AC 2007-8: ENGINEERING IS ELEMENTARY: AN ENGINEERING AND TECHNOLOGY CURRICULUM FOR CHILDREN

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Engineering is Elementary: An Engineering and Technology Curriculum for Children

Overview

As our society becomes increasingly dependent on engineering and technology, it is more important than ever that everyone have a basic understanding of what engineers do, and the uses and implications of the technologies they create. Yet few citizens are technologically literate, in large part because technology and engineering are not taught in our schools [1].

Just as it is important to begin science instruction in the elementary grades by building on children's curiosity about the natural world, it's important to begin engineering instruction in elementary school by building on children's natural inclination to design and build things, and to take things apart to see how they work [2]. At the heart of engineering is an understanding of the *engineering design process*—a highly flexible method of solving problems that is parallel to, but distinct from, the inquiry process in science.

Introducing engineering education at the elementary level is challenging because the school curriculum is already full, and few elementary teachers are comfortable teaching science and math, let alone technology and engineering.

Engineering is Elementary: Engineering and Technology Lessons for Children (EiE) was designed to meet the need for an appropriate and engaging engineering curriculum, while addressing the challenge of adding a new subject to the elementary school curriculum. By creating and testing lessons that are closely integrated with elementary science topics, EiE strengthens the science program while introducing key engineering concepts and fostering positive attitudes towards engineers in ways that include girls and boys from a wide variety of ethnic and cultural backgrounds. EiE also seeks to expand children's images of engineering, and broaden their interests and expectations for the future.

The EiE project is unique in a few ways—it focuses on engineering and it integrates engineering with the science content that teachers already teach [3-6]. It has been designed to complement excellent science inquiry programs such as *Full Option Systems Science (FOSS)*, *Science and Technology for Children (STC), Great Explorations in Math and Science (GEMS),* and *Insights* that have a high level of use despite recent increased emphasis on math and reading. However, it also has close connections with literacy, social studies, and mathematics.

This paper provides an overview of this curriculum project, outlining some of the educational philosophical underpinnings as well as the intensive research and data collection that has informed the final design of the EiE curriculum. It also presents data from teachers about their perspectives on the curriculum.

Rationale

The Engineering is Elementary project is rooted in the belief that children can benefit from early exposure to engineering and technology concepts. The earlier children engage with these subjects, the easier it is to maintain their interest. Reasons to introduce children to engineering in elementary school include:

- *Children are fascinated with building and with taking things apart to see how they work***,** they engineer informally all the time. By encouraging these explorations in elementary school, we can keep these interests alive. Describing their activities as "engineering" when they are engaged in the natural design process can help children develop positive associations with engineering, and increase their desire to pursue such activities in the future [2].
- *Engineering projects integrate other disciplines.* Engaging students in hands-on, real-world engineering experiences can enliven math and science and other content areas. Engineering projects can motivate students to learn math and science concepts by illustrating relevant applications [1,7,8].
- *Engineering fosters problem-solving skills*, including problem formulation, iteration, testing of alternative solutions, and evaluation of data to guide decisions [9].
- *Engineering embraces project-based learning, encompasses hands-on construction, and sharpens children's abilities to function in three dimensions*—all skills that are important for prospering in the modern world [10].
- *Learning about engineering will increase students' awareness of and access to scientific and technical careers*. The number of American citizens pursuing engineering is decreasing. Early introduction to engineering can encourage many capable students, especially girls and minorities, to consider it as a career and enroll in the necessary science and math courses in high school [2,8].
- *Engineering and technological literacy are necessary for the 21st century.* As our society increasingly depends on engineering and technology, our citizens need to understand these fields [11,12].

Goals and Objectives

Engineering is Elementary has three major goals that guide the project.

Goal 1. Increase children's technological literacy

At the elementary school level, we define technological literacy as acquiring essential understandings and skills that include:

Knowledge (Know about):

- What engineering and technology are and what engineers do
- Various fields of engineering
- Nearly everything in the human world has been touched by engineering
- Engineering problems have multiple solutions
- How society influences and is influenced by engineering

- How technology affects the world (both positively and negatively)
- Engineers are from all races, ethnicities, and genders

Skills/Experience (Be able to do):

- Apply the engineering design process
- Apply science and math in engineering
- Employ creativity and careful thinking to solve problems
- Envision one's own abilities as an engineer
- Troubleshoot and learn from failure
- Understand the central role of materials and their properties in engineering solutions

Goal 2. Increase elementary educators' abilities to teach engineering and technology to their students.

