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An Overview of the Literature: Research in P-12 Engineering Education

NOEMI V. MENDOZA DIAZ
Brazos School of Inquiry and Creativity
Houston, TX
and

MONICA F. COX
Purdue University
West Lafayette, IN

ABSTRACT

This paper presents an extensive overview of preschool to 12th grade (P-12) engineering education literature published between 2001 and 2011. Searches were conducted through education and engineering library engines and databases as well as queries in established publications in engineering education. More than 50 publications were found, including books, articles, and reviews that discussed P-12 engineering education research efforts. With the synthesis of literature and distinct criteria to classify the literature, a rubric was developed. This rubric allowed authors to synthesize retrieved publications in seven ways: (1) overarching agenda, (2) nature of the engineering program or intervention, (3) assessment methods, (4) object of the study/unit of analysis, (5) population/sample of interest, (6) informing theory, and (7) standards addressed. Discussions of the current levels of research based on recommendations of National Agencies are presented along with a set of recommendations for the advancement of the P-12 engineering education research.

INTRODUCTION

Several national trends are driving the advancement of engineering education within the United States. These trends include a declining interest of U.S.-born students in engineering (Melsa, 2007); a decrease in national achievement in mathematics and sciences at pre-college levels (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies, 2007); and a lack of technological literacy for all Americans (Pearson and Young, 2002).

Adding to these concerns are expectations that in the U.S. government, science and engineering professionals reaching retirement age will not be replaced by a younger generation of professionals (National Science Board, 2006a; Selingo, 2008). In mathematics and science, U.S. pre-college students "perform at or near the bottom on international assessments" (National Science Board, 2006b, p. i).

In order to pose alternatives to improve situations facing science, technology, engineering, and mathematics (STEM) education, several authors have identified the necessity of focusing on the education of pre-college populations (National Academy of Engineering, 2005). For example, the National Science Board (2006b), via the companion to the 2006 Science and Engineering Indicators, identifies the following priorities for developing high quality STEM education:

- Strong public support of STEM education for all students and citizens,
- A high quality teaching workforce,
- Appropriate learning opportunities for all students,
- Effective guidance counseling on STEM education and careers, and
- Assessment tools that reinforce learning in STEM fields (p. ii).

Experts also advocate the integration of engineering activities in current curricula to increase students' interest in STEM (Schunn, 2009; Katehi, Pearson, and Feder, 2009; Brophy, Klein, Portsmore, and Rogers, 2008). One discipline that is focused upon operationalizing these priorities is engineering education.

Engineering education is an emerging field of study that is gaining momentum and recognition within the United States. Within the last eight years, Purdue University, Virginia Polytechnic Institute and State University, Utah State University, and Clemson University have created doctoral-granting engineering education schools/departments within their respective Colleges of Engineering that are devoted to developing engineering education scholarship. Other universities throughout the country are developing innovative models to conduct engineering education research across the educational continuum (e.g., the Colorado School of Mines' Center for Engineering Education and Washington State University's Engineering Education Research Center).

The development of formal departments and centers in engineering education has occurred concurrently with the development of a number of engineering education initiatives targeting preschool to 12th grade (P-12) students. Some of the most widely known research-based P-12 efforts are being conducted by the following groups:

- The National Center for Technological Literacy Initiative, the Boston Museum of Science (http://www.mos.org/nctl/)
- Project Lead the Way (http://www.pltw.org/)
- The Infinity Project[SM] (http://www.smu.edu/lyle/infinity.aspx)

- National Center for Engineering and Technology Education (NCETE) (http://ncete.org/flash/index.php)
- The Center for Engineering Education Outreach (http://ceeo.tufts.edu/)
- The Institute for P-12 Engineering Research and Learning (https://engineering.purdue.edu/INSPIRE/)

Two macro-initiatives for P-12 education include the recently extinct National Science Foundation's Graduate Teaching Fellows in K-12 Education Program (GK-12) and the American Society for Engineering Education's (ASEE) Engineering K-12 Center. In addition to these initiatives, public high schools in states such as Arkansas, Florida, Maryland, Massachusetts, New Hampshire, and Texas require engineering coursework for their students (Field, 2004; Meyers-Sharp, 2004).

The literature is abundant in engineering education pre-college programs. Through an extensive literature review, this paper organizes, analyzes, and synthesizes recent P-12 engineering education research efforts using detailed criteria and categories. The authors provide detailed information about the publications included in the literature review and provide recommendations for the advancement of future scholarship in this area.

Purpose and Research Questions

The purpose of this investigation is to understand and to inform audiences about the current state of research in the P-12 engineering education area. Using engineering education publications, including peer-reviewed journals, conference proceedings, and dissertations, the authors extract key points and synthesize the literature to inform engineering education and other audiences about the current state of P-12 engineering education research and to offer suggestions for future work within this area. The research questions of interest in this paper ask, (1) What is the current state of research in the P-12 Engineering Education area?, and (2) How can this research be classified and synthesized?

Operationalization of Research within This Study

To identify P-12 engineering education literature that would be included in this paper, the authors developed criteria for inclusion and developed a working definition of research. For a paper to be included in this paper, it had to meet *all* of the criteria listed in Table 1 and had to align with the authors' definition of research as derived from pertinent literature.

An emphasis on research in this paper is needed, since engineering education is an emergent field in which most engineering professors are not familiar with rigorous educational research frameworks (Borrego, Streveler, Miller, and Smith, 2008; Borrego, Douglas, and Amelink, 2009). Following Boote and Beile's (2005) guidelines of educational literature reviews, this section presents the authors' definition of "research," which has been developed from a previous review of foundational works

Criteria	Operationalization of Criteria
Engineering Focus	Engineering is the discipline of interest
Assessment/Research-Related	Assessment or research components (descriptive and/or experimental) are present.
National Study	Studies include U.S. populations, or reporting efforts occurring in the U.S.
Recently Published	Studies were published between 2000 and 2011.
Publication Type	Empirical studies were published in peer-reviewed journals, conference proceedings, and dissertations. They might have not stated research questions or sections on methodologies, but they included analysis of data.

Table 1: Criteria for Including Studies into the Literature Review.

within the field and the community. With this definition, readers who are engaged and are not engaged in engineering education research might understand the types of publications included and not included in this synthesis of P-12 engineering education research.

Research methods are “the procedures used to support the data collection process and are an important consideration in any educational research design” (Rogers and Sando, 1996, p.13). The methods, under this framework, are divided in two overarching types, descriptive and experimental. Descriptive studies are defined as those that describe the current state of a phenomenon or that try to answer the question, “What is happening”? (Olds, Moskal, and Miller, 2005; Shavelson and Towne, 2002). Descriptive methods encompass surveys, interviews and focus groups, conversational analysis, observations, ethnographic studies and meta-analyses. Experimental and quasi-experimental studies, on the other hand, are defined as those that examine how a phenomenon changes as a result of an intervention or examines the effects of a treatment (Fraenkel and Wallen, 1990; Olds et al., 2005). Experimental or quasi-experimental methods might encompass randomized controlled trials and matching trials, baseline data, post-test-only, and longitudinal designs.

Another division in methodological approaches pertains to the nature of the data and its analysis. Quantitative approaches involve numerical data that may be statistically analyzed whereas qualitative approaches involve other types of information such as words or images for analysis of their meaning in descriptions and themes (Creswell, 2002; Olds et al, 2005). Finally, mixed methods “focus on collecting, analyzing, and mixing both quantitative and qualitative data in a single study or series of studies.” (Creswell and Plano Clark, 2007, p. 6).

METHODOLOGY

Taking into account the abundance of approaches that P-12 engineering education studies have incorporated in their respective works, this literature review synthesizes studies that emphasize assessment-focused, research- based evidence of data collection used to answer classroom, curricular, or research questions. Details about data collection methods are included in the next section.

