation, and assessment of hands-on, inquiry-based activities; 3) how to integrate their technical background and expertise into secondary STEM classrooms; and 4) appropriate teaching practices and methods for secondary students, as well as local, state, and national curricula standards. The next section is a brief list of the Outcomes and Nuggets from this project.

Outcomes of Grant

There were several beneficiaries from the grant activities over the past four years. The benefits or outcomes associated with graduate education, K-12 school practices, the materials created, the K-12 students and teachers, the Fellows themselves, and dissemination of the activities are summarized in the sections that follow.

Changes at the University level in attitudes and practices concerning graduate education.

- Implementation of a three credit hour course called *Incorporating Authentic Science and Mathematics Activities into the Secondary School* (to be renamed to *Principles of Science and Mathematics Authentic Education).* Students receive upper-level credit towards their engineering or education degree.
- Seventeen of 22 graduate Fellows' advisors knew of their participation in ATA and had positive reactions. Six advisors were consulted in ATA activity developments and two hosted field trips to their laboratories.
- Students interested in pursuing doctoral studies in engineering education are eligible for the ongoing Graduate Fellowship Program, awarded by the OU Foundation, and offered through the OU Vice President for Research and Dean of the Graduate College.

Changes in practices in schools.

- In response to 2002 ATA activities, Dibble High School, in rural Oklahoma, implemented technology graduation credits requiring all students to be able to use Internet search engines, use Power Point and Excel spreadsheets, use technology to prepare and present a topic of interest not currently offered within the high school curriculum (e.g., philosophy or Greek mythology), and participate in at least one community technology project. As part of 2003 ATA activities, the school implemented a "Student Bioterrorism School Safety Plan" at the request of Biology II students. This activity involved students meeting with personnel from the

Memorial Institute for the Prevention of Terrorism and the Oklahoma Red Cross, as well as participating in the National Bioterrorism Safety Agenda.

- Due to 27 parents requesting additional classes with ATA activities, Dibble High School now offers a semester-long course on "Technology Integration" that is comprised completely of ATA activities ranging from broad topics such as artificial intelligence and cyberspace to practical topics such as internet search engines and locating college programs over the internet.
- In 2002, one of our high school principals, Mr. Brewster of Santa Fe School (Oklahoma City District), attended the annual NSF GK-12 meeting where he was the only principal.

Use of ATA materials and program by others.

- Fellowship programs at OU that require community outreach are providing their recipients full support for participating in ATA. From 2001-2002, the Carl Albert Fellowship program for political science undergraduates had their recipient participate in all ATA activities and work with Fellows and teachers in order to incorporate how mathematics and science affect history and our society into ATA lessons.
- Non-ATA faculty at OU have collaborated with ATA in order to fulfill the educational component required in their NSF research grants. For example, Dr. Robert Anex from the Institute for Science and Public Policy, his chemical engineering graduate student, two ATA Fellows and a secondary chemistry teacher created authentic lessons addressing bio-based material production. BE/MUSES - Understanding Biocomplexity: Developing Methods of Defining Sustainable Uses for Agricultural Products (BES-0224006).
- Two teams of engineering graduates and seniors designed permanent exhibits for the Omniplex, a large science/technology museum in Oklahoma City, using ATA contacts.
- The widespread promotion of ATA by the PI's, CoE faculty, and the Deans in the College of Engineering and the College of Education across Oklahoma has resulted in at least eight events outside of ATA, in the past 1.5 years, in which ATA Fellows engage in various K-12 activities ranging from teaching the ATA activities to K-12 students in summer day programs to serving as a resource through speaking, presenting, and judging inventions at elementary schools.