The vast majority of elementary school teachers have had no education about engineering and technology concepts or pedagogical strategies. Thus, this is a new topic for them. Support through professional development and resources is needed to scaffold their understanding and instructional abilities.

Goal 3: Modify systems of education to include engineering at the elementary level.
While Massachusetts has included engineering and technology in elementary school standards and assessments, most states do not. We believe that children need to understand both how the natural world and the human-made world operate and are created.

Development Process

Ultimately, EiE will create twenty units that meet both the Massachusetts State Technology/Engineering frameworks [13] and the national Standards for Technological Literacy [14]. This section describes the development process for this research-based curriculum: feasibility and teacher/district needs, curriculum mapping, development, pilot testing, review by experts, and field testing.

Step 1: Feasibility and Needs

The EiE project began with a series of meetings in 2003-2004 with Massachusetts district science curriculum coordinators and pilot teachers to discuss whether and how they were addressing engineering and technology in their classrooms (as mandated by the new state frameworks) and the kinds of activities and materials that would help them to do so. The teachers and coordinators recommended that engineering be integrated with content they already teach and that each unit consists of a few short engineering/technology activities and one long project.

Step 2: Curriculum Mapping and Guiding Principles

To ensure that the units work smoothly together and that the curriculum communicates key concepts, the team mapped all units in terms of content and process skills, design parameters, and teaching methods.

Content and Process Skills

The development team reviewed national and state technology, engineering, and science standards; identified essential understandings (listed above); explored existing educational research and related curricular materials, and then outlined the EiE unit topics and interrelationships. Table 1 provides an overview of curricular content—it outlines the 20 units of EiE; the engineering, technology, and science topics; and the context and character for the storybooks.

Table 1: EiE Curricular Content

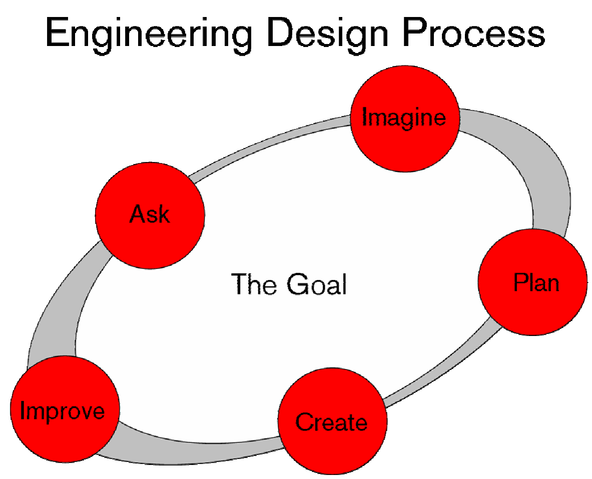
Available to Public	Science Topic	Engineering Field	Design Challenge	Country
currently	Wind & Weather	Mechanical	Windmills	Denmark
currently	Water	Environmental	Water filters	India
currently	Earth Materials	Materials	Walls	China
currently	Balance & Forces	Civil	Bridges	USA - Latino
currently	Simple Machines	Industrial	Potato chip factory	USA - Af. American
currently	Sound	Acoustical/ Communication	Soundproof box	Ghana
currently	Insects / Plants	Agricultural	Pollinators	Dominican Republic
currently	Organisms	Bioengineering	Model Membrane	El Salvador
currently	Electricity	Electrical	Farm Alarm	Australia
August 2007	Solids & Liquids	Chemical	Playdough Process	Canada
August 2007	Landforms	Geotechnical	Bridge Siting	Nepal
August 2007	Plants	Packaging	Plant package	Jordan
August 2007	Magnetism	Transportation	Maglev trains	Japan
August 2008	Energy & Power	*Civil*		*Botswana*
August 2008	Astronomy	*Aero/Astro*		*Chile*
August 2008	Chemical Reactions	*Chemical*		*Russia*
August 2008	Ecosystems	*Systems*		*US- American Indian*
August 2009	Computers	*Computer Science*		*Egypt*

August 2009	Human Body	*Biomedical*		*Thailand*
August 2009				*Greece*

Note: Items in italics subject to change.