Data Collection

Publications retrieval occurred in four phases. In the first phase, we retrieved references from educational and engineering library databases such as Academic Search Premier, Omnifile, Compendex, WorldCat, and ProQuest Dissertation Abstracts. Key terms such as "engineering", "engineering education," "K-12," "outreach," "elementary," "secondary," "evaluation," and "assessment" served as the initial filtering mechanisms. Further reading of retrieved abstracts provided the necessary information to parse out publications that fully met the criteria. The second phase of the bibliographical inspection included browsing the websites of the established engineering education initiatives (listed previously) to investigate reports or chronicles. For example, the Boston Museum of Science and the National Center for Engineering and Technology Education (NCETE) websites provided links to publications that were used in this review. The third phase involved a systematic search in acknowledged forums within the engineering education research community such as the *Journal of Engineering Education*, the *International Journal of Engineering Education,* the *Journal of Professional Issues in Engineering Education and Practice*, the *European Journal of Engineering Education,* and *IEEE Transactions in Education*. A final phase consisted of using, for a second time, library databases (such as EBSCO and Wilson), and inspecting closely non-acknowledged engineering education forums such as the *Teacher Education* or the *Journal of Industrial Teacher Education*. The purpose of this final phase was to identify studies that might meet the selection criteria but might have been overlooked by previous searches.

DATA ANALYSIS

The search resulted in the retrieval of over 50 publications that met the criteria described in Table 1. Previous literature reviews, not necessarily focused on research, informed our initial approach to the publications (Lewis, 2007; Jeffers, Safferman, and Safferman, 2004; Garmire and Pearson, 2006; and Douglas, Iversen, and Kalyandurg, 2004). The initial criteria and research definitions developed by the authors were used to narrow studies in this paper. Inspired by previous literature reviews and given the common elements located across the 55 documents, seven themes or categories emerged (Table 2)- (1) overarching agenda, (2) nature of the engineering program or intervention; (3) assessment methods,

Theme or Category	Findings addressed in the literature to date
Overarching agenda	• Math & Science achievement improvement • Pathways to increase the number of engineers • Technological literacy improvement
Nature of the engineering education program or intervention	• Teacher Professional Development or Outreach activity • Engineering Design Process • Hands-on Math & Science • Engineering Disciplines
Assessment Method	• Descriptive and Quasi-experimental (pre- and post-tests)
Object of Study/Unit of Analysis	• Students' attitudes and knowledge • Teachers' attitudes and knowledge • Principals' perceptions • Parents' perceptions • University students' perceptions
Population/Sample	• Students • Teachers • Parents and caregivers • Principals
Informing Theory	• Constructivism (Constructionism, Guided Inquiry, Communities of Practice) • Self-efficacy
Standards Addressed	• National and State Mathematics, Science and Technology • Massachusetts Technology/Engineering

Table 2: Summary of Literature Synthesis, Rubric of Research in Engineering Education at the P-12 Grade Levels.

(4) object of the study/unit of analysis, (5) population/sample of interest, (6) informing theory, and (7) standards addressed. An overview of the broad findings for each theme is provided in Table 2 also.

A brief overview and justification of these seven themes follow. To contextualize each study in P-12 engineering education, an *overarching agenda* was identified. This agenda was usually presented in publications' abstracts and introductions. Next, using the initial criteria for selecting publications, *assessment/research methods and populations/samples* were categories that detailed what was studied, how it was studied, and who was studied, respectively. The *object of study/unit of analysis* was inspired by the evaluation schema for professional development written by Lawless and Pellegrino (2007) and Tech Tally's "primary purpose" of the instruments (Garmire and Pearson, 2006). In Lawless and Pellegrino's schema, the unit of analysis refers to the "focus of any research/evaluation on the outcomes and efficacy of that program" (p. 582). When the publications were analyzed, they were placed in this pre-established category. The last categories*, informing theory* and *standards addressed*, were inspired by academic understanding that research is closely related to the development and advancement of theoretical frameworks and that the P-12 classroom is largely influenced by policies and standards.

Synthesis of Literature across Themes

The synthesis that follows is based upon the themes depicted in the rubric in Table 2. These themes could serve the purpose of locating future publications or current unpublished studies that meet the selected criteria and can provide additional opportunities for further research and practice. The extended analysis across documents is located in the Appendix. The following sections situate the retrieved literature into the themes in Table 2.

Overarching Research Agenda

All publications provided a rationale that fell into one or more of three categories; (1) pathways to increasing the number of engineers; (2) math and science achievement improvement; and (3) technological literacy improvement. We called this elemental group of categories the "overarching research agenda."

Pathways to increasing the number of engineers is a popular topic. Documents such as "Educating the Engineer of 2020: Adapting Engineering Education to the New Century" (National Academy of Engineering, 2005) provide persuasive arguments to authors when implementing engineering education activities. However, due to the difficulty in measuring how many students are attracted to engineering as a result of an intervention, most of the studies measure other outcomes such as mathematics, science, technological literacy, or perceived satisfaction with the interventions. Thirteen studies provided as its unique justification information about the number of students pursuing an engineering or STEM career. Some of them such as DeBartolo and Bailey (2007), Boynton and Hossain (2010), and Martin (2011) focus on certain populations such as women, rural students, or black high school students. The way they measure the impact of the interventions relates to perceptions of teachers, students, or parents/caregivers. According to DeBartolo and Bailey (2007), more long-term impact studies are expected to take place in the future. Three dissertations address this rationale (Oware, 2008; Martin, 2011; and Lanigan, 2009).

Math and science achievement improvement is a favored rationale in the publications reviewed, in combination with pathways to increasing the number of engineers. Authors make a case for improving mathematics and science at the same time that students are introduced to engineering. As could be expected, the interventions that occurred within the studies in this category are informed by national and state science and mathematics standards. McKay and McGrath (2007) present new documents to the already compelling pool of materials that support this rationale. They are the "Excellence: Comparison of International Eighth-Grade Mathematics and Science Achievement from a U.S. Perspective, 1995 and 1999" and "The Nation's Report Card: Science Highlights 2000" (as cited by McKay and McGrath, 2007). In their study, McKay and McGrath (2007) report the result of an initiative geared towards developing Internet-based real-world applications in order "to provide students with problem-solving opportunities that are similar to the engineering problem-solving process" (p. 37). The unit of analysis in this study was students' knowledge in mathematics and science. The study showed improvement in students' knowledge through standardized and "in situ" tests, when engineering concepts are incorporated into the curriculum via online activities. Cantrell, Pekcan, Itani, and Velasquez-Bryant (2006) report an intervention in the form of a teacher professional development program that upgrades "content knowledge in engineering to facilitate integrated technology that supports effective science and mathematics instruction" (p. 301). The target population was science teachers and their respective students. The results of the science standardized tests were statistically compared to the tests developed by eight teachers during the program. The author converted mean performance scores from each group across assessments to a percentage of deviation from the overall mean for each assessment (p. 305, Cantrell et al., 2006). The results show increases and decreases in students' science knowledge with respect to gender, ethnicity, economic status, special education, and type of assessment (such as project-based versus pencil/paper unit test).

Church, Gravel, and Rogers (2007) present an innovative science intervention based on a movie-making approach. The students were expected to present parabolic motion principles in the manner of animations. The purpose of the study was to present a new way of teaching science and no comparisons were performed against standardized models of testing science. Barnett (2005) analyzed physics knowledge from a conventional perspective (via the district's final exam) and pre-posttests, therefore this study is also considered to be focused on improving science knowledge. Similarly, Hardre, Nanny, Refai, Ling and Slater (2010) focused on science and mathematics teachers. Two dissertations, Marculu (2010), and Martinez Ortiz (2010), explored math and science teachers and students' math knowledge.

