Evaluation Framework for Engineering Education Curriculum: a Review of *Engineering is Elementary*

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About: Engineering is Elementary [1]

Engineering is Elementary (EiE) is a research-based, standards-driven, classroom-tested curriculum claims to integrate engineering and technology concepts and skills with elementary science topics and mathematics learning, as well as literacy and social studies. EiE is a project of the Boston Museum of Science. EiE identifies four main goals:

1. Increase children's technological literacy.
2. Improve elementary educators' ability to teach engineering and technology.
3. Increase the number of schools in the United States that include engineering in their curricula.
4. Conduct research and assessments to further the first three goals and to develop a knowledge base on the teaching and learning of engineering at the elementary school level.

To accomplish these goals, EiE has developed curricular materials and resources, professional development workshops and resources for teachers and teacher educators, a system of national partnerships, and a research and assessment program. EiE's foundational principle is a fervent commitment to engaging and interesting *all* children in engineering and science, particularly children in groups that have traditionally been underrepresented and underserved.

The EiE team states that EiE units and activities reflect the following considerations:

- Engineering design challenges must demonstrate how engineers help people, animals, or society.
- Projects must be set in a large, real-world context to show where and how engineering information and tasks might be relevant.
- Engineering role models must be of both sexes, from a variety of races and ethnicities, and have different abilities/disabilities and a wide range of hobbies and interests.
- Design challenges must be truly open-ended with more than one correct answer.
- Challenges must be amenable to evaluation by both qualitative and quantitative measures.
- Failure must be treated as a necessary and inherent part of engineering that invites subsequent improvements in designs.
- Steps in the process should be explicitly organized to build student skills progressively, without making the process formulaic.
- No previous familiarity with materials or terminology should be assumed.
- Addressing design challenges must require very low cost, readily available materials.
- Activities must encourage a culture of collaboration and teamwork.
- Situations must create an atmosphere in which all students' ideas can be heard and considered.
- Activities must require that students engage in active, hands-on engineering.
- Materials must be easily scalable, up or down, to meet the needs of different kinds of learners.
- The overall focus must be on developing problem solving skills.

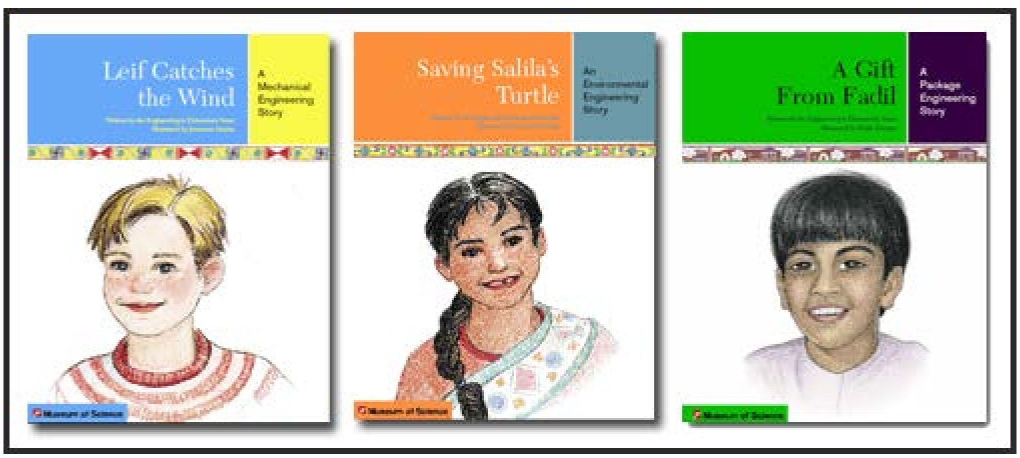
The EiE team adopted an integrated approach to facilitate the introduction of this new discipline in elementary classes. Science was selected as the subject most closely connected to engineering. EiE staff identified 20 of the most commonly taught elementary school science topics, based on a review of curricula and standards from across the nation. Through application, the team designed EiE units that build upon and reinforce these concepts. Each unit also connects to language arts, mathematics, and social studies skills and topics.

