AC 2011-893: MAKING ELEMENTARY ENGINEERING WORK: LESSONS FROM PARTNERSHIPS AND PRACTICEMUSEUM OF SCIENCE

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Making Elementary Engineering Work: Lessons from Partnerships and Practice—Museum of Science

Increasingly, elementary schools and teachers are beginning to introduce engineering concepts and skills to their pupils. Engineering challenges can tap into children's natural curiosity and creativity and help to foster their problem-solving abilities. However, incorporating a new discipline—one that few elementary educators are knowledgeable about or comfortable teaching—into an already-packed elementary curriculum can present challenges. This paper will draw upon the experiences of educators at the Museum of Science, Boston who have been supporting the implementation of elementary engineering for over seven years. Specifically it will address how the Museum of Science has engaged in three kinds of partnerships fostered by EiE that have enabled the development and dissemination of the program—partnerships associated with (1) development and testing of resources, (2) building teacher capacity, and (3) fostering national dissemination and advocacy. It briefly describes the goals of these partnerships, the roles that partners can play, sets forth some characteristics of good partners/partnerships, and identifies some of the benefits for the parties involved.

Introduction: Engineering is Elementary

Engineering is Elementary (www.mos.org/eie) is a research-based, standards-driven, and classroom-tested curriculum developed by the Museum of Science, Boston that integrates engineering and technology concepts and skills with elementary science topics. EiE materials also connect with literacy, social studies, and math. Each of the 20 EiE units reinforces one elementary science topic, focuses on one field of engineering, and is set in a different country. The units each begin with an illustrated storybook in which a child confronts a problem. S/he solves it with the mentoring of an adult engineer who introduces the child to the engineering design process. Three subsequent lessons help students to learn more about the focal field of engineering, engage children in science and engineering experiments that can inform their designs, and culminate in pupils applying the engineering design process to solve the same challenge as the story's protagonist. Unit materials include teacher lesson plans, background information, student worksheets, and assessments. The EiE project has reached over 1.7 million students and 22,000 teachers in all 50 states to date. (Visit www.mos.org/EiE for more information about the EiE curriculum.)

From its inception, a number of principles guided the development of EiE. Core among these was that the curriculum interest and engage *all* students, particularly those who were underperforming or traditionally underrepresented in STEM. Also critically important was that the materials be readily accepted and implemented in a wide variety of classrooms by elementary school teachers who are often uncomfortable with science and engineering topics. We recognized that introducing a new, unfamiliar discipline into schools and classrooms would be challenging and would require the engagement of a number of partners—teachers and administrators, schools, districts, state educational entities, institutions of higher education and their faculty, and corporate and grant agencies.

Partnerships

A variety of partners and partnerships have contributed in a number of different ways to the development and dissemination of the curriculum. This section explores the various roles of partners or partnerships in our program. We offer some insights into characteristics of good partnerships and then articulate some of the benefits involved.

(1) Development and Testing of Resources

The ability to draw on the expertise of practicing teachers is critically important for developing high-quality materials that will be used by educators nationwide. From the project's conceptualization, EiE has partnered with practicing teachers to understand the opportunities and constraints that introducing engineering into the curriculum might afford and to tap and leverage their expertise related to how to best structure an elementary engineering program. What types of formats, supports, and resources are necessary and ideal? Teachers steer the EiE project; to make sure we created a curriculum that could be easily implemented, the core resources were produced in collaboration with a small group of pilot teachers and revised based on the input of hundreds of field teachers. Virtually all of the supplemental and support resources created by EiE have been suggested by educators. A number of groups of teacher-partners work with the EiE staff to help craft the structure and content for resources and provide critical feedback to improve them.

Close partnerships with two groups of teachers enabled development of high-quality EiE curricular materials. A group of approximately 15 pilot teachers in Massachusetts provided the first set of feedback about EiE curricular materials; this feedback was instrumental in two main ways. By sharing what and how they were already teaching, offering ideas about how to infuse engineering into their curriculum and integrate it with the science topics, these pilot teachers were able to guide initial content development and help us strengthen the connections between engineering and science lessons already taught in a typical elementary classroom. By testing the nascent EiE units in their classrooms, and providing copious feedback about how to improve individual lessons and the program as a whole, we were able to create lessons that are maximally accessible for teachers, students, and classrooms. To elicit/gather/collect this feedback, the pilot teacher partners convened as a group 4-5 times during the school year. Staff were also in constant contact with the teachers via telephone or email throughout the year and visited their classrooms to conduct observations and collect data. The pilot teachers provided written comments for any units that they tested. Staff, in turn, used this feedback to revise pilot versions of units for further testing.