In addition to these studies, which can be considered "purely" science and math driven, there are other studies that maintain a mathematics and science emphasis but also present their rationale as providing increases in numbers of students attracted to engineering (Bergin, Lynch, Khanna, and Nair, 2007; Cunningham, Knight, Carlsen, and Kelly, 2007; DeGrazia, Sullivan, Carlson, and Carlson, 2001; Elton, Hanson, and Shannon, 2006; Lumpp, Bradley, and Haines, 2007; Mooney and Laubach, 2002; Moskal, Skokan, Kosbar, Dean, Westland, Barker et al., 2007; Pickett, Oliver, Giles, Fridman, Fetters, and Cooks, 2000; Poole, DeGrazia, and Sullivan, 2001; Richards, Hallock, and Schnittka, 2007; Iskander, Kapila, and Kriftcher, 2010; Mehalik, Doppelt, and Schuun, 2008; Nugent, Barker, Grandgennett, and Adamchuk, 2009; Klein, 2009; and Caldwell, McCoy, Albers, Smith, and Parry, 2007). Baker, Yasar-Purzer, Robinson-Kurpius, Krause, and Roberts (2007) expose the linkages between science and technology education and the implied impact in increasing the engineering 'pipeline'. They make a case for an intervention targeting participants of a graduate course in science education centered on the inclusion of Design, Engineering, and Technology (DET) concepts into the curriculum. As a result of infusing DET into the graduate content, participants (two in-service teachers and one museum curriculum specialist) changed their knowledge and attitudes towards engineering. Cunningham et al. (2007) provided a different rationale for merging science and engineering, and noted that "in this model, engineering concepts are one tool for teaching science and mathematics" (p. 3). This statement shows a subordination of engineering to other subject agendas. In this study, the outcomes under measure were teachers' self-reported knowledge and comfort with teaching engineering and technology.

The last overarching research agenda is *technological literacy improvement*. It involves the importance given to infusing engineering and technology in the education of all citizens, or in the words of Rogers and Portsmore (2004), "it becomes increasingly important that we make sure that students are comfortable with technology when they graduate from high school" (p. 17). Except for Powers, Dewaters, and Venczel (2011), the studies inspired by this category tend to address early grade levels such as kindergarten and elementary school. Tufts University's Rogers and Portsmore (2004) report their intervention, "ROBOLAB," and the impact it has on teachers and students from kindergarten to 5th grade. Bers (2007) cites "Technically Speaking: Why All Americans Need to Know More About Technology" (Pearson and Young, 2002) as a vehicle for stressing the need of increasing technological literacy. She looks into families with children between 4-7 years old. Portsmore's dissertation looked into first graders' understandings of technology and engineering design.

To conclude, there are also studies that address all aspects of the overarching research agenda (Rogers, 2006; Rogers, 2007; Sorby and Schumaker-Chadde, 2007; Yasar, Baker, Robinson-Kurpius, Krause, and Roberts, 2006; Tran and Nathan, 2010; Nathan, Tran, Atwood, Prevost, and Phelps, 2010; Asunda and Bill, 2008; and DeBartolo and Bailey, 2009). However, as will be presented later, their units of analysis, nature of interventions, assessment methodologies and theoretical frameworks vary.

Nature of the Engineering Education Program or Intervention (Curriculum Content)

The majority of the programs across studies attempt to integrate mathematics and science content to technology and engineering. Therefore, most of the interventions that target the P-12 classrooms try to build alliances with teachers in already established science and math fields. Teacher-oriented programs are very popular (Baker et al., 2007; Barnett, 2005; Cejka et al., 2007; Moskal et al., 2007; Pickett et al., 2000; Poole et al., 2001; Rogers, 2006; Rogers and Portsmore, 2004; Richards et al., 2007; Sorby and Schumaker-Chadde, 2007; Brockway, McGrath, McKay, and Schultz, 2009; Hardre et al., 2010; Iskander et al., 2010; Mehalik et al., 2008; Nugent et al., 2009; Klein, 2009; Nathan et al., 2010; and Asunda et al., 2008). Other studies, with or without the emphasis in science and mathematics, focus more on students (pre-college or college) via *outreach activities*. These outreach studies, including dissertations within this exploration, are not as interested in building alliances with teachers. Both approaches seem to complement each other well and both share common curriculum content regardless of the primary populations they are targeting. DeBartolo and Bailey (2007) describe a very interesting set of interventions at the Rochester Institute of Technology. Targeting girls as early as 6th grade, the activities are aimed to attract women to engineering. Park rides, a robot competition, sleepovers, and weekend visits are part of these activities. Another innovative approach is presented by Church et al. (2007) in which parabolic motion is introduced through a movie making-animation approach. A commonality of all interventions is that they introduce their content in a "hands-on" manner. It is observable that at the heart of these hands-on experiences is the engineering design process, although design may not be referred explicitly. Therefore, the engineering design process can be comfortably used to define engineering education at the P-12 levels. In addition, other constructs related to engineering are also part of these interventions; for example, communication and teamwork skills (Bergin et al., 2007; Cantrell et al., 2006), engineering as a career choice (DeBartolo and Bailey, 2007; Elton et al., 2006; Mooney and Laubach, 2002; Cantrell and Ewing-Taylor, 2009; Zhe, Doverspike, Zhao, Lam, and Menzemer, 2010), physical and/or economic constraints to design (Bergin et al., 2007; Richards et al., 2007), and some specific disciplinary content such as manufacturing and bioengineering technologies (Hynes and Dos Santos, 2007; Davis, Maltbie, Myers, Forry, and Wolf, 2009; and Klein, 2009), electronic circuits (Lumpp et al., 2007; Reisslen, Moreno, and Ozogul, 2010; Mehalik et al., 2008), robotics (Bers, 2007; Cejka et al., 2007; Rogers and Portsmore, 2004; Nugent et al., 2010; Marulcu, 2010; Martinez Ortiz, 2010; and Portsmore, 2009), civil engineering (Elton et al., 2006; Boynton et al., 2010), environmental (Rose and Miller, 2009; Hardre et al., 2010; and Powers et al., 2011), and computer (Maxim and Elenbogen, 2009).

Only three of the studies reported do not assess any type of intervention. Yasar et al. (2006), report the development of an instrument to assess teachers' attitudes, Lyons and Ebert (2005) report on an exploratory survey applied to Engineering Education Centers in order to know how they incorporate K-12 activities, and Beck, Diefes-Dux, and Reed-Rhoads (2009), report on counselors' perceptions of engineering.

Assessment Method

As previously mentioned, assessment methodologies in this review are explored under a framework of descriptive/quasi-experimental/experimental and qualitative/quantitative. In this sense, almost all studies involve descriptive and quasi-experimental approaches via surveys, observations, interviews, and questionnaires applied either once or in a pre-post fashion. Only four studies, including one dissertation, involved a control group (Mooney and Laubach, 2002; Mehalik et al., 2008; Tran &

Nathan, 2010; and Marulcu, 2010). For qualitative and quantitative perspectives, almost all surveys and questionnaires were analyzed statistically. Observations and interviews were qualitatively analyzed in the form of "inductive-generative- constructive-subjective" techniques (Lincoln and Guba, 1985) also known as open coding (Strauss and Corbin, 1998). Non-traditional assessment was applied in the form of rubrics for project evaluation. Poole et al. (2001), at the University of Colorado at Boulder, provided an extensive study of assessment approaches to outreach activities. An array of different instruments is proposed and used in this publication in the form of a matrix they call an "embedded assessment matrix" (p. 44).

Object of Study/Unit of Analysis

This category, in general terms, refers to what is assessed or how the learning of engineering is measured. In a simplistic definition, learning entitles the changes in intellectual skills, attitudes, or psychomotor skills exhibited by participants (Gagné, 1985). In this review the majority of the studies focus on knowledge or attitudes of teachers and/or students in a self-reported fashion. In this review knowledge is attributable to the cognitive domain and exemplified by content-concepts acquisition (Barnett 2005; Church et al., 2007; McKay and McGrath, 2007; Reisslein et al., 2010; Nugent et al., 2010; Powers et al., 2011; Iskander et al., 2010; Mehalik et al., 2008; Tran & Nathan, 2010; DeBartolo and Bailey, 2009; Marulcu, 2010; Martinez Ortiz, 2010; and Portsmore, 2009). Attitudes include perceptions, beliefs, level of comfort-confidence, enjoyment, or satisfaction (Bergin et al., 2007; Baker et al., 2007; Cejka et al., 2007; DeBartolo and Bailey, 2007; Lumpp et al., 2007; Rogers, 2006; Rogers, 2007; Sorby and Schumaker-Chadde, 2007; Yasar et al., 2006; Boynton, et al, 2010; Cantrell et al., 2009; Zhe et al., 2010; Thompson and Lyons, 2009; Rose et al., 2009; Maxim et al., 2009; Davis et al., 2009; Beck et al., 2009; Zarske, Sullivan, Knight, and Yowell, 2008; Brockway et al., 2009; Hardre et al., 2010; Klein, 2009; Caldwell et al., 2007; Nathan et al., 2010; Asunda and Bill, 2008; Oware, 2008; Martin, 2011; and Lanigan, 2009). The psychomotor domain was not directly addressed by any assessment in this review. However, anecdotal information was provided in the sense that the "hands-on" approach afforded opportunities for learning content other than the traditional paper-and-pencil ones or it fostered spatial abilities (Barnett, 2005; Bergin et al., 2007).