"The essence of engineering is design, and so by understanding the nature of design even the youngest student can have a head start on an engineering education" [15, p7]. Because understanding design is central to understanding engineering, student engagement in this problem-solving process is essential. The EiE project created a simple five-step engineering design process for children—Ask, Imagine, Plan, Create, and Improve. It also created a series of question to guide students through each step. The Engineering Design Process and the questions are depicted in Figure 1.

Figure 1: The Engineering Design Process



Moving through the Engineering Design Process might involve asking the following questions or making the following decisions:

ASK
- What is the problem?
- What have others done?
- What are the constraints?

IMAGINE
- What are some solutions?
- Brainstorm ideas.
- Choose the best one.

PLAN
- Draw a diagram.
- Make lists of materials you will need.

CREATE
- Follow your plan and create it.
- Test it out!

IMPROVE
- Talk about what works, what doesn't, and what could work better.
- Modify your design to make it better.
- Test it out!

EiE follows the criteria for good design challenges compiled by Crismond [16], which include: "authentic hands-on tasks…. made from familiar and easy-to-work materials…possessing clearly defined outcomes that allow for multiple solution pathways." The design challenges also "promote student-centered, collaborative work and higher order thinking and allow for multiple iterations to improve the product…with clear links to a limited number of science and engineering concepts" (p. 793).

Design Parameters

The EiE project is rooted in a set of design parameters. These include:

a. *Integration with Science*: The Engineering is Elementary curriculum is not an independent curriculum. Rather, it is integrated with science; the lessons assume that the students are studying or have already studied the science concepts that are then utilized in the engineering lessons. Each EiE unit is paired with a science topic or topics that are commonly taught in elementary school. We suggest that the EiE unit be taught only in conjunction with, or soon after the science topic is taught. The EiE curriculum does not explicitly teach science topics, although science content may be referred to or reviewed. Each unit also focuses on:

- one field of engineering (such as mechanical or environmental)
- one country and culture from around the world.

b. *Grade Level:* An EiE unit should be taught in the grade level when the corresponding science concepts are addressed. Since most science topics are taught in a range of grade levels in different districts and states, the EiE units can be used in almost any grade. For each unit, the lesson plans are written either for beginning or advanced students based on when the science units are more frequently taught. In EiE units, Grades 1-2 are generally considered beginning and Grades 3-5 are considered advanced. However, depending on the abilities of students in any individual class, teachers can choose those that are best suited for their students. If the lesson plans are written for beginning students, suggestions are included throughout the lesson plans for slight modifications that make the lesson more applicable for advanced students. If the lesson plans are written for advanced students, the reverse is true (suggestions are provided for teaching the unit with beginning students).

Similarly, each lesson contains two levels of student handouts—beginning (labeled "B") and advanced (labeled "A"). Teachers can choose which set best fit the capabilities of their students.

c. *Engineering Field*: An engineering field (e.g., mechanical, materials science, environmental) is the unifying theme for each unit. Throughout the unit, the story and activities explore the type of work done by engineers in this field.

d. *Stand Alone*: While the units are closely integrated with science concepts, they "stand-alone" with respect to other EiE engineering units—the units do not sequentially build upon one another and so can be used in any number and order.

e. *Flexibility*: The units are designed for children in grades 1-2 or 3-5. Cognitive and motor skills of the age group are considered in the development of EiE student materials, activities, and design challenges. However, because many science topics spiral through multiple grades the materials are designed for maximum flexibility. Teachers can make the design challenges simpler or more complex so with slight modifications teachers can often use the materials effectively with all elementary grade levels.

f. *Scaffolding*: The activities within a unit progress from simple explorations of related science and engineering ideas through the introduction of the engineering design process and culminate with open-ended design challenges. Design challenges are used as the final project as they allow students with varying academic abilities to succeed; they are easily scaled to meet the needs of gifted or special education inclusion students [17].

e. *Materials*: Materials in the activities and design challenges are simple and inexpensive.

e. *Appealing to Underrepresented Groups*: Engineering examples and design activities are carefully chosen to be of interest to females and minority students. Women and most minority groups are still greatly underrepresented in engineering and technology. One core commitment of the project is to portray engineering and technology as fields that any person—regardless of sex, race, or ability—can succeed in. Educational research has identified ways that the format and content of activities can be more attractive to girls and marginalized populations [18-22].