Changes in K-12 student and teacher: achievement in STEM; STEM knowledge; attitudes toward STEM; knowledge concerning STEM careers

- Of 664 secondary students surveyed, 75.8% felt what they learned in ATA activities would be *somewhat* to *very valuable* in their lives; 67.5% believed what they learned through ATA would be beneficial to them once they held a job; and 88.1% felt they had learned *some* to *very valuable* information.
- After completing a 2004 ATA activity in collaboration with the Oklahoma Zoological Society (OZS), seven Norman High School students applied for summer OZS internships. Moreover, two seniors involved in this specific activity expressed interest in majoring in zoology. In an exit interview, their teacher shared on her surprise at these seniors' interest since they had not planned to attend college.
- Four external competitive grants totaling $42,000 were awarded to ATA teachers and Fellows with the help of ATA PIs from agencies such as the Oklahoma Space Industry Development Authority and the Oklahoma Zoological Society.
- All nine teachers interviewed in 2004 would recommend authentic teaching to their peers; six claimed that they already had done so. Two reported mentioning and sharing lessons during departmental meetings, two others shared equipment, resources, and lesson plans with other

teachers, and two developed additional authentic lessons while partnering with their colleagues. All nine teachers said they will continue to work as ATA teachers even without weekly collaboration with Fellows.

Changes in Fellows' attitudes, practices, career choices and STEM content knowledge

- Fellows reported a number of positive changes in their writing abilities such as: writing with detail; writing for different audiences; using technology to enhance communication; and an increase in learning through reviewing other Fellows' work.
- 15 of 22 Fellows reported that opportunities to teach in ATA opened the door for them to become a research professor at an institution of higher learning. Many Fellows felt that before ATA they could not teach, but later felt that teaching was more accessible and possible after experiencing all aspects of teaching: planning learning objectives and considering students' needs, as well as designing appropriate lessons with respect to students' cognitive level and technical knowledge.
- Before participating in ATA, 15 of 21 Fellows noted that public speaking was emotionally draining and that they lacked the confidence to speak to large groups. After at least one year of ATA participation, 18 of 21 Fellows reported having more confidence in speaking abilities, in having gained experience in speaking to different audiences about a variety of topics, and in having the ability to articulate content at different levels from beginning learners to experts.
- None of the 22 Fellows was required to change their programs of study, or increase the length of time to matriculation, as a result of participating in ATA.
- Over 50% of the 17 former undergraduate Fellows were accepted into STEM graduate programs
- 73% of undergraduate and graduate Fellows said they had transferred authentic learning practices to their own personal education as university students. Also, 60% of undergraduate and graduate Fellows reported that they will continue to work in educational outreach programs after gaining employment.
- 59% of all ATA Fellows have been female. As well, 32% of ATA graduate Fellows and 24% of undergraduate Fellows belong to underrepresented groups; this is in comparison to the College of Engineering average of 11% for graduate and 19% for undergraduate students.

Dissemination, Publications and presentations

- In three years, ATA has worked with 19 science and mathematics teachers, in 11 secondary schools, impacting over 2578 students. Fellows and teachers designed, implemented, and assessed over 100 authentic learning, inquiry-based activities for chemistry, physics, biology, and mathematics, many are available on the ATA website.
- One peer-reviewed publication on the development of information literacy in Fellows[10]; two peer-reviewed publications in progress, one on increasing secondary student motivation by teaching authentically, and the second on the impact of K-12 outreach on rural schools[11, 12]; and two conference proceedings, one on the collaborative efforts between the OU Colleges of Engineering and Education resulting from ATA, and a second on ATA authentic assessment methods[13, 14].
- ATA has given 28 platform presentations at 18 national and 4 regional conferences.
- An ASEE workshop, an IEEE Deans' Summit, and a Frontiers in Education (FIE) presentation have all portrayed ATA as an example of best practices for collaborations between engineering and education colleges. Additionally, ATA lessons were displayed at an NSF-sponsored

regional discussion on GK-12 sustainability held in Oklahoma City and at an EPSCoR-wide grant development workshop held at OU.

- As a result of local publicity and meetings with state government and education officials, one of our PIs and authors is serving on the State CareerTech Advisory Board for Pre-Engineering Education and on the State Regents for Higher Education 21st Century Math and Science Committee.