Similarly, a set of approximately 60 field teachers (for each of the 20 units) in about five sites across the country served as a second set of curriculum testers. After participating in a professional development workshop about the EiE units, field teachers implemented revised versions of the engineering materials and provided extensive feedback regarding how they worked with their students and within the constraints of their schools and classrooms and what might be changed.

We continue to develop additional resources to supplement or support the EiE core curriculum and we continue to work closely with educators to do so. Ideas for most of our resources stem from a teacher or administrator suggesting that we create a new product. For example, the How-To Videos, Content Connections, Teacher Videos, and the Out of School Time initiative were all

requested by teachers. And as with the development of the core EiE curriculum, our collaboration with educators on these new resources is present throughout their development. We hold focus groups with educators to understand what they need, how they would like it to be structured, and the constraints within which they are working. Then, as we create drafts of products these are reviewed, tested, and critically assessed by practitioners in the field.

Characteristics of Good Partners for Development and Testing of Resources:

- Access to a diverse range of students: We aim to develop products that reach a wide range of students. Thus, we need to test drafts with such students and try to find a group of teachers whose students as a pool are diverse.

- Have a range of teaching experience and ability: Because the products will be used by large groups of teachers, we need to get feedback from experienced, highly skilled teachers as well as those who are less skilled.

- Willing to "just try" something new: Working as part of development team requires a willingness sometimes to suspend belief and experiment with something new. Sometimes it works….sometimes it doesn't. But development partners need to welcome a challenge outside their comfort zone and exhibit flexibility about their teaching.

- Willing to be extremely critical: Feedback, critical or laudatory, is how the EiE development team determines what remains and what is discarded. Both the teachers and the EiE staff need to be extremely critical of lessons, with an eye toward improving how they work.

- Willing to allow observers: It's necessary to see how the lesson works in a variety of classes. Our teacher partners must be willing to have us watch the lesson. Partly, we are observing where the materials could better support the lesson. But equally as important, teachers who are very skilled at their profession often improve a lesson as they teach. They can ask just the right question, find an explanation that better resonates with the children, or as they are reflecting think of better ways to structure the activity. They contribute all this expertise to the building of better lessons.

Characteristics of Good Partnerships for Development and Testing of Resources:

- Capitalize on teachers' strengths—lesson modification: teachers are generally extremely skilled at offering feedback about a lesson and thinking about how it could translate to elementary level. We have found that providing drafts or a set of ideas and asking teachers to respond to these is an extremely effective way of tapping their expertise.

- Flexible communication: Teachers are generally working with children all day. Offering a range of modes of communication has worked well. Some prefer email, some the phone.

- Defer to teachers' time constraints: All our teacher partners are full time teachers. Thus, we need to be very cognizant that they are already working a full time job. Our staff keep track of particularly busy times during the school year and try to schedule events when teachers have more time.

- Respect teachers' expertise: For a successful partnership, and indeed a successful project, we find it critical to take seriously teachers' concerns and work to solve the problems they point out, even if it means abandoning an idea.

Benefits: The benefits of partnering with teachers in materials development are immense. Tapping the expertise of practicing teachers who implement the materials in their own classrooms helps highlight where the materials are working well, and more importantly, are not working well. Since our goal is to design a program that can be implemented in all classrooms, first listening to teachers' constraints and suggestions and then observing how it works means that we are getting feedback from the target audience. Nothing can replace testing in actual classrooms with real students; though we have worked developing elementary engineering units for the past 8 years, still about 20% of what we develop does not work, smoothly, once in classrooms. We credit the quality of the EiE materials largely to the intensive testing and feedback we receive from the teacher partners.

From the partners' perspective, they have expressed their enjoyment and satisfaction in helping to create new materials that open a new field. Teacher partners have written and told us how working with us and the lessons has changed the way they think about the world around them (as largely a product of engineering) and their teacher pedagogies (to include more truly open-ended challenges). Our partners also indicate that they enjoy being part of a larger community that is focused on developing high-quality materials. Some of them have received awards or taken on leadership positions related to disseminating engineering education in their schools or districts.