<u>Teaching Methods</u>

The curriculum recommends teaching methods that are based in a social constructivist view of learning, in which the ideas and skills that students bring to the learning situation are recognized. Students are encouraged to share their initial ideas about the problems and to examine these ideas in light of new information and activities introduced by their peers, teacher, and experiences. The pedagogical methods emphasized throughout the course include:
Learning Cycle: EiE uses the five "E" learning cycle [23]: In *engagement,* the students are drawn to the challenge because it is interesting to them. The read-aloud stories that commence each unit are designed to capture students' imaginations. Students share their ideas about the problems raised in the story. In *exploration,* the students begin to explore related science and engineering principles in brief activities. During this phase they encounter problems or ask questions leading into the *explanation* phase, in which students describe what they think is happening and are ready to learn from their peers and teacher. In the *elaboration* phase students apply what they have learned to meet the larger design challenge. Finally, in *evaluation* students reflect on what they learned.

Contextual Learning and Problem Solving. Students often fail to connect what they learn in school with the world around them. The engineering problems in EiE demonstrate how math, science, engineering, and creativity are needed to solve a problem. Situating learning in a larger context piques students' interest and helps them to understand how what they are learning interacts with the real world or solves a problem [24].

Collaborative Learning and Teamwork: Like real-world engineering projects, most EiE activities are done in small groups. With good management from the teacher, this can encourage students to consider more than one solution or idea and work together to develop the product. Working in small groups also contributes to communication skills [25].

Communication: Students need to communicate what they are doing and why, which can encourage deeper reflection. The EiE project encourages children to communicate their ideas

through a number of modalities—verbal, written, drawn, and built. Whole class discussions moderated by teachers can prompt students to share their insights and learning.
Projects: To fully do engineering or assess understanding requires more than paper and pencil assessment. The EiE projects encourage teamwork and communication. Particularly during the engineering design challenge, students work together to design and create a solution to a problem.

Step 3: Development

The EiE development model is rooted in Wiggins and McTighe's [26] "backward design" process in which assessment is closely linked with curricular development. A brief description of the development process follows; Appendix A outlines the process we follow in more detail. Development of each unit begins with identification of the desired understandings—what should students know and be able to do at the conclusion of the unit? This step is often interlaced with researching students' conceptions—what do they know about the topic? There is a robust body of knowledge investigating children's science conceptions that we can draw upon e.g., [27]; however, almost no research has been done about elementary school students' conceptions of engineering. Consequently, as part of the development process the team has been researching children's engineering knowledge and skills.

The plan for assessment and the outline of the story, lessons, and activities are developed simultaneously. Activities are tested and a first draft of the lesson plans is created. In a workshop setting, lead teachers try the activities and provide extensive feedback. Their comments are used to develop the draft that will be used in pilot testing.

Curricular Materials

With our lead teachers, we have identified a set of curricular materials and resources to support engineering teaching. EiE materials include:

- A *storybook* narrated by a child character from around the world. As the child tries to solve a problem, s/he is introduced to engineering, some basic engineering concepts, related science content, and cultural knowledge about the country. The storybook sets the context for the engineering challenge that readers will engage with.
- *Lessons plans* with detailed instructions for teachers.
- *Duplication masters*--ready-to-photocopy activities and handouts for students available in two levels: basic and advanced.
- *Assessments*--rubrics, multiple choice, and open-ended questions

Lesson Plan Structure

The EiE curricular materials and lesson plans follow a similar structure that consists of a Preparatory Lesson and four Unit Lessons. This structure and its application in one unit—our *Water, Water Everywhere: Designing Water Filters* unit—is described below.

- Preparatory Lesson (20-30 min): The preparatory lesson is designed to prompt students to think about engineering, technology, and the engineering design process. If teachers have done little with engineering and technology in their classrooms, we suggest that they start an EiE unit with this short introductory activity.