Population/Sample

It became evident that the population of interest of most publications is teachers or students. DeBartolo and Bailey (2007), Bers (2007), Rose and Miller (2009), Caldwell et al. (2007), are the only four studies involving parents' assessment. The first aimed to assess perceptions of parents or caregivers' as a measure of success in attracting women to engineering, and the second examined the interactions between parents and children through robotics activities. Rose and Miller (2009) looked into parent's perceptions of summer camps devoted to raise interest in engineering careers and Caldwell et al. (2007) examined the feedback of parents' nights. Administrators, specifically principals and counselors (and their perceptions) are the populations of interest for Rogers (2007), Sorby, Schumaker-Chadde (2007), and Beck et al. 2009. For universities implementing these programs, few studies address faculty, undergraduate, graduate students, or university administrators (Baker et al., 2007; Lyons and Everts, 2005; Moskal et al., 2007; Sorby and Schumaker-Chadde, 2007; Thompson et al., 2009; and Zarske et al., 2008).

The population sample sizes of these reports vary but are not much greater than a thousand. At the extremes of the spectrum, there was a case study of three participants (Baker et al., 2007) and a study involving more than a thousand students (Mehalik et al., 2008). Twenty two publications reported a sample between 3 and 46 participants, fourteen studies a sample between 46 and 150 participants, eight between 151 and 500, one with 519, and one with 1053 participants.

The demographic composition is also variable but not intended explicitly towards under-represented groups. Barnett (2005) report on a high-school composition of 85% racial/ethnic minorities in the Boston area. Cantrell et al. (2006) and Rogers and Portsmore (2004) researched special education students in an incidental way.

Theoretical Frameworks

Perhaps the most interesting perspectives relate to researchers' explanations or predictions of engineering education phenomena in the P-12 arena. Because of the emergent nature of the field of engineering education, the studies' theoretical underpinnings are interesting from a research perspective. In this sense, only eleven references included a clear theoretical perspective. The most prevalent educational perspective among these authors was constructivism. Seven publications, including a dissertation, used constructionism, one explored experiential learning, two referred to communities of practice, and one focused upon guided inquiry.

Constructionism, termed by Seymour Papert (Papert and Harel, 1991) at the Massachusetts Institute of Technology, is a learning theory that contains the elements of constructivism through learners' cognitive construction but has an additional hands-on attribute. In the words of Hynes and Dos Santos (2007), this attribute involves the "construction of a real-world or virtual-world artifact" (p. 25). With strong emphasis on robotics and computer design, Barnett (2005), Bers (2007), Cejka et al. (2006), Church et al. (2007), Hynes and Dos Santos (2007), and Martinez Ortiz (2010) use constructionism as a theoretical justification for their interventions. Only one of them challenged or added to the model, however. In this sense, the theory of constructionism is, in general, not expanded.

Kolb's (1984) experiential learning, used by Cantrell et al. (2006), engages students in experiences, reflections, conceptualization and experimentation. In their study, this theory inspired the way the module content was delivered to students. Communities of practice is the second theoretical framework that Bers presents in her parent-child study, and the way she introduces it is innovative in the sense that it is called a "constructionist community of practice" based in the situated learning work of Lave and Wenger (as cited by Bers 2007). Although she does not present a case for marrying both traditions, the way she describes the family dynamics through this doubled-concept could be considered an expansion to both communities of practice and constructionism. Guided inquiry and learning by design, understood as a subset of inquiry-based science or a "learning by doing" approach to learning science, was mentioned by Richards et al. (2007), Mehalik et al. (2008), and Tran et al. (2010), as the pedagogical technique used to develop their intervention.

Finally, in a more cognitivist trend, Bergin et al. (2007), Brockway et al. (2009), Powers et al. (2011), and Nugent et al. (2010) used self-efficacy as the theoretical foundation in which they created a scale to assess confidence to learn about electricity, fuels, traffic control, math, hands-on building, and how to become an engineer. This operationalization of self-efficacy to create an instrument expands this theoretical perspective in engineering education.

Standards Addressed

We found that seventeen of the fifty five studies incorporated national mathematics, science, and/or technology standards. Twelve incorporated state mathematics, science, and/or technology standards and six incorporated the Massachusetts Technology/Engineering standards.

DISCUSSION

This literature review analyzed and synthesized current P-12 engineering education research initiatives. Fifty-five studies were analyzed and synthesized based upon the categories presented in Table 2. This rubric was developed to understand, in greater detail, the roles that recent P-12 engineering education studies play in developing a "big picture" of engineering education research at the P-12 grade levels. In this section, we summarize and discuss our findings in an effort to substantiate later recommendations. Following Boote and Beile's (2005) guidelines of educational literature reviews, the authors seek to build a "thorough, critical examination of the state of the field" (p. 9).

In the overarching agenda category, we found that 34 studies use the rationale of improving mathematics and science achievement through engineering education interventions. In ten of these studies, short term measures of impact are possible via paper-and-pencil tests and/or via comparisons with standardized tests. A plausible explanation about the preference given to this rationale is precisely this "facility" of measuring this type of impact. In this sense, engineering education seems to attempt a point of entry through established P-12 subject areas. The downside of this rationale is that engineering education appears to be a subfield of other more well-established areas, thereby raising questions about the field's identity and visibility.

The second rationale mentioned in the literature is pathways to increasing the number of engineers. As stated above, to measure the impact in this area is quite a challenge, although some authors have attempted to do so. For example, Cantrell and Ewing-Taylor (2009) administered weekly questionnaires to high school students asking their career goals. Another example is Zhe et al. (2010), who checked if their participant high school students enrolled in STEM majors. A possible explanation to this is that in order to provide significance for their studies, authors take ideas from major national reports. However, when posing research questions or units of analysis, the authors take other routes such as Lanigan (2009), who focused on student motivation based on surveys and observations. Authors might consider implementing longitudinal studies or other innovative approaches.

The last rationale of preference among engineering education publications is technological literacy improvements. Considering the knowledge base coming from the technology education community, it is surprising that technological literacy is practically excluded from the P-12 engineering education research agenda. The possible explanation to this phenomenon is that the engineering education community is building its own knowledge base while differentiating itself from technology education. In the quest of its own knowledge, however, interventions seem to be more preoccupied on validating their engineering education content (their own identity) instead of finding intersections with literacy in technology education. Smith and Burghardt report this tension in the *Technology Teacher* (2007). The disadvantage of this approach is that by not widening the scope and pertinence of P-12 engineering education to impact all citizens, the desired changes in educational policies, standards, and curriculum are limited.

The nature of the engineering education program or intervention has been confined primarily to either teacher professional development or outreach activities. Few programs or interventions explicitly state research as their primary focus. The disadvantage of this approach is that engineering education research seems to be incidental or dependent upon initiatives devoted mainly to service. In addition, as part of the nature of the program, this review paid attention to the curricular content reported in the literature. Without a solid knowledge base, it was most interesting to see what constituted engineering education across initiatives and to what extent the curriculum content aligned to engineering literacy as described by guidelines and standards (Dym, Agogino, Eris, Frey, and Leifer, 2005; Massachusetts Department of Education, 2001; Hill, 2006). As expected, the content incorporated only partially the nature of engineering as described in the aforementioned guiding works. Again, the novelty aspect of the field is the attributing cause, since by the time these guidelines and standards were developed, many of the initiatives have or were taking place. This should constitute a motivation for educational researchers interested in engineering, since it affords multiple opportunities to explore new questions.

