AC 2008-1684: OVERVIEW OF ENGINEERING EDUCATION ASSESSMENT AT PRESCHOOL-12TH GRADE LEVELS

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Overview of Engineering Education Assessment at Preschool-12th Grade Levels

Abstract

In the era of No Child Left Behind and continuous well-funded efforts to increase the interest and readiness for engineering of P-12 and pre-college students, several initiatives have been launched. Among the current and most well known are the Infinity Project,; Project Lead the Way; the National Center for Technological Literacy; the National Center for Engineering and Technology Education; and the research-oriented Institute for P-12 Engineering Research and Learning (INSPIRE).

Despite their relevance, rigorous empirical studies of these initiatives as well as other outreach efforts are reported scarcely in the literature. More specifically, within available reports, few have performed assessments and evaluations of their activities. This lack of evaluation and published resources hinders the progress of the national P-12 engineering education agenda, since it does not provide the necessary background elements to validate more generalized interventions.

The purpose of this study is to present an overview of assessment components within established U.S. P-12 engineering education initiatives and outreach programs. This overview provides a foundational understanding of the state of these initiatives that in turn would serve as the basis of further inquiry and implementation. The resources of this review are initiatives' websites, Engineering and Education databases, peer-reviewed journals, conference proceedings, and other search engines.

In this overview, trends and patterns among activities and research have been identified and categorized in clusters. These clusters are presented and discussed under the light of the national engineering education agenda in an effort to influence new directions of practice and research within the P-12 engineering education community.

Introduction

American public policy has focused attention on the lack of preparedness in science and mathematics at P-12 level students[1]. It has also brought to attention the disparity between the number of engineers and technicians attracted to American Colleges and Universities and the number of jobs demanded and projected in these areas[2-3]. In addition, some authors have emphasized the need of providing technological literacy for all citizens through engineering education at the P-12 level[4-5].

The academic community has responded to the challenge with a growing number of initiatives and outreach programs. However, the No Child Left Behind Law (NCLB) has brought to the Pre-College public education a system of accountability procedures that are influencing greatly what is been taught in schools[6]. The challenge seems to be in the alignment between the demands of NCLB with new and unproven engineering education interventions[7]. Because the Law is rooted in measuring student improvement[8], assessment and evaluation are key components in NCLB and should also be key components in engineering education initiatives at this level.

The purpose of this study is to present an overview of assessment components within established U.S. P-12 engineering education initiatives and outreach programs. This overview provides a foundational understanding of the state of these initiatives that in turn would serve as the basis of further inquiry and implementation.

We are using as guidelines of this work, the assessment definition and the assessment methods provided by Olds et al.[9] Assessment is defined there as "the act of collecting data or evidence that can be used to answer classroom, curricular or research questions" (p. 13). In this sense, we are analyzing the kind of questions, implicit or explicit, that each assessment within published P-12 engineering education studies are trying to answer. Olds et. al divide assessment methodologies into two primary types: "(1) studies that describe the current state of a phenomenon (descriptive studies) and (2) studies that examine how a phenomenon changes as a result of an intervention (experimental studies)" (p. 14). In this sense, we looked if the methodologies were descriptive or experimental. In addition, we looked at the population of the studies, whether teachers, P-12 students or other interested parties. Finally, we looked at the theoretical frameworks that might have informed the efforts. In summary, we looked at publications and reports in terms of what they are measuring, how they are measuring it, and whom they are measuring under a certain theory.

Literature Review

We started our literature review making use of educational and engineering library search engines. The criteria to perform these literature inspections was based on terms associated with engineering education, K-12, elementary, secondary, evaluation, and assessment. We later performed investigations in reports and chronicles published by acknowledged members of the Engineering Education Community in the United States. These reports pointed us to a number of K-12 programs, initiatives, and in turn to other reports.

Infinity Project

Description: The Infinity Project, founded in Texas and with current presence in 34 states, is an initiative aimed to high school and early college math- and science-based engineering and technology education. It consists of a yearlong engineering course. It also offers curriculum, professional development and partnership with industry and school systems. University credit transfer is available to students.