Each EiE engineering unit is based on a science topic (e.g., plants), revolves around a field of engineering (e.g., packaging engineering), and highlights a technology from that field (e.g., plant carrier boxes). All EiE units have a common structure consisting of a preparatory lesson designed to prompt students to think about engineering, technology, and the engineering design process and four unit lessons. The structure of each of the four EIE lessons within each unit are:

1) An Engineering story
2) A Broad view of an engineering field
3) Using Scientific data to inform engineering design
4) Solving an Engineering Design Challenge

The EiE unit guide provides teacher lesson plans, student duplication masters (worksheets), background resources for teachers, and assessment items. By design, the program requires that children DO engineering; there is no student textbook.

Figure 1 EiE Storybooks Evaluated



Purpose & Scope

The purpose of this paper is to evaluate the Engineering is Elementary program according to the criteria I identify in subsequent sections. The primary materials examined for this review are the EiE storybooks and EiE teacher's unit guides.

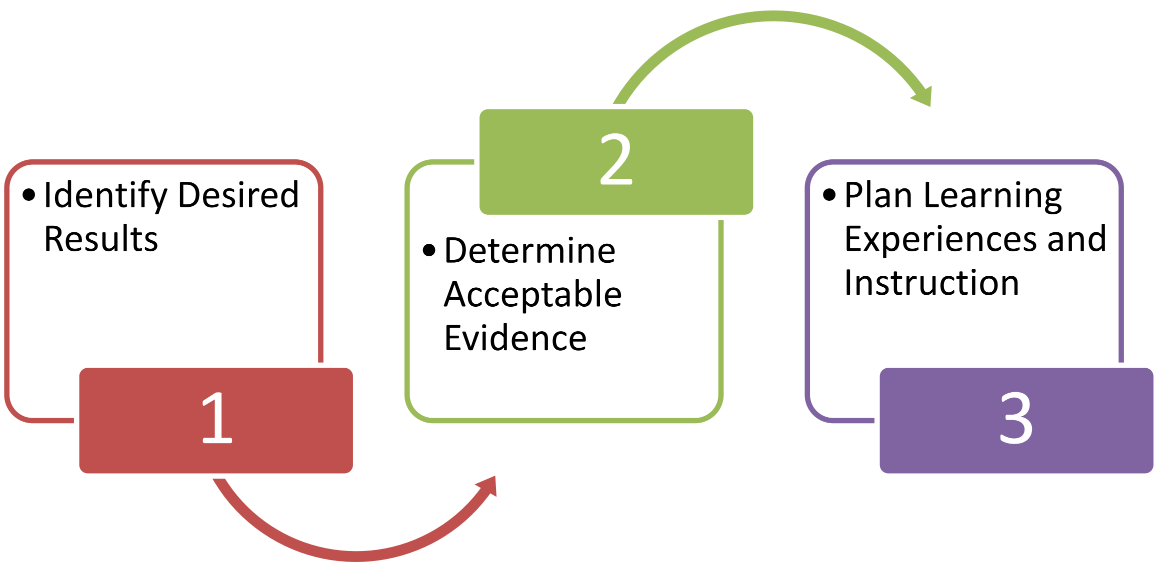
Reviewer Bias

It is important to identify my bias as a reviewer. I have worked with EiE curriculum, specifically the three units reviewed in this paper. EiE curriculum is used by the Institute for P-12 Engineering Research & Learning (INSPIRE) Summer Teacher Academies. The Summer Academy is a one-week program for P-6th grade educators who are interested in learning about innovative methods for integrating engineering into their classrooms. Over the course of two academies in the summer of 2009, I taught the participating teachers these three EiE units.

Evaluation Framework

The framework used to develop the evaluation rubric for this report is based on the Wiggins & McTighe process known as *Backwards Design*[2], as shown in Figure 1. First identify desired results, then determine acceptable evidence, and finally plan learning experiences and instruction. This process is an alignment of content, assessment, and pedagogy, the three components I am using as the measure of quality programmatic elements.

Figure 2 Wiggins & McTighe Stages of Backwards Design



Content: Desired Results

The report by the National Academy of Engineering (NAE) and National Research Council (NRC), *Engineering in K-12 Education: Understanding the status and improving the prospects*, outlines three general principles for K-12 Education[3]:

Principle 1: K-12 engineering education should emphasize engineering design.

Principle 2: K-12 engineering education should incorporate important and developmentally appropriate mathematics, science, and technology knowledge and skills.

Principle 3: K-12 engineering education should promote engineering habits of mind.

- Habits of mind are systems thinking, creativity, optimism, collaboration, communication, attention to ethical considerations.