In the assessment methods, most studies incorporated descriptive or quasi-experimental research designs in self-reported fashions. The possible causes might be the newness of the field as well as the researchers' struggles with rigorous educational research (Borrego, 2007). One problem with this advancement within the area of assessment is the lack of progression of engineering as an educational field of study. This implies tardy maturation of the field. Lawless and Pellegrino (2007), in the technology integration-professional development arena, speak about this in the following manner:

> Case studies are a useful first step to illuminate which variables are important to examine in more depth, but we need to push ourselves to take the next step and design more controlled studies that are more experimental in nature…Finally, new and more innovative approaches to collecting evidence and measuring change are desperately needed. The common practice of using self-report measures is not going to yield the type of data required to make evidence-based decisions regarding the adoption of professional development programs (p. 601).

In addition, *Scientific Research in Education* (Shavelson and Towne, 2002) provides advice about advances in assessment in educational research by stating:

> An area of research that, for example, does not advance beyond the descriptive phase toward more precise scientific investigation of causal effects and mechanism for a long period of time is clearly not contributing as much to knowledge as one that builds on prior work and moves toward more complete understanding of the causal structure (p. 101).

The object of study or unit of analysis of studies was primarily focused upon students' and teachers' knowledge and attitudes in engineering. Knowledge and attitudes are important aspects of learning that should be studied. However, the variety of knowledge concepts and attitudinal constructs among studies is very limited. Most studies report about the same kind of knowledge base or the same type of self-reported perceptions. Pellegrino, Chudowsky and Glaser (2001) stress the need of "translating what is already known in cognitive science to assessment practice, as well as on developing additional cognitive analyses of domain-specific knowledge and expertise" (p. 104).

The populations/samples targeted by studies were primarily teachers and students. A scarce number of publications reported details about parents (or caregivers) or administrators (principals or counselors). This phenomenon might inadvertently hinder the establishment of engineering education in the P-12 classroom, since it disengages interested groups that play significant roles in the education of P-12 students.

Perhaps the most neglected factor in the analysis of interventions and literature in P-12 engineering education has been the use of theoretical frameworks, particularly in educational fields.

Guidelines on scientific research are emphatic about the importance of informed research for the advancement of knowledge. They state that "studies that do not start with clear conceptual frameworks and hypotheses may still be scientific, although they are obviously at a more rudimentary level and will generally require follow-on study to contribute significantly to scientific knowledge" (Shavelson and Towne, 2002, p.101)

A small number of articles in this review incorporated a theoretical framework, and an even fewer number attempted a critical analysis of these frameworks in order to modify and to add to existing theories. The disadvantage of this approach is diminished contributions to the advancement of scientific knowledge when given the opportunity and the resources.

The last factor analyzed in this literature was the standards addressed. National and state standards in mathematics, science, and technology dominated the articles that referred to standards. This is a positive aspect; however, in the era of the "No Child Left Behind Act," (2002) more influence of these standards is expected when conducting interventions at these grade levels.

IMPLICATIONS AND CONCLUSIONS

Based on the previous discussion, the implications of practice are clear. First, practice should be informed by research on an ongoing basis. The emerging nature of the field of engineering education requires that the content and the nature of interventions should be related to advances about the understanding of engineering. It also implies that the targeted populations should include not only student and teacher groups if the field is to establish itself as a P-12 content area. The final aspect to consider in practice has to do with standards. Again, in an effort to connect P-12 interventions to standards, more development in engineering standards and more incorporation to curricula is expected if the community is to become a leader in the development of engineering specific policies and the incorporation of these policies into P-12 classrooms.

In addition, more theoretical frameworks are expected to be incorporated, to be advanced, or to emerge out of P-12 classroom environments. With clear theoretical perspectives, more experimental designs are needed. It is also expected that advances on understandings of what constitutes engineering (whether a noun or a verb) emerge out of the P-12 classroom. It is finally expected that increases in literacy for all citizens and in the number of students attracted to engineering be attributable to interventions or treatments within the research agenda. Although material resources are in place for these research activities, more engineers and educational researchers must reach consensus about these efforts. It is anticipated that this integrative literature review will serve as a basis for research and practice advances.

This paper provides information about the current state of research in engineering education at the P-12 levels and offers a rubric for future exploration of research within this community. Although numerous articles have been disseminated about P-12 engineering education interventions over the past few years, few consistently include rigorous research methods that are connected to diverse theoretical perspectives. In addition, the breadth of P-12 engineering education work is relatively narrow given its primary focus upon students and teachers and upon its exploration of students' and teachers' knowledge and attitudes. Within this paper, we encourage multiple communities (e.g., engineers, engineering education researchers, interdisciplinary K-12 educators, and policymakers) to work collaboratively to increase the quality of work produced within the P-12 engineering education community. Given the increasing number of private and public funding that is being awarded to conduct such studies and the number of national policy bodies and agencies that request evidence about the effectiveness of P-12 efforts to increase the number of students within the STEM pathway, we anticipate that the number of P-12 articles informed by theoretical frameworks and thorough assessments such as those recommended within this review will increase.

VIDEO: http://youtu.be/bdaTGhHopOc

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AUTHORS

Noemí V. Mendoza Díaz, Ph.D., is the Technology Integration Specialist for the Brazos School for Inquiry and Creativity, a P-12 Charter School in the College Station and Houston, Texas areas. She is also the Coordinator of the Community of Engineering Education for the University Corporation for the Advancement of the Internet in Mexico. In 2006, Dr. Mendoza Díaz obtained her Ph.D. from Texas A&M University in Educational Administration and Human Resource Development and during 2007-2009 she worked as a Postdoctoral Researcher with the Institute for P-12 Engineering Research and Learning (INSPIRE) at Purdue University. Prior to her arrival to the US, she had been an Electrical Engineering Professor for two Mexican universities. In 2009, she was awarded with the prestigious Apprentice Faculty Grant from the Engineering Research Methods Division of ASEE. Her research interest is in the engineering education K-20 spectrum seen as a continuum with an emphasis on minorities. She is also interested in pre-college and college engineering readiness, relevant engineering learning, and theory building in engineering education.

Monica F. Cox, Ph.D., is an Associate Professor in the School of Engineering Education at Purdue University. She obtained a B.S. in mathematics from Spelman College, a M.S. in industrial engineering from the University of Alabama, and a Ph.D. in Leadership and Policy Studies from College of Vanderbilt University. Teaching interests relate to the professional development of graduate engineering students and to leadership, policy, and change in science, technology, engineering, and mathematics education. Primary research projects explore the preparation of engineering doctoral students for careers in academia and industry and the development of engineering education assessment tools. She is a NSF Faculty Early Career (CAREER) award winner recipient of a Presidential Early Career Award for Scientists and Engineers (PECASE)

APPENDIX. Analysis of Publications Arranged in Accordance to the P-12 Engineering Education Rubric

Agenda 1: Pathways to increase the number of engineers

	Content of Intervention	Assessment	Unit of Analysis	Population
DeBartolo, E., & Bailey, M. (2007). Making engineering appealing for girls: Programmes for grades 6-12. *International Journal of Engineering Education, 23*(5), 853-860.	Five programs reported emphasizing the engineering design process, science, engineering disciplines, and engineering as a career option. 1. Travelling engineering activity kits (TEAKS) 2. Park and Ride 3. Expanding your horizons (EYH) 4. SWE Sleepover and Shadow Programme 5. WE@RIT Weekend	Descriptive and quasi-experimental. 1. Pre and post- surveys 2. Observations	Student and (in one program) parent-caregiver' perceptions	19 students in the EYH program. 26 students in the WE@RIT program.
Boynton, M., Hossain, F. (2010). Improving engineering education outreach in rural counties through engineering risk analysis.*Journal of Professional Issues in Engineering Education and Practice, 136(4),* 224-232.	Principles of Engineering (POE) Course based on Project Lead the Way. Lesson on Risk Failure and Water Resources Infrastructure.	Descriptive of factors affecting decision to attend Tennessee Technological University. Experimental for Pre- and Post-Questionnaire about knowledge of Risk Failure and Water Resources Infrastructure.	Freshmen student enrollment in engineering and High School students' knowledge (Fourteen students in the treatment group and 20 students in the control group).	(Unspecified) All engineering freshmen at Tennessee Technological University during the period (2005-2007) and Jackson County High School.
Cantrell, P., Ewing-Taylor, J. (2009). Exploring STEM career options through collaborative high school seminars. *Journal of Engineering Education, 98(3),* 295-303.	K-12 Engineering Education Programs (KEEP) Seminar series (8 sessions per year) devoted to increase career knowledge.	Descriptive through a questionnaire administered weekly to participants asking their career goal.	Student's attitudes towards careers in STEM fields.	One hundred and sixty-one high school students (5 year time-span)