(2) Development of Teacher Capacity

The vast majority of elementary educators have never engaged with engineering. To foster adoption and support implementation, teacher professional development is necessary. While EiE has offered hundreds of workshops directly for teachers, as the national lead, our efforts are focusing primarily on developing models for professional development that can be disseminated to teacher educators (who in turn work with teachers).

Preservice Education

One core way to expose elementary teachers to engineering and how to teach it is to embed such instruction in their preservice education courses. For four years, EiE staff have been working with community college and four-year college faculty and administrators to introduce engineering concepts to preservice elementary teachers. We have formed working partnerships with a number of community colleges and their four-year transfer schools. After introducing science, engineering, and education faculty to what engineering can look like at the elementary level through an EiE professional development workshop, we invited teams of faculty from each institution to reflect upon how they might introduce basic engineering concepts in the courses

that they teach for preservice students and to develop a work plan to implement such modifications. Over the course of several academic years, the faculty met repeatedly to share their projects and progress.

The first set of projects focused mainly on education courses taken by preservice students. EiE staff worked closely with the education faculty—meeting with them, offering additional EiE workshops for their colleagues to build department support and knowledge, and co-teaching courses. In doing this work, however, it became clear that one good opportunity for reaching preservice students was through the core *science* courses that they were required to take. A second initiative is now focusing more intensively on the science faculty, working in partnership with them to modify existing courses or create new ones so they infuse engineering knowledge making connections to relevant science content and model open-ended pedagogical practices. Preservice students who enroll in these classes experience the engineering content and pedagogy. To date approximately 44 education faculty and 50 science faculty have modified their courses for preservice teachers to include engineering. These faculty come from 7 of the 9 community colleges in the state that offer elementary education and five of the 4-year colleges. So in Massachusetts, we have begun to address how engineering can be taught to preservice teachers. We plan to share our partnership models and the course models they have created with additional colleges in MA and the country.

Characteristics of Good Partnerships with Preservice Education Providers:

- Build a common understanding of elementary engineering and goals for preservice learning: For partners to share a common vision of what is meant by elementary engineering and what is needed to support elementary education students, it is useful to have all faculty participate in an EiE unit. The common experience can be used as a referent for later thinking and planning.

- Let faculty drive innovation: Faculty know what they are capable and comfortable of implementing. Letting them propose the magnitude of the innovation and project they will undertake ensures that the projects are doable and done.

- Engage the whole department: Working to change the expectations and culture of a department so peers are informed of efforts and invited to join them can help foster colleagues who are supportive. Workshops offered for fellow faculty about engineering have been valuable. Conducting meetings with administrators builds higher-level support for the initiatives.

- Work across departments: Faculty expressed that the opportunity to sit with other peers from different departments and talk about educational initiatives was both unique and valued.

Benefits:
Teachers teach the way they were taught. Creating models of inquiry-based engineering education for future teachers to follow means that they enter the classroom ready to employ such techniques.

Faculty create programs that botheducate students for the academic standards they will be expected to cover and model effective pedagogy around science inquiry and engineering education.. In tailoring their classes to make them more relevant to preservice students, faculty have also indicated that their teaching has evolved, the engagement of their students increased, and students and faculty's attitudes toward engineering changed.

Teacher Educator Institutes

Educating the hundreds of thousands of elementary teachers already in the classroom will require significant inservice teacher professional development. EiE staff have conducted over 300 of EiE workshops for approximately 4,500 teachers in Massachusetts and across the country. However, it became clear that meeting demand for teacher education related to elementary engineering would require the efforts of many more teacher educators. Thus, about five years ago, EiE staff adopted a train-the-trainer model and began working with other teacher educators through a series of Teacher Educator Institutes (TEI). These three-day workshops engage professional development providers in EiE lessons and activities, but also invite them to reflect upon of the pedagogical underpinnings for offering a high-quality workshop.

To date, EiE staff have offered over 8 TEI programs for over 160 teacher educators. These educators come from school districts, universities, museums, state educational collaboratives, or other educational organizations. As they have run EiE workshops in their region, they have asked for the creation of support materials; they wanted resources that would help them replicate the workshop that EiE staff run. Accordingly, EiE staff secured funding to develop a set of EiE Professional Development Guides. As with teacher materials, these materials are being creating with input, feedback, and critique from teacher educators.