Assessment: According to "Tech Tally: Approaches to Assessing Technological Literacy" the Infinity Project has a pretest and a final test. "The problem-solving pre-test has 10 questions to measure cognitive skills, such as recognition of discrete patterns from continuous patterns, proportional reasoning, and reverse implication. All questions are open-ended and include at least one figure. The end-of-year basic test (from May 2003) consists of 12 multiple-choice knowledge-based questions that cover course content" (p. 305). *Population:* High school students. The report did not have theoretical framework embedded within it.

National Center for Technological Literacy Initiative (Boston Museum of Science)

General Description: The Center's goal is to integrate engineering as a new discipline in schools nationwide and to inspire the next generation of engineers and innovators. It offers curriculum, professional development, and partnership with industry, and school systems. The Center is responsible for the following programs:

Engineering is Elementary: Engineering and Technology Lessons for Children (EiE) is aimed to elementary level students. The program integrates engineering content with elementary science concepts. "Each unit focuses on a field of engineering—for example, materials engineering, mechanical engineering, and environmental engineering—and includes a child's illustrated storybook, lesson plans, and student materials. The lessons are correlated with technology/engineering curriculum standards"[10].

Assessment: This program publishes the largest number of research-based reports in comparison to other initiatives listed in this paper. The studies emphasize teachers' achievement of the professional development content and more recently, students' achievement of engineering content. Two studies were selected for this literature review. The study, "Engineering in Elementary: Children's Changing Understanding of Science and Engineering"[11], aimed to investigate what students know about engineering, technology, and the engineering design process, and to evaluate the Engineering is Elementary curriculum in terms of its effects on students. It used an experimental design with pre –and post-tests of student achievement of the concepts provided applied to an experimental group (sample size = 5, 139 students), and, when available a control group (sample size = 1, 827 students). The target population was elementary students ranging from grades 2-6 in 6 states. The other study, "Museum of Science: Engineering is Elementary Exploring the Impact of EiE on Participating Teachers"[12], intended to investigate the impact of the EiE training on teachers. It used an experimental design with pre –and post-surveys about their definitions and utilization of engineering in their classroom. The target population was 24 teachers who attended the summer or fall of 2005 EiE training. No theoretical framework was reported for both studies.

Engineering the Future: Science, Technology, and the Design Process™ is a full-year course designed to introduce high school students to technology and engineering, as a first step in becoming technologically literate citizens.

Assessment: According to the program's website[13], the assessment tools are focused on measuring the students' content achievement. They are descriptive, project-based, and criterion-referenced since they include rubrics for the development of projects. No theoretical framework was stated.

Project Lead the Way (PLTW)

Description: Project Lead the Way (PLTW) is a not-for-profit organization that "promotes pre-engineering course for middle and high school students. PLTW seeks to create dynamic partnerships with schools to prepare an increasing and more diverse group of students to be successful in engineering and engineering technology programs"[14]. The program offers curriculum, professional development and partnership with industry and school systems. University credit transfer is available. The curriculum is divided in three programs: (1) High School Engineering- a four year sequence of courses that, in combination with mathematics and science courses at the high school level, introduces students to the scope, rigor, and discipline of engineering prior to entering college; (2) Middle School Engineering- a five independent 9-week units course for grades 6-8 that should be taught in conjunction with academic curriculum. Each unit contains performance objectives and suggested student achievement assessment methods; and (3) High School Biomedical Science- a four-year sequence of courses in principles of Biomedical Sciences, Human Body Systems, Medical Intervention and Scientific Research.

Assessment: According to the official website, there are longitudinal studies of student progress underway. Two studies of Project Lead the Way were found in the literature for the state of Indiana. The first, “The Effectiveness of Project Lead the Way Curricula in Developing Pre-Engineering Competencies as Perceived by Indiana Teachers”[15], aimed to investigate the perceptions of high school teachers about the effectiveness in developing pre-engineering competencies for their students as well as the differences between high school teachers’ perceptions. It used a descriptive design with a Likert-type survey and a population of 76 technology education teachers who completed the PLTW Professional Development Institute at Purdue University. The second, “The Perceptions of Indiana High School Principals Related to Project Lead the Way”[7], intended to investigate the perceptions of Indiana high school principals about the effect of PLTW on their schools as well as the relationship between their attitudes toward PLTW and their personal characteristics, experience, and school characteristics. This study used a descriptive design with a Likert-type survey and a population of 37 out of the 57 high school principals whose schools had implemented PLTW prior to the 2006-2007 academic year. No theoretical framework was presented.