Reisslein, M., Moreno, R., Ozogul, G. (2010). Pre-college electrical engineering instruction: The impact of abstract vs. contextualized representation and practice of learning.*Journal of Engineering Education, 99(3),* 225-235.	Contextualized vs. abstract representations of parallel circuit analysis via an instructional computer program.	Experimental via performance on post-test. Descriptive via a Likert-type survey of students' self-perceptions of learning.	Students' knowledge of circuits. Students' perceptions of self-learning.	One hundred and forty-eight 8th grade students. Control group (abstract representation): 48 Treatment group (contextualized representation): 49 Combined group (abstract and contextualized representation): 51.\
Zhe, J., Doverspike, D., Zhao, J., Lam, P., & Menzemer, C. (2010). High-school bridge program: A multidisciplinary STEM research program. *Journal of STEM Education, 11*(1&2), 61-68.	STEM summer bridge program devoted to encourage students to consider choosing engineering major. Emphasis on: (1) Characterization of modern steel components (2) Development of a smart balloon (3) Hybrid car powered by sun and water (4) Sensors for health monitoring.	Descriptive based on: (1) Enrollment to colleges in STEM majors (2) Focus groups in students' expectations, interests and skills	Students' enrollment and attitudes.	Thirty-three high school students
Thompson, S., & Lyons, J. (2009). Engineering outreach in middle school: The influence of a long-term, school-based collaboration. *International Journal of Engineering Education, 25*(3), 452-460.	Engineering Fellows Program consisting on preparation of graduate students in order to enter the K-12 science classroom.	Descriptive based on: (1) Pre-Post surveys and interviews of fellow. (2) Pre-post surveys and Draw and Engineering Tests for students.	Fellows beliefs and students' attitudes.	Nineteen fellow graduate students and slightly more than 1200 middle school students.
Rose A. T., & Miller, A. L. (2009). A collaborative approach to offering summer engineering camps for middle school students. Proceedings of the ASEE/ IEE Frontiers in Education Conference 2009. San Antonio, TX.	Engineering summer camps: (1) Engineering for girls (2) Engineering of cities (3) Advanced Mechanical Engineering (4) Alternative Energy	Descriptive –Post-surveys	Students' and Parents' perceptions	Undetermined number of students and parents.

Maxim, B. R., & Elenbogen, B. S. (2009). Attracting K-12 students to study computing. Proceedings of the ASEE/ IEE Frontiers in Education Conference 2009. San Antonio, TX.	One day computing workshops	Descriptive, Pre-Post-Kay's computer attitude scale	Student's attitudes	Forty-four boy scouts and 86 high school students.
Nugent, G., Barker, B., Grandgenett, N., Adamchuk, V. (2009). The use of digital manipulatives in K-12: Robotics, GPS/GIS and programming. Proceedings of the ASEE/ IEE Frontiers in Education Conference 2009. San Antonio, TX.	Building and programming of robots using LEGO Mindstorms	Experimental involving pre- and post-tests.	Students' knowledge and attitudes.	One hundred and forty-seven middle school students in the treatment group and 141 in the control group.
Davis, K.C., Maltbie, C. V., Myers, B., Forry, R., & Wolf, M. (2009). Incorporating industrial co-op experience in high school classroom outreach. Proceedings of the ASEE/ IEE Frontiers in Education Conference 2009. San Antonio, TX.	Co-op experiences involving: Medical imaging, Computer chip design, and Land mobile radios	Descriptive involving pre- post-surveys and reflective journals.	Students' perceptions	Thirty-one high school students.
Beck, M., Diefes-Dux, H., & Reed-Rhoads T. (2009). K-12 School counselors: A pilot study of support needs for advising students about engineering. Proceedings of the ASEE Conference and Exposition 2009. Austin, TX.	No intervention or treatment	Descriptive involving a Likert-type survey.	Counselors' perceptions.	Fifty-two counselors.
Zarske, M., Sullivan, J., Knight, D., & Yowell, J. (2008). The impact on engineering graduate students of teaching in K-12 engineering programs. Proceedings of the ASEE Conference and Exposition 2008. Pittsburgh, PA.	Tomorrow's engineers create, imagine, succeed program (TEAMS)	Descriptive- Likert type survey, focus groups and observations.	Graduate students' and teachers' perceptions	Twenty-seven graduate students and undetermined number of teachers.

Brockway, D., McGrath, E., McKay, M., & Schultz, D. (2009). Analysis of a state-wide K-12 engineering program: Learning from the field. Proceedings of the ASEE Conference and Exposition 2009. Austin, TX Informed by Self Efficacy (Bandura)	Engineering our future New Jersey (EOFNJ) teacher professional development.	Descriptive- Likert-type survey.	Teachers' satisfaction and perceptions.	One hundred and seventy in-service teachers, 21 pre-service teachers, 19 administrators and 10 other stakeholders.
Agenda 2: Math and Science achievement improvement				
Barnett, M. (2005). Engaging inner city students in learning through designing remote operated vehicles. *Journal of Science Education and Technology, 14*(1), p. 87-100. Informed by Constructionism (Papert, 1991)	Remote Operated Vehicle (ROV) Project centered on learning science and mathematics using the design process	Descriptive and quasi-experimental through: 1. Pre-Post Knowledge Tests 2. Observations (including attendance) 3. Interviews with a sample 4. Field Notes	Students'	3 ninth grade teachers and 42 students
Cantrell, P., Pekcan, G., Itani, A., & Velasquez-Bryant, N. (2006). The effects of engineering modules of student learning in middle school science classrooms. *Journal of Engineering Education, 95*(4), 301-309. Informed by Theory of Experiential Learning (Kolb, 1984)	The Teachers Integrating Engineering into Science (TIES) program (professional development program). Emphasis given to the engineering design process and communications skills.	Descriptive for students and teachers with: 1. Students' Unit Tests 2. Students' Rubric for the design project 3. Students' Interview Protocol 4. Teachers' journals 5. Teachers' interviews 6. Teachers' final questionnaire	Student Knowledge as compared to a State standardized Criterion Referenced Test (CRT) in science. Teachers' attitudes and beliefs about the results of the program.	434 8th grade students for the unit tests and the rubric of the design project. 858th grade students for the interviews. 8 middle-school science teachers. State of Nevada.
Church W., Gravel B., & Rogers C. (2007). Teaching parabolic motion with stop-action animations. *International Journal of Engineering Education, 23*(5), p. 861-867. Informed by Constructivism and Constructionism (von Glasserfeld, Papert, 1991)	Activity consisting on the making of animation design (movies) centered around science (parabolic motion)	Descriptive based on observations	Students' knowledge of parabolic motion	High School students in New Hampshire

McKay, M., & McGrath, B. (2007). Real-world problem-solving using real-time data. *International Journal of Engineering Education, 23*(1), 36-42.	Online curriculum units titled "Wonderful World of Weather", "Global Water Sampling", and "Stowaway Adventure" with focus given to science and mathematics education making use of real-world problems and real-time data.	Report on two studies: (1) Descriptive and Quasi-experimental with Pre-post tests and observations of students use. (2) Analysis of student achievement on the Grade Eight Proficiency Assessment (GEPA).	Student Impact	For study one, 78 students in grades 3rd, 7th, 10th and 11th located in Cleveland, Phoenix and Miami. For study two, middle school students of a urban New Jersey district.
Hardre, P. L., Nanny, M., Refai, H., Ling, Ch., Slater, J. (2010). Engineering a dynamic science learning environment for K-12 teachers. *Teacher Education Quarterly, 37*(2), 157-178.	Teacher six-week resident learning experience focused on specific engineering disciplines: -Industrial Engineering -Computer Engineering -Environmental Engineering	Descriptive based on: (1) Observations of work and projects (2) Interviews (3) Focus groups	Teachers attitudes, perceptions and	Seventeen teachers (science and mathematics).
Agenda 3: Technological literacy improvement				
Bers, M. U., (2007). Project InterActions: A multigenerational robotic learning environment. *Journal of Science Education and Technology, 16*(5), 537-552. Informed by Constructionism (Papert, 1991) and Communities of Practice (Lave & Wenger, 1991)	Curriculum centered on the design process and robotics.	Descriptive and quasi-experimental design via 1. Participants' journals 2. Websites created by participants 3. Observations 4. Interviews 5. Pre-Post Likert-type Questionnaires	Students' and Parents' perceptions and knowledge.	170 pairs (Parent-student) and 16 student-only. Massachusetts.
Cejka, E., Rogers, C., & Portsmore, M. (2006). Kindergarten robotics: Using robotics to motivate math, science, and engineering literacy in elementary school. *International Journal of Engineering Education, 22*(4), 711-722. Informed by Constructionism (Papert, 1991)	Report of the Systemic School Change in Engineering Project (SSCE) at Tufts University. Teachers and Tufts personnel build curriculum. Emphasis given to Engineering Design, Lego/Logo robotics applications, science and math concepts.	Descriptive via: 1. Teachers surveys 2. Discussions 3. Classroom observations	Program Evaluation-teacher's perceptions, and behaviors in the classroom.	A sample from the 43 teachers who had participated in the program. Massachusetts.