Lessons Learned to Date

Many Fellows mistake their ability to use a vast array of technology, i.e. being technologically savvy, with being information literate. Brown et al., (2003) found that information literacy instruction that focuses on the learning styles and preferences of the target population. is more effective than information literacy instruction to college students in a traditional format. This study was conducted in the context of the Fellows' searching for information to include in ATA activities and was motivated by the recurring inclusion of poor-quality data and information. Despite two traditional information searching sessions, little improvement was noticed. However, careful and thorough instruction in the use of popular Internet search engines for authoritative information coupled, with instruction in the use of traditional library resources, led to substantial improvement in the ATA activities created by the Fellows. Furthermore, it was discovered that the Fellows possess a high need for clarity and a low tolerance for ambiguity. Therefore assignments are more effective when thoroughly, yet succinctly, described.

Fellows are more successful and feel more confident about their teaching when they are members of an extensive and multifaceted learning community. Originally, two Fellows were paired with a teacher, but beyond that extensive interaction rarely occurred with other ATA Fellows and teachers. Although teachers were active in mentoring Fellows, the Fellows still reported insufficient educational guidance and advice. Moreover, the content depth of the early ATA activities was often shallow and trivial, a result of the Fellows' feeling overwhelmed by trying to find content information, organize age appropriate learning objectives, and trying to determine how to present it authentically to the students. As a result of these weaknesses, Learning Clusters were formed around topical areas: biology, chemistry, physics, and mathematics. Each cluster included all teachers and Fellows working within these topical areas (typically 3-4 teachers and 6-8 Fellows). Clusters were required to meet formally once each month and to collaborate on ATA activities, thereby sharing ideas and insight, as well as finding synergy by working together on similar topics. Many times, teachers and Fellows designed activities involving classes of different age groups and topics, e.g., introductory physical sciences for freshmen and physics for seniors. In addition to formal meetings, Fellows reported that they contacted other teachers within the cluster for ideas and advice, as well as obtained technical support from other Fellows within the cluster. Many Fellows utilized each other as informal reviewers of their activities before submitting them for formal ATA review. Overall, Fellow morale improved considerably, as did the quality and quantity of ATA activities. Likewise, teachers became more enthusiastic and willing to try innovative activities in their classrooms

To teach Fellows how to prepare and use learning objectives, how to design appropriate activities to teach those objectives, and how to assess if the students learned the objectives, an

intensive one-week summer workshop was developed. The first half of this workshop was led by Dr. Dee Fink, Director of the Instructional Development Program at OU, using the framework outlined in Creating Significant Learning Experiences: An Integrated Approach to Designing College Courses[15]. During the latter half of the week, Fellows and teachers designed two of the three activities they would use in the fall semester. This process involved extensive collaboration with members within their clusters and peer-review by Fellows and teachers from other clusters. Fellows reported that spending an intense week with their collaborating teachers created a strong professional bond that lasted throughout the remaining year. To maintain the rigor established from this workshop, a formal peer-review process, similar to that of peer-reviewed research manuscripts, was initiated: teachers, Fellows, the Program Director, and one research faculty reviewed each lesson for appropriateness and accuracy of content, alignment with state and national standards, authenticity, safety, and originality. The Fellows reported that acting as peer-reviewers greatly increased their content knowledge and gave them new teaching insight.

Sustaining the Program

As this grant draws to a close, the key goal is sustaining this type of outreach to science and mathematics classrooms. One means of sustainability can be achieved through curricular programs at the higher education level. In collaboration, the Colleges of Engineering and Education, along with the Graduate College, have proposed a minor in education for engineering undergraduates and a dual STEM-education degree for graduates which is referred to as the *Teaching as a Profession* curriculum. Through this curriculum, college and university STEM students will gain the pedagogical knowledge, teaching experience, and professional skills necessary to become successful educators at levels ranging from elementary through graduate school and on into the professional workplace. In addition, this curriculum will provide the essential core education leading to alternative certification to be a STEM teacher, thereby possibly increasing the number of potential future K-12 science and mathematics teachers. This curriculum will be open to all STEM students across campus. The curriculum will require students to spend one semester (for course credit) in secondary STEM classrooms implementing authentic activities they design. *Thus, this curriculum provides the primary pathway for advanced STEM undergraduates and graduate students to maintain involvement in ATA K-12 outreach activities in classrooms beyond NSF support*. The details of the curriculum and its associated courses, as well as survey results indicating interest in the program of engineering students will be presented.