The remaining details of the content analysis are listed in the following paragraphs.

Increase technological Literacy

An earlier report by the NAE & NRC, suggests that because our economy is increasingly being driven by technical innovation, and because an increasing percentage of jobs require technological skills, a rise in technological literacy would have positive impacts for our community[4]. Technological literacy is defined as encompassing at least three distinct dimensions: knowledge, ways of thinking and acting, and capabilities[4].

The message of engineering is correct and clear

According to the 2008 report by the NAE, Changing the Conversation, it is imperative for engineering education to have an aligned message of engineering. So, K-12 engineering education efforts should not stray from the new positioning statement for engineering (Box 1).

Box 1 NAE New Positioning Statement

> No profession unleashes the spirit of innovation like engineering. From research to real-world applications, engineers constantly discover how to improve our lives by creating bold new solutions that connect science to life in unexpected, forward-thinking ways. Few professions turn so many ideas into so many realities. Few have such a direct and positive effect on people's everyday lives. We are counting on engineers and their imaginations to help us meet the needs of the 21st century.

The material should be inclusive

There are consequences to having material and activities that ignore gender and race[5]. Naturally, implicit bias are rampant in American culture, and it is important to ensure that these biases are not perpetuated in new curriculum[6].

The material integrates well with STEM

The NAE & NRC call for an integrated STEM education[3]. Science, Technology, Engineering, and Math are so closely intertwined that it should be impossible for an education in one to be in isolation of another[7].

The program provides for career exploration

In a nation that was seeded by freedom and opportunity, the roots of the United States of America are grounded by hard work, innovation, and determination. Most often through identification with a worker, ages 5 to 10 is the stage of life when the concept of working becomes ingrained in the child's conception of his or her adult life[8]. Immersed in a society that is dominated and driven by work, and vulnerable to social influences of prestige and gender bias, children as young as five years of age begin to postulate what career they will one day have [9]. Young people tend to choose professions that are familiar [10], whether traditions in their family, or professions they have been exposed to them through education and experience. Young children can begin to gather information about careers and acquire the skills and competencies that will one day support success in the workplace [11]. Harkins states that since work readiness is developed over time, so it makes sense to begin with young children[12]. It is important that the program curriculum include plenty of opportunities to explore careers, in this case various disciplines of engineering.

Assessment: Acceptable Evidence

When considering assessment, as Wiggins & McTighe describe, we must ask this question: "What assessment tasks and other evidence will anchor our curricular units and thus guide our instruction?[2]" For the purposes of this evaluation, we will be looking for integrated student assessments, both formative and summative. Since most likely teachers will not be familiar with this content, it would be helpful for teachers to be provided with tools to help them grade/assess the students. Finally, it is important to know if the program itself has been assessed. Does the program show proven results to support learning of science & engineering?

Pedagogy: Planned Learning Experiences and Instructions

Quality programs are more than merely content covered and assessment. The final stage in the evaluation framework is pedagogy, the planned learning experiences and instructions. For this portion of the evaluation, the following details are the evaluative components.

Let it be noted that a good majority of these are addressing the needs of the teachers. It is important for them to be adequately prepared and to have resources available to help them as they implement a new program.

- Available Teacher training or professional development
- Resources are available for teacher support
- Realistic/practical integration in Classroom
- Lesson plans to teachers are provided for teachers
- Worksheets, handouts, activity descriptions, etc are provided to teachers

The curriculum material should be designed so that it helps the teacher during implementation. If the material does not address various learning styles, multiple intelligiences, and Bloom's taxonomy of cognition, then this adds a tremendous challenge to teachers.

- Material addresses various learning styles through multiple activities.
- Material is flexible to address varying levels of student skill & knowledge

Data Collection Plan

Three EiE units are evaluated in this review (Table 1). Each of the teacher guidebooks and storybooks (Figure 2) were analyzed for the established evaluation framework.

Table 1 Three EiE Units Reviewed

Unit Title	Science Topic	Engineering Field	Storybook (Setting)	Grade Level (A = Advanced Grades 3-5, B = Basic Grades 1-2)
Thinking Inside the Box: Designing a Plant Package	Plants	Package	**A Gift From Fadil (Jordan)**	A
Catching the Wind: Designing Windmills	Wind & Weather	Mechanical	**Leif Catches the Wind (Denmark)**	B
Water, Water Everywhere: Designing Water Filters	Water	Environmental	**Saving Salila's Turtle (India)**	A

Analysis

An analysis of the materials are measured on a 3 factor scale: 1) Does not meet expectation, 2) Partially meets expectation, 3) Meets expectation. The two tables below highlight the details previously discussed for each of the three components of the evaluation framework: content, assessment, pedagogy. The final column in the two tables answer the question: "to what extent does EiE meet each component detail?