Rogers C., & Portsmore M. (2004). Bringing engineering to elementary school. *Journal of STEM Education, 5*(3 & 4), p. 17-28.	"LEGO/ROBOLAB" intervention centered on the engineering design process. It also stresses mathematics, science, reading and writing.	Descriptive based on observations	Students' knowledge	Kinder-5th grade students in the state of Massachusetts
Hynes M. M., & Dos Santos A. (2007). Effective teacher professional development: Middle-school engineering content. *International Journal of Engineering Education, 23*(1), 24-29. Informed by Constructionism (Papert, 1991)	Professional development aimed to prepare teachers to teach an after-school LEGO robotics program. Curriculum strands on Engineering Design Process, Communications Technologies, Manufacturing Technologies, and Bioengineering Technologies. A two-week programme.	Descriptive and quasi-experimental 1. Confidence survey applied at two different times. 2. Content tests 3. Observations 4. Interviews	Two-week programme effectiveness through teachers' knowledge and confidence.	13 middle school in-service teachers of Massachusetts
Powers, S. E., DeWaters, J. E., Venczel M. Z. (2011). Teaching life-cycle perspectives: Sustainable transportation fuels unit for high-school and undergraduate engineering students. *Journal of Professional Issues in Engineering Education and Practice, 137(2),* 55-63. INCREASE TECH LITERACY Informed by Project-base and Inquiry Based and Self-Efficacy (Bandura)	High School Advanced Placement Environmental Science Class. Development of an Analysis of Fuels efficiency and impact via a Lyfe-Cycle Assessment (LCA).	Descriptive and Quasi-experimental using: (1) Perception Surveys (2) Knowledge Questionnaires	High School student attitudes and knowledge of energy systems via: (1) Energy related knowledge (2) Attitudes toward energy issues (3) Perceptions of Self-efficacy (4) Energy consumption behaviors and intentions.	Thirty-nine HS students.

Agenda 1-2: Pathways to increase the number of engineers and Math and Science achievement improvement

Baker, D., Yasar-Purzer S., Robinson Kurpius, S., Krause, S., & Roberts, C. (2007). Infusing design, engineering and technology into K-12 teachers' practice. *International Journal of Engineering Education, 23*(5), 884-893.	Study as a component of a graduate course in science education. Emphasis given to (1) Engineering Design process, (2) Discussion of articles related to using Design, Engineering, and Technology (DET), (3) Development of hands-on activities for the classroom.	Descriptive and quasi-experimental (all qualitative). 1. Open-ended pre/post questions 2. Seven reflection papers written by each participant 3. DET units designed by participants 4. Interviews with participant teachers.	3 case studies of teachers' practice perceptions, reflections, and intentions	3 graduate students (in the science education master's programme), two of them in-service teachers (third grade and high school) and the other one taught at a Science Centre in a Museum. Arizona
Bergin, D., Lynch, J., Khanna, S. K., & Nair, S. S. (2007). Infusing design into the G7-12 curriculum-Two example cases. *International Journal of Engineering Education, 23*(1), 43-49. Informed by Theory of Self-Efficacy (Bandura)	Two Cases of Hands-on design project units. Curriculum emphasized (1) Design process, (2) Teamwork, (3) Economic Constraints. First Unit –"Boat", Second Unit-"Bulldozer".	First case (Boat) used a descriptive "individual reflection" post-test. Second case (Bulldozer) used also descriptive assessment in the form of: 1. Observations 2. Self-efficacy survey 3. Survey of interest in hands-on units.	Student Attitudes	First case (Boat)- 106 students (junior high level) Second case (Bulldozer)- 15 students (high school). Missouri
Cunningham C. M., Knight M. T., Carlsen W. S., & Kelly G. (2007). Integrating engineering in middle and high school classrooms. *International Journal of Engineering Education, 23* (1), 3-8.	Professional development program titled "Pre-College Engineering for Teachers" (PCET) focused around the engineering design process targeting science, mathematics, and technology teachers. A two-week institute and mentorship with experts (Massachusetts partners) during the school year.	Descriptive and Quasi-experimental. 1. Background Survey 2. Pre-Post Survey assessing knowledge and comfort with teaching engineering and technology 3. Teacher's project plan. 4. Interviews with a random sample of 10 participants.	Program Effectiveness through teachers' knowledge and comfort with teaching engineering and technology.	108 middle school and high school in-service teachers of Massachusetts
DeGrazia, J. L., Sullivan, J. F., Carlson, L. E., & Carlson, D. W. (2001). A K-12/University partnership: Creating tomorrow's engineers. *Journal of Engineering Education, 90* (4), 557-563.	GK-12 Fellows program aimed to bring graduate students to STEM K-12 education. The fellows were provided with pedagogical tools in order to develop and implement curriculum. Emphasis given to applied technology, physical science, and mathematics.	Descriptive, 1.Open ended questionnaire applied to K-12 teachers.	Teacher perceptions of the program	Ten students from five different departments at University of Colorado-Boulder and 19 K-12 teachers

Elton D. J., Hanson J. L., & Shannon D. M. (2006). Soils Magic: Bringing civil engineering to the K-12 classroom. *Journal of Professional Issues in Engineering Education and Practice, 132*(2), p. 125-132.	Program titled "Soils Magic" based on units of experiments centered on increasing interest in civil engineering.	Descriptive based on a survey	Students' knowledge and attitudes	102 elementary school students
Lumpp, J. K., Bradley, K. D., & Haines, R. T. (2007). A Kentucky electronics education project (KEEP): Putting professional development into practice. *International Journal of Engineering Education, 23*(5), 910-915. (*inquiry-based writing assignments*)	Kentucky Electronics Education Project (KEEP) aimed to provide hands-on experiences via circuit design and building lessons aligned with STEM standards	Descriptive 1. Likert-based student satisfaction survey 2. Open-ended questions	Student satisfaction	200 high school students. Kentucky
Lyons, J., & Ebert, C. (2005). A survey of engineering, science and mathematics education centers in the United States. *International Journal of Engineering Education, 21* (3), 457-466.	Exploration and description of centers devoted to Engineering, Science, and Mathematics Education with K-12 outreach services.	Descriptive based on a survey	Center Directors' general questions related to their centers.	173 respondents
Moskal, B. M., Skokan, C., Kosbar, L., Dean, A., Westland, C., Barker, H., et al. (2007). K-12 outreach: Identifying the broader impacts of four outreach projects. *Journal of Engineering Education, 96*(3), 173-189.	Four programs emphasizing the teaching of mathematics and science through hands-on experiences and exposure to engineer role-models 1. Engineering our world (EOW) 2. Engineering in the Middle School Classroom (EMSC) 3. Physical Science and Mathematics in the Middle School Classroom (PSMM) 4. GK-12 Learning Partnerships (GK-12)	Descriptive and quasi-experimental via: 1. Teachers' focus groups 2. Teachers' open-ended questionnaires 3. External evaluator observations 4. Teachers' pre-and post-tests 5. For one program (Tech Camp 101), students' pre- and post-test Additional analysis of state mandated test scores	Teachers' perceptions and knowledge as well as students' knowledge	142 teachers in Colorado