National Center for Engineering and Technology Education (NCETE)

Description: The National Center for Engineering and Technology Education is a collaborative network of scholars with backgrounds in technology education, engineering, and related fields. The Centers’ goal is “to build capacity in technology education and to improve the understanding of the learning and teaching of high school students and teachers as they apply engineering design processes to technological problems”[16].

Assessment: Two studies were selected for this literature review. The first titled “Delivering Core Engineering Concepts to Secondary Level Students”[17] is aimed to assess the effectiveness of a unit of instruction in teaching core engineering concepts to secondary level technology education students. It used an experimental research design based on mixed methods with a pre –and post test for all participants and focus groups with randomly selected participants. The target population was 114 students. The second, titled “African American High School Student’s Perceptions of Engineering and Technology Education”[18], seeked to investigate the perceptions of African American high school students toward engineering and technology education as a profession and career choice. The research design was descriptive and qualitative; it involved interviews to seven students. No theoretical framework was reported.

In addition to the well established initiatives we have described so far, there are a number of "stand-alone" publications of P-12 engineering education initiatives with assessment components. Table 1 summarizes these reports.

Table 1. Reports from Peer-Reviewed Journals in Education Databases

Name and Journal of origin	Description and Assessment
'The Future is Old': Immersive Learning with Generation Y Engineering Students[19]. European Journal of Engineering Education.	*Location:* Australia *Description:* This study explores the results of designing context-specific learning opportunities to prepare students. *Assessment:* Descriptive, based on observations of 12 middle school students (ages 12-14) classified as mildly disabled. Male and Female. *Theoretical Framework*: Immersive Learning
Engaging Inner City Students in Learning Through Designing Remote Operated Vehicles[20]. Journal of Science Education and Technology.	*Location:* Massachusetts, USA *Description:* The study intends to investigate if students learn science content through design, the logistical challenges, and students and teacher perceptions of a program centered in the design and construction of remote operated vehicles. *Assessment*: Descriptive and Experimental research design that used mixed methods approach with observations, interviews, field notes, and final physics exam results of the 25 low income, high risk, minority ninth grade participating students versus 42 non participating ninth graders. In addition, pre –and post-tests of participating students. The study also looked into increases in attendance. *Theoretical Framework*: Learning through Design
A Partnership Incorporating Labs into an Existing Chemistry Curriculum: Access Science[21]. Journal of Chemical Education.	*Location:* Philadelphia, USA *Goals:* This is a report of a partnership between the University of Pennsylvania and local elementary, middle, and high schools in West Philadelphia aimed to improve hands-on science and engineering education. It presents analyses of attendance. *Assessment:* Descriptive research design based on analysis of attendance records and a survey applied to students. The survey was responded by 30 students of different classes of a single chemistry teacher. *Theoretical Framework missing*

Hands-on Engineering Experiments for Secondary School Students[22]. Journal of Professional Issues in Engineering Education and Practice	*Location*: Ohio, USA *Description:* Study aimed to investigate the impact of the program "Teaching Teachers to Teach Mathematics and Science via Engineering Activities". *Assessment:* The study used a descriptive research design with a teacher's survey and an examination of mathematics proficiency results for 9th graders. *Theoretical Framework missing*
Soils Magic: Bringing Civil Engineering to the K-12 Classroom[23]. Journal of Professional Issues in Engineering Education and Practice.	*Location:* Unspecified, USA *Description*: This is a report of the Soils Magic Program applied to K-12 and other pre-college programs. The purpose of the program is to increase the interest of students for Civil Engineering. *Assessment*: Descriptive research design with a survey applied measuring Soils Magic attitudes to 100 participant students *Theoretical Framework missing*
Bringing Engineering to Elementary School[24]. Journal of STEM Education.	*Location:* Massachusetts, USA *Description:* This is a report of a program titled ROBOLAB and its results at K-12 level. The overall purpose of the program is to excite students about engineering, math, and science, to teach them these disciplines in a hands-on and practical way. *Assessment:* Descriptive research design with observations of students and systems. *Theoretical Framework missing*
Teaching Parabolic Motion with Stop-action Animations. International[25]. International Journal of Engineering Education.	*Location:* New Hampshire, USA *Description:* This is a publication of a physics laboratory activity based on movie-based reports with animations showing constant horizontal motion, vertical accelerated motion and parabolic trajectory as engineering uses for pedagogical approach. *Assessment:* It is a descriptive research design based on observations of high school students *Theoretical Framework*: Constructivism