For example, this lesson might ask students to examine a set of "common" technologies (stapler, book, sock etc.) and describe what problem they were designed to solve and why they are made of the materials they are.

- Lesson 1, *Engineering Story* (40-50 min): The first lesson sets the context for the unit through an illustrated storybook. A series of questions to promote student reflection before, during, and after the story encourage students to reflect upon the story and its engineering components and reinforce literacy skills

  For example, in the *Saving Salila's Turtle* storybook, a young girl, Salila, living in India finds a turtle in a polluted area of water. Working with her mother, an environmental engineer, Salila thinks about ways that she could filter pollutants from the water to create a pollution-free habitat for her turtle.

- Lesson 2, *A Broader View of an Engineering Field* (30-40 min): The second lesson focuses on helping students develop a broader perspective on the unit's engineering field of focus. Through hands-on activities, students learn more about the types of work done by engineers in these fields, and the kinds of technology they produce.

  In the Water/Environmental Engineering unit, the second lesson asks students, working in small groups, to each identify the air, water, and pollution that is going on in a mural of a town and country landscape.

- Lesson 3, *Scientific Data Inform Engineering Design* (40-50 min): The third lesson is designed to help students understand the linkages between science, mathematics, and engineering. In this lesson, children collect and analyze scientific data that they can refer to in Lesson 4 to inform their designs.

  In Lesson 4, children will be designing and constructing a water filter to filter "dirty" water containing soil, cornstarch, and loose tea. In Lesson 3, each group of students is given water with only one contaminant (tea water or cornstarch water or soil water) and they test the water against the filter materials (cotton ball, screen, cheesecloth, sand) to determine how well they remove particles and color. Then, as a class, they create a big data table with the information.

- Lesson 4, *Engineering Design Challenge* (1-3 sessions of 45 min): The unit culminates with an engineering design challenge. Following the steps of the engineering design process, students design, create, and improve solutions to an engineering problem. Design challenges are used as the final project because they allow students with varying academic abilities to succeed; they are easily scaled to meet the needs of gifted or special needs students.

During the design challenge, students use the five-step engineering design process to design, construct, test, and improve a water filter that removes particles and color from dirty water using the filter materials proviced.

Teacher Professional Development Materials:

The project has also developed a Guide for Professional Development for EiE that includes materials for and tips about developing and running professional development programs for elementary school teachers to introduce them to engineering and the EiE materials.

Step 4: Pilot Testing (and Revision)

An essential element of curriculum development is pilot testing. Each lead teacher pilot tests the units that integrate with the science content s/he teaches. Students are given a pre and post-assessment to determine whether or not the materials are effectively communicating the desired concepts. During pilot testing, EiE staff observe lessons, write extensive field notes, and debrief with the lead teacher about strengths and needed improvements. The teachers themselves complete a feedback form for each unit with detailed information about the content, preparation, management, and modifications they made for each lesson. The lead teachers also gather as a group a few times a year to discuss the program, materials, and units. On an ongoing basis, pilot test data are analyzed and discussed as a team, and materials revised.

Step 5: Review by Experts

Once the materials have been pilot tested and revised, experts from a number of fields will formally review them. An engineer in the targeted field reviews the materials for content accuracy, and a person from the country in which the story is set reviews the materials for cultural accuracy. Depending on the unit experts from the following areas might also review the materials: child development experts, elementary science and technology education faculty, science and technology curriculum development experts, assessment experts, and members of national science, engineering, and teacher organizations.

Step 6: Field Testing (and Revision)