Components of Quality Programmatic Elements		Details	Does Not Meet	Partially Meets	Meets	To What extent?
Content	1	Principle 1: K-12 engineering education should emphasize engineering design.			✓	Lesson 4 focuses on the engineering design process. Some commentary may be worthwhile in regards to the simplicity of the EiE design process and how it lacks an iterative element.
	2	Principle 2: K-12 engineering education should incorporate important and developmentally appropriate mathematics, science, and technology knowledge and skills.			✓	Designated age group identified with modifications in the margins of the teacher guide for alternate grades.
	3	Principle 3: K-12 engineering education should promote engineering habits of mind.			✓	Habits of mind are systems thinking, creativity, optimism, collaboration, communication, attention to ethical considerations -- are all built into the design of the EiE curriculum, based on my analysis.
	4	Increase technological Literacy			✓	It would be impossible for students to participate in these EiE activities and not increase technological literacy. Each Unit engages a specific technology. Students learn to talk about and use technology.
	5	The message of engineering is correct and clear			✓	The curriculum promotes the correct image of engineering, but it is no guarantee that the teacher's misconceptions of engineering are not perpetuated.
	6	The material should be inclusive for all			✓	The storybook characters across the units are very diverse: gender, race, ethnicity. The design projects and science themes are appropriate for the different interests of females and males.
	7	The material integrates well with STEM			✓	Recommended Tie-in to Science Units; mapped to ITEA National Standards & Benchmarks, as well as MA Engineering & Technology Standards.
	8	The program provides for career exploration			✓	Each unit focuses on a different discipline of engineering. It is embedded in the unit that the students will explore another facet of engineering as a career.

Components of Quality Programmatic Elements		Details	Does Not Meet	Partially Meets	Meets	To What extent?
Assessment	9	Integrated student assessments (Formative & Summative)			✓	Rubrics are provided for assessment within each lesson.
	10	Teachers are provided with tools to help them grade/assess the students			✓	Rubrics are provided for formative assessment of each lesson, and pre/post summative tests are also included.
	11	Program has shown proven results to support learning of science & engineering.			✓	There are many publications not only from Boston Museum of Science, but other groups using this curriculum for research.
Pedagogy	12	Available Teacher training or professional development		✓		The website indicates that there are TPD, but there are not upcoming opportunities listed. Other organizations, such as INSPIRE, offer training, but these are not listed on the mos.org site.
	13	Realistic/practical integration in Classroom			✓	Each unity has a breakdown of each lesson, how long the prep is, and the length of each lesson.
	14	Lesson plans to teachers are provided for teachers			✓	Extensive unit plans are available for purchase. Includes overview, prep lesson, and each of the four lessons within each unit. Each lesson includes clear objectives.
	15	Material addresses various learning styles through multiple activities.			✓	Activities cross learning styles through the variety of activity, interaction, inquiry and reflection.
	16	Worksheets, handouts, etc are provided to teachers			✓	Worksheets, handouts, and answer keys are provided for ease of copying.
	17	Material is flexible to address varying levels of student skill & knowledge			✓	Teacher tips are included for english language learners, and simplified/advanced modifications.
	18	Resources are available for teacher support			✓	Additional online resources available at www.mos.org/eie

Cost

An additional analysis of the cost is broken down in Table 2.

Table 2 EiE Cost Analysis

Material & Quantity	1	3	8
Teacher Guide	45.00	127.50	320.00
Storybook	6.99		35.99
Material Kits (Average Price, 30 students)	310.00	930.00	2,480.00
Refill Kits (Average Price, 30 students)	136.00	408.00	1,088.00
Total	$497.99	$1,465.50	$3,923.99

Conclusion

Using Wiggin's and McTighe stages of backwards design [2] as a framework, a program evaluation rubric was developed based on education literature. The Engineering is Elementary curriculum was analyzed and found to be a superior program. Based on my analysis, I would recommend this program for use in any K-6 setting.

References

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