To conclude, we also found two aggregates of different initiatives. The first, titled "Understanding K-12 Engineering Outreach Programs"[26], provides a list of 42 different efforts. In a revision of the references section, we found that most of the original sources came from proceedings of the American Society for Engineering Education and Frontiers in Education conferences as well as the Journal of Engineering Education. Unfortunately, in this publication, there is no mention of assessment components. However, the authors synthesize by categories the goals of the initiatives, the nature of the activities, and the audiences they approach. These categories, as the title of the publication suggests, are of value since they foster understanding of many outreach programs. The second, a list of 28 different initiatives, is part of the "Tech Tally: Approaches to Assessing Technological Literacy". The purpose of the assessment instruments "included diagnosis and certification of students, input for curriculum development, certification of teachers, resource allocation, program evaluation, guidance for public policy, suitability for employment, and research" (p. 94). Twenty instruments were targeted towards K-12 students, 2 to K-12 teachers, and 6 to out-of-school adults. Only 5 of the studies reported research as their primary purpose. However, no mention of descriptive or experimental design is done and no mention of a theoretical framework is included.

Trends and Patterns

Based on Olds et. al's model, most of the assessment components of the initiatives of this review were descriptive in nature since they did not draw comparisons between groups or through baseline data. Very few research designs were framed as empirical. This lack of empirical designs hides the true impact of the interventions when compared to scenarios of no intervention at all.

Tech Tally catalogs assessment instruments by primary purpose and target population. Under this framework, we could confidently state that most assessments in this review intended to study the notions and perceptions about engineering education programs and/or their content. Some also tried to measure student achievement. Targeted populations were in general K-12 students and teachers.

Lewis et. al make a case of the rationale behind K-12 engineering education efforts. Under his framework, most of the studies were inspired by one of two agendas; (1) the increase in number of students in engineering, and (2) the increase of the level of mathematics and science education through engineering concepts.

In summary, the P-12 national engineering education agenda has been grouped in the following three assertions:

1) P-12 engineering education efforts should attract students to engineering and technology programs in American colleges and universities.
2) P-12 engineering education efforts should increase the student academic performance in science and mathematics.
3) P-12 engineering education efforts should increase technological literacy in all Americans.

Under this agenda, a considerable number of P-12 engineering education initiatives, sponsored by the academic community, have been launched. However, few of them have incorporated rigorous research components in order to validate the impact of their interventions. In this literature review, we described a framework by which to judge this impact. We have critically paid attention to the research design of the reports available. We have divided them in descriptive and experimental designs and have identified the instruments they employ such as surveys or observations. We have also looked into the population they have targeted, and the theoretical frameworks they have used to inform their interventions.

Under this rationale, we have found that most initiatives have attempted to increase the number of students attracted to engineering or technical studies as well as to increase the performance of students in mathematics and science. We also have found that most research has been designed to describe student or teacher perceptions of the interventions or has tried to measure student achievement of the content provided. We have finally noticed that most initiatives are aimed towards P-12 students or P-12 teachers without any theory informing them.

Conclusions and Recommendations

This analysis of the literature reveals the aspects that the academic community has overlooked when assessing their P-12 initiatives. The first, the lack of focus on "technological literacy for all" limits the arguments of those interested in widening the scope and pertinence of P-12 changes in educational policies, standards, and curriculum. The second, the lack of experimental research designs and theoretical frameworks, suggests a lack of well informed –in depth comparisons of the interventions. The end result is a diminished voice of those who are demanding changes in the policies, standards, and curriculum. The third, the lack of studies aimed to other than P-12 students and teachers, disengage a number of interested groups which might have influence over the desired changes, for example parents or school administrators.

The recommendations would be three: (1) to pay more attention to the "technological literacy for all" as the research agenda; (2) to conduct more experimental research; and (3) to consider other stakeholders, not only teachers or students, when assessing P-12 engineering education interventions.

This paper did not focus on the particular results of the assessments nor provides specific recommendations per initiative. It is intended to provide overview information about the state of the assessment incorporated into past (recently) and existing efforts. This review should serve as an informational tool with implications for practice and for research involving P-12 engineering education initiatives.

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