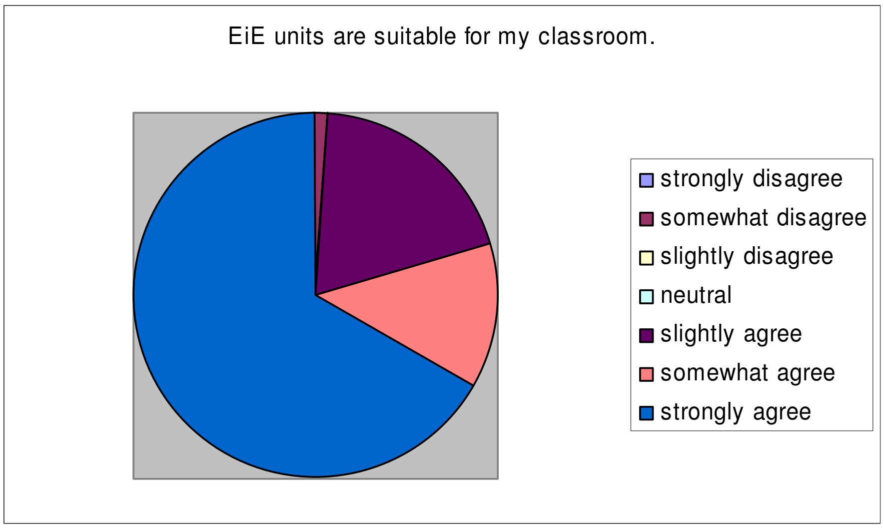
To determine how well the materials will work nationwide without the intensive staff contact available during pilot testing, we field test the EiE materials in five states across the nation: Massachusetts, California, Minnesota, Colorado, and Florida. Partnering organizations in each site offer a professional development workshop for teachers in their region. These teachers test the materials during the school year, collect student pre- and post assessment data, and complete a feedback form about the unit. The feedback from the 50 teacher across the country is compiled, reviewed, and then revisions are undertaken based on the student and teacher data.

Results of some of the student assessment are reported in the “Engineering is Elementary: Children’s Changing Understandings of Science and Engineering” paper in these conference proceedings.

Teacher Perspectives on the Curriculum

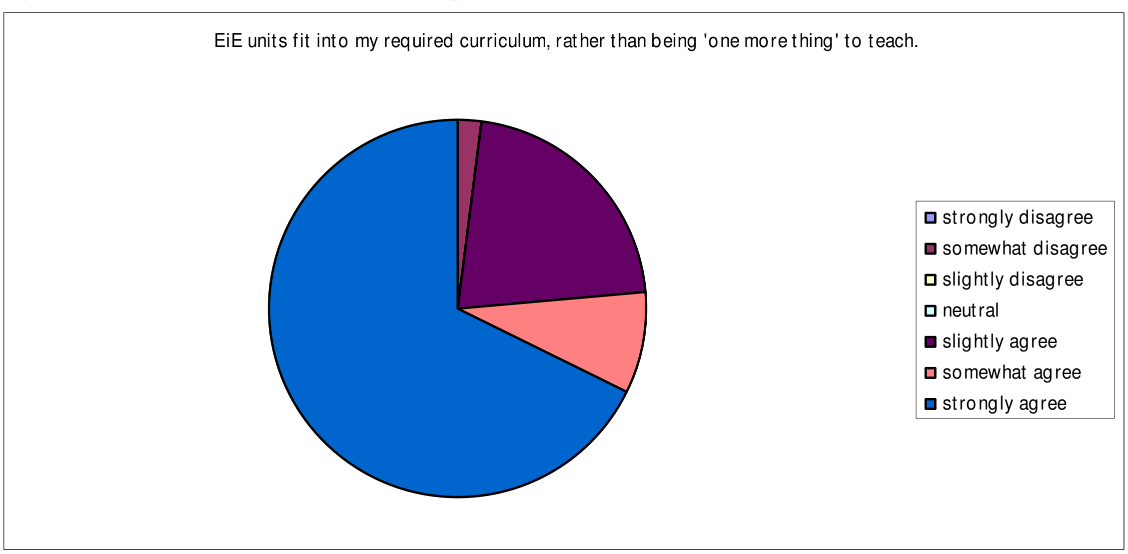
Teacher feedback about the Engineering is Elementary curriculum indicates that they feel the materials work in their classroom and help them to integrate engineering. A survey of 102 grade 1-2 teachers who had engaged with the EiE materials and activities revealed that 66.7% of teachers strongly agree that the EiE units are suitable for their classroom and another 32.4% slightly or moderately agree they are suitable as depicted in Figure 2. (Only 1%, or one teacher, thought they were not suitable.)