Close communication with some EiE Teacher Educators, and the benefit of their experiences and perspectives suggested a level of partnership that now forms the crux of EiE professional development, dissemination, and advocacy—Regional Hub Sites.

(3) National Dissemination and Advocacy through Regional Partnerships—Building Capacity

To encourage and support elementary engineering at a national level, we have begun to work in close partnership with some of our teacher educators to develop EiE Hub Site Partnerships. These entities assume leadership in their region for advocacy and support of the inclusion of engineering activities in elementary classrooms. EiE Hub sites include universities, Museums, school districts, and other educational entities that engage in high-quality teacher professional development. Furthermore they are willing to engage in an advocacy role—encouraging schools, teachers, or districts to think about implementing engineering. Once a school expresses interest, the Hub Site offers professional development for the teachers and provides ongoing support as these teachers try the activities with their students. Oftentimes Hubs work with schools or districts to raise funding to support their efforts, or work with corporate grantors to identify schools or districts in which to use engineering.

Hub partners are in active communication with the EiE staff. They provide updates about the status of engineering in their region, request additional materials that can support their effort, and share supplemental information that they have developed. The information and innovations that they try are shared with EiE staff. EiE has begun to foster a community of learners among these Hub Partners. In June 2010, Hub Partners were invited to a Symposium where they shared their experiences and challenges with others. As requested by conference attendees, EiE staff are beginning to plan a second Symposium, bolster the online resources, and create an online community where Hub partners can connect.

Characteristics of Good Partners for Dissemination and Advocacy:

- Espouse similar philosophies of education: EiE student and teacher materials are based on philosophies of teaching and learning that are project-based, open-ended, and student-centered. Partners who have experiences supporting these types of initiatives thrive and contribute most to the collaboration.

- Have close ties with schools and districts: EiE Hub partners who have existing networks of teachers and schools and have a solid reputation for offering professional development can effectively utilize their networks as they roll out engineering and EiE.

- Have a leader(s) who dedicates significant time to outreach or professional development: Engaging in teacher professional development, advocacy, and support requires time. Organizations that already have staff dedicated to such initiatives are most likely to participate and be successful as Hub partners.

- Capable of raising funds to support their initiatives: Regional Hub Sites may occasionally be seeded with funding from EiE, but generally speaking the sites need to secure funding to support regional efforts and be self-sustaining. Organizations with a structure and history of supporting initiatives with external or state funding are often most successful in establishing a vibrant EiE Hub Site.

Characteristics of Good Partnerships for Dissemination and Advocacy:

- Share data collection: EiE is grounded in the collection and analysis of data. Institutions and individuals who are data-driven and those who are also interested in conducting research and evaluation studies are particularly valuable collaborators; EiE in turn can provide data for collaborators to use in their advocacy efforts.

- Open communication: Sharing knowledge, expertise, and resources with others and learning from them helps foster a partnership. EiE staff are creating systems to help support such communication with EiE and between hub sites. Some sites also serve as mentors for others.

Benefits:
By sharing experiences, knowledge, and resources, the various sites can learn from each other. Partner sites are valuable because as entities with strong connections in the region serve as active

advocates of elementary engineering and disseminators of EiE. With many more smart minds working on elementary engineering, solutions and resources can be developed more quickly. By establishing a network of providers, EiE can serve a much larger number of students and teachers—thus fostering and supporting the inclusion of engineering at the elementary level.

Summary

The EiE project has heavily relied on a wide range of partners to accomplish its work—developing and implementing materials for elementary engineering requires many entities involved in the funding, development, advocacy, dissemination, research, and classroom implementation. This paper has explored three functions that partners and partnerships have served. Across all roles and types of partners some common characteristics of good partners exist—there must be an alignment of philosophy, a willingness to offer (and hear) feedback or constructive criticism, and a respect for the expertise of those involved. The EiE project and resources will continue to be built upon a network of partners and partnerships; we believe the community of elementary engineering educators benefits from multiple talented, smart people sharing their expertise and experiences. As the community grows, more and more children and teachers across the country can engage in elementary engineering.