Interest and enthusiasm is high among OU engineering students for such a program. Based on a survey done in April of 2003 of 105 OU engineering undergraduate and graduate students, 40% "very strongly agreed" that "teaching with a science/math teacher in a K-12 school would be fun." When asked to rate the importance of various educational skills to their future engineering careers, depending upon the skill listed in the survey, 35.2 to 52.3% of students responded "very important." The following percentage of students responded that they found the following incentives "very attractive" for participating in such a program:

- course credit towards STEM degree - 49.5 %;
- special notation on transcripts - 42.0%;
- wavier of fees for taking K-12 certification exams - 41.0%;
- and receiving a stipend for teaching in K-12 schools - 38.0%.

The proposed undergraduate minor consists of 18 hours of the required course work:

- *Principles of Science and Mathematics Authentic Education* (3 credit hours, 4000 level) (Fall semester) (Prerequisite: enrolled in the "Teaching as a Profession" program or permission of the instructors) Introduction for scientists, engineers, and mathematicians to the fundamentals of authentic education for K-12 students. Topics include: cognitive development and learning styles of K-12 students; foundations of authentic education; authentic education case studies; designing, implementing, and assessing authentic science and mathematics activities; state and national education standards; and classroom observations. Co-taught by science/engineering and education faculty. This course originated from the original ATA course developed exclusively for ATA Fellows.
- Three Education Courses (as specified by the College of Education): Education of Exceptional Learners (EDSP 3053); Developmental Psychology (PSY 2603), and either Introduction to Mathematics Education (EDMA 3052) or Introduction to Science Education (EDSC4092), (9 credit hours) (Fall and Spring semester) (Taken after completion of *Principles of Science and Mathematics Authentic Education*).
- *Principles of Science and Mathematics Authentic Education – Classroom Practicum* (3 credit hours, 4000 level) (Spring semester) Classroom practicum working with a K-12 science or mathematics teacher in designing, implementing, and assessing authentic activities for that teacher's class. Weekly lecture sessions focus on: incorporating real-world science and mathematics components into K-12 authentic activities; best practices for developing student motivation, interest, and ownership in the activities; and peer-reflection and feedback on the developed authentic activities. Co-taught by science/engineering and education faculty.
- Seminar (1 credit hour/semester for a total of 3 credit hours) taken each semester while in the program.

The proposed dual graduate degree program allows graduate students to simultaneously pursue degrees in two fields of study in addition to allowing 20% of course credit to count towards both an engineering graduate degree and an education graduate degree. The OU Graduate College has a formal dual degree structure in place. To obtain a dual degree, students must satisfy the admission, course requirements, and examination requirements of both programs, therefore through the College of Education's requirements, classroom teaching will be experienced. While students will be required to obtain a solid foundation of knowledge of fundamental engineering and education principles and concepts, participants in this dual degree program will focus on specific educational areas, e.g. engineering students interested in teaching at a college or university level may emphasize adult learning rather than elementary or secondary education. In this case, courses counting towards both degrees will emphasize undergraduate STEM education, while graduate students interested in K-12 education would take coursework similar to that highlighted for the education minor. Students interested in pursuing doctoral studies in engineering education are eligible for the ongoing Graduate Fellowship Program, awarded by the OU Foundation, and offered through the Vice President for Research and Graduate Dean.

Conclusions

As many of our large funded projects draw to a close with respect to the funding, it is imperative that means are found to sustain the successful portions of each program. Sustainability must be defined for each location since what works in one state or for one institution may not transfer to a different state or institution. For a National Science Foundation funded GK-12 grant, the Authentic Teaching Alliance, this sustainability has been found through curricular and programmatic reform.

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