Figure 2: Perceptions of EiE Suitability for the Classroom



Similarly, after working with the EiE curricular materials, teachers saw how engineering could be integrated into their curriculum instead of being an additional topic. When queried, the teachers 50.0% of teachers indicated that they strongly agreed this was the case, 9.8% somewhat agreed, and 33.3% slightly agreed as depicted in Figure 3. Only 4.9% of teacher disagreed with this statement.

Figure 3: "Fit" of EiE units into Required Curriculum



In their written comments teachers also articulated their appreciation for the fit of the units into topics they already teach:

"The strengths of these units are that engineering design is now much more understandable for me and I can see how I can implement the engineering design steps into some of the topics I already teach."

"I think the main strength is the way these will integrate seamlessly into what I already teach. Please hurry up with the other units."

Teachers also found a strength of the project to be the real-world application science to solve problems:

"The EiE units provide excellent opportunities for students to think and solve problems."

"I liked the EiE units and felt that they fit into my science curriculum easily. I also think that it is nice to give the kids an opportunity to apply the science knowledge that they are learning through experiments to show them real life applications for the science."

"The units help incorporate a standard that I was not sure of how to address with my students. The process is very strong and can really help the students start thinking about how to solve real life problems. The hands-on activities keep the students interested in the topics and so they should absorb more of the information and actually internalize it as they have to utilize the information that they are learning."

Finally, teachers found the units well structured and organized:

"The units and the curriculum are easily accessible and organized in the binders. The binders contain all the connections to the Frameworks and the outlines of each lesson prepare each teacher for the unit. The assessments, rubrics, and the leveled worksheets (A,B, and AB) make the units extremely user friendly."

"I am very excited to teach the EiE units this year. They fill a crucial gap in our current science curriculum and I can see many ways in which they will fit beautifully with the science we currently teach. Specifically, I think they will help to make the science come alive for students as they apply their knowledge to create useful, effective, and efficient solutions to real-world problems. To me, one of the best aspects of each unit is its structure. The stories provide a great context for the design challenges and link the engineering to the real world just as they link science to literacy. Lessons 2 and 3 provide an excellent background on the field of engineering and really do give students valuable experiences to prepare them for the design challenges. And almost without exception, I would say that the design challenges are very well constructed, meaningful, and exciting activities that can be easily adapted to different grade levels."

When asked what challenges of the curriculum might be, the most common answers by teachers were the fact that the projects required materials that they would need to get and manage and space to put the students' projects.

EiE evaluation and assessment data collected from 179 teachers in five states nationally (MA, CA, CO, FL, MN) who field tested EiE materials in their classrooms surface some of the attributes of the curricula as reported by teachers in open ended questions. According to teachers, the benefits to students of using the EiE materials closely align with the goals of the project. Among the most commonly cited benefits were:

- Learning about/using the engineering design process (42)
- Knowledge of engineering (33)
- Groupwork/teamwork (32)
- Improved science knowledge (29)
- Designing a product (22)
- Hands-on activities (22)
- Problem-solving skills (14)
- Cultural knowledge (10)

Conclusion

The EiE curriculum began with a set of goals and some guiding principals. However, the curriculum development process has been research-based—the developers have looked to the research, but more importantly to classroom observation, teacher feedback, and student data to guide the design and development decisions. Teachers' perspectives on the curriculum are encouraging as they indicate that the structure and goals have been communicated through the curricular materials, that the teachers are finding the materials easy to use, and that the teachers value the curricular materials and lessons they teach.

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Appendix A
Curriculum Development Process

The Engineering is Elementary project team has developed a detailed curriculum development process that structures the creation of curricular materials. This process is based heavily in Wiggins and McTighe's *Understanding by Design*. The steps we follow include:

CURRICULAR MAPPING (Whole Curriculum):

1. Define Engineering Concepts / Essential Understandings

a. Review engineering and technology standards and science standards
b. Outline the "essential" list of concepts
c. Assure concepts are in accord with engineering and technology standards
d. Outline possible unit concepts & skills

2. Identify Core Content and Pedagogical Strategies

a. Review educational research about effective teaching strategies, cognitive development
b. Examine other high-quality curricular materials
c. Talk with other expert curricular materials developers
d. Identify a list of principles that guide content and pedagogy
e. Decide what types of materials and resources are needed in short and long-term
f. Identify an overarching format for the materials

3. Determine Curricular Materials and Format

4. Create Master List of Units to be Developed

a. Read FOSS, Gems, Insights and STC lessons to become familiar with lessons and objectives
b. Review FOSS/STC/etc. materials lists to create master lists of materials available
c. Try out some of the FOSS/STC/etc. experiments or schedule to observe in the classrooms
d. Identify corresponding field of engineering
e. Create a grid of FOSS/STC/etc. and correlate with potential design activities/ unit themes as well as standards
f. Research potential activities
g. Research potential resources
h. Revise grid of FOSS/STC/etc. and EiE while checking alignment with standards
i. Settle on unit concepts & skills

FOR EACH UNIT:

I. DEVELOPMENT

1. Identify Desired Understandings

a. Which engineering concepts will be particular to the unit?
b. Which science concepts?
c. What skills will be taught/reviewed?
d. Which enduring understandings will be emphasized?

2. Research Students' Conceptions

a. What prior research has been conducted about students' understanding of the science topic?
b. Conduct research to determine what students think about the engineering field for the unit
c. Talk with teachers about what they understand and what resources they will need
d. Revise desired understandings if necessary

3. Plan for Assessment
a. Determine: What kinds of evidence are suitable to demonstrate desired understandings?
b. Develop rubrics
c. Plan outline of design challenge/ what students need to demonstrate
d. Quizzes/tests/prompts--outline form
e. Worksheets for gathering observation evidence
f. Plan for journal/student feedback/self-assessment

4. Plan Lessons & Activities
a. What kinds of activities will support learning of desired understandings?
b. What kinds of activities will prepare students for assessments?
c. Sequence & emphasis
d. Test main activity ideas for feasibility & develop

5. Select Storyline Character, Setting, & Technology
a. What story line/technology/country & situation will best showcase & support the desired design activity and science learning?
b. Develop list of key ideas & understandings to focus on
c. Select a character: balance gender, ethnic cultures, and disabilities

6. Develop Preliminary Story Outline
a. Research technology & real-life engineering/setting for storyline
b. Research setting for historical, geographical and community project background
c. Develop a preliminary storyline/outline: Obstacles, problems? Dramatic tension? Surprises? Resolution?
d. Research name, customs, clothing and other factors important to the setting

7. Develop a Solid Draft of the Story
a. Share drafts in-house, collect feedback
b. Check against list of key ideas & understandings: sufficient emphasis?
c. Check against other key factors list: community emphasis, lesson activity, etc.
d. Plan for key factors & activities to be in illustrations
e. Editing (grammatical, text layout, etc.)
f. Revisions to near-final draft

8. Illustration
a. Meet with illustrator: share story, work on illustration ideas
b. Be sure key factors & activities will be represented in story
c. Review draft illustrations as they arrive & note problems to be fixed
d. Add final illustrations to story

9. Develop the First Draft of Lessons (simultaneous with 4, 5, 6 & 7)
a. Write up planned activities & lessons
b. Continue testing activities in-house; revisions
c. Write up duplication masters
d. What misunderstandings are likely? Difficulty with skills?
e. Edit /revise assessments

10. Lead Teacher First Review
a. Introduce unit materials to lead teachers in a workshop, review with them
b. Revise materials according to lead teacher feedback

II. PILOT TESTING

11. Pilot Testing, Feedback

a. Observe pilot lessons, take notes

b. Discuss with teachers. Feedback on usability, skill level, sophistication required, etc. Ideas for improvements

c. Have teachers complete Pilot Testing Feedback form

12. Lesson Review & Revision

a. Does the unit meet design criteria? Does it work towards desired understandings?

b. Editing of all elements (story, lessons, assessments, etc.)

c. Revisions

13. Review by Experts

a. Review by experts in engineering, cognitive psychology, curriculum development, disabilities, people from the country

III. FIELD TESTING

14. Field Testing, Feedback

a. Teachers use lessons

b. Observation of some lessons by field staff

c. Teachers complete Field Testing form. Feedback on usability, skill level, sophistication required, etc. Ideas for improvements

d. Interviews with a subset of teachers

15. Final Lesson Revision