Mooney, M. A., & Laubach, T. A. (2002). Adventure engineering: A design centered, inquiry based approach to middle grade science and mathematics education. *Journal of Engineering Education, 91*(3), 309-318. Informed by Inquiry-based learning	AE Curriculum centered on infusing science and mathematics through design inquiry-based scenarios.	Experimental design through control groups for 3 of the four scenarios and with pre-post likert-type surveys for control and treatment groups.	Students' attitudes and knowledge	97 students in treatment group 113 students in control group. Oklahoma
Pickett M., Oliver D., Giles S., Fridman E., Fetters M., & Cooks H. (2000). Hands-on engineering experiments for secondary school students. *Journal of Professional Issues in Engineering Education and Practice, 126*(2), p. 69-73.	Program titled "Teaching Teachers to Teach Mathematics and Science via Engineering Activities"(T4MS/E) focused on teaching science and math concepts via practical (hands-on) applications	Descriptive based on surveys	Teachers' and students' attitudes comparing with the 9th grade standardized test performance.	79 in-service (math/science) teachers, 2 (math/science) pre-service teachers, and a sample of the 11,400 students impacted by this program in Ohio.
Poole, S. J., DeGrazia, J. L., & Sullivan, J. F. (2001). Assessing K-12 pre-engineering outreach programs. *Journal Engineering Education, 90*(1), 43-48.	Summer workshops organized by the Integrated Teaching and Learning (ITL) program centered on exposing K-12 teachers and students to pre-engineering concepts in a hands-on manner	Descriptive and quasi-experiemental via: 1. Teachers' Post-workshop questionnaire 2. Teachers' Pre-post workshop survey 3. Students' project, observation, and questionnaire rubric 4. Students' Post-workshop questionnaire 5. Parent/Guardian questionnaire	Teachers' attitudes, student knowledge and perceptions and parent/guardian perceptions.	Teachers, students and parents/guardians in the state of Colorado
Richards L. G., Hallock A. K., & Schnittka C. G. (2007). Getting them early: Teaching engineering design in middle schools. *International Journal of Engineering Education, 23*(5), 874-883. Informed by Guided Inquiry (Thier & Bennett)	Engineering Teaching Kits (ETKs) built and delivered through the Virginia Middle School Engineering Education Initiative (VMSEEI). ETKs focusing on (1) Discussion of the nature of engineering and science, (2) Design process, (3) Physical and economic constraints. All ETK's field-tested on math and science and/or math classes.	Descriptive and Quasi-experimental through 1. Teacher focus groups 2. Observations of students 3. Pre-Post student knowledge tests	(1) Teachers perceptions of the ETK's through focus group via workshop (2) Students knowledge	(1) 17 Middle school teachers (2) 34 eight grade science students

Iskander, M., Kapila, V., Kriftcher, N. (2010). Outreach to K-12 teachers: Workshop in instrumentation, sensors, and engineering. *Journal of Professional Issues in Engineering Education and Practice, 136(2),* 102-111.	Two-week workshop in instrumentation, sensors, and engineering (WISE) in: -Science and Math -Sensor Technology (physical, chemical, biological). -Hands-on Engineering Design.	Descriptive based on -Pre- and Post-surveys on self-perceived skills (skills inventory) -En of Project Survey -Observations of Modified Lesson Plans	(1) Teachers perceptions of their knowledge (2) Observations of Modified Lesson Plans (3) Interviews	20 Middle and High school Teachers
Mehalik, M. M., Doppelt Y., Schuun, C. D. (2008). Middle-school science through design-based learning versus scripted inquiry: Better overall science concept learning and equity gap reduction. *Journal of Engineering Education,97(*1), 71-85. Informed by Learning by Design (Kolodner)	Alarm system (4 to 5 weeks) module for science 8th grade (in equivalence to the Electricity unit)	Descriptive demographical analysis Experimental via pre- and post-tests in electricity knowledge	(1) Overall Student knowledge (2) Student knowledge based on gender (3) Student knowledge based on ethnicity (4) Student knowledge based on socioeconomic status	Experimental group (Design group): Ten teachers and 587 students (26 classes). Contrast group (Inquiry Group): Five teachers and 466 students (20 classes).
Nugent, G., Kunz G., Rilett, L., Jones, E. (2010). Extending engineering education to K-12. *The Technology Teacher, April 2010,* 14-19. Informed by Theory of Self-Efficacy (Bandura)	Summer Institute for Teachers aimed at solving real-world engineering problems. Emphasis on traffic control, bridge and high way design.	Descriptive based on Likert-type surveys and pre-post knowledge	(1) Teachers knowledge (2) Teachers perceptions	Teachers, no mention as to the number.
Klein, S. S. (2009). Effective STEM professional development: A biomedical engineering RET site project. *International Journal of Engineering Education, 25(*3), 523-533. Informed by Adult learning theories.	Biomedical Engineering RET summer progra with a choice between: (1) Electrocardiogram mosaic (2) LASIK/Optics mosaic	Descriptive, pre-post Likert-type surveys	Teachers' attitudes	Forty-two high school teachers.

Caldwell, K., McCoy, J., Albers, L., Smith, A., & Parry, E. (2007). The impact of K-12 outreach programs on graduate and undergraduate experiences. Proceedings of the ASEE Conference and Exposition 2007. Honolulu, HI.	Recognizing accelerated math potential in underrepresented people program (RAMP-UP)	Descriptive-Likert-type surveys	Parents attitudes and perceptions. Undergraduate student satisfaction Graduate student perceptions	Undetermined number of parents, undergraduate and graduate students.
Agenda 1- 2-3: Pathways to increase the number of engineers, Math and Science achievement improvement, and technological literacy improvement				
Rogers, G. E. (2006). The effectiveness of Project Lead the Way curricula in developing pre-engineering competencies as perceived by Indiana teachers. *Journal of Industrial Teacher Education, 18*(1), p. 66-78.	Project Lead the Way, design activities linked to science and mathematics content.	Descriptive design via a Likert-type survey	Teachers' perceptions	34 technology education teachers in the state of Indiana
Rogers, G. E. (2007). The perceptions of Indiana high school principals related to Project Lead the Way. *Journal of Industrial Teacher Education, 44*(1), 49-65.	Project Lead the Way, design activities linked to science and mathematics content.	Descriptive design via a Likert-type survey	Principals' perceptions and attitudes	37 high school principals in the state of Indiana.
Sorby, S. A., & Schumaker-Chadde, J. (2007). Partnering to bring engineering concepts to elementary students. *International Journal of Engineering Education, 23*(1), 65-72. Informed by inquiry-based learning	Internship program for university engineering major students who might get certified as teachers. Curriculum centered on hands-on activities.	Descriptive and quasi-experimental 1. Pre-post survey applied to university student (quantitatively). 2. Post-survey applied to elementary students. 3. Post-survey applied to school principals.	Program Evaluation -internship program through assessment of (1) University student confidence, interest in teaching, and perception of importance of teaching. (2) Students enjoyment (3) Principals' observations and perceptions.	University students, elementary level students and school principals (number unspecified). Michigan

Yasar, S., Baker, D., Robinson-Kurpius, S., Krause, S., & Roberts, C. (2006). Development of a survey to assess K-12 teachers' perceptions of engineers and familiarity with teaching design, engineering, and technology. *Journal of Engineering Education, 95* (3), 205-216.	No intervention	Descriptive consisting of a Likert-based survey with 41 items	Assessment of teachers' perceptions of DET education as defined by national science and technology standards	Ninety eight teachers. Arizona.
Rogers, G. E. (2006). The effectiveness of Project Lead the Way curricula in developing pre-engineering competencies as perceived by Indiana teachers. *Journal of Industrial Teacher Education, 18*(1), p. 66-78.	Project Lead the Way, design activities linked to science and mathematics content.	Descriptive design via a Likert-type survey	Teachers' perceptions	34 technology education teachers in the state of Indiana
Tran, N. A., & Nathan, M. J. (2010). Pre-college engineering studies: An investigation of the relationship between pre-college engineering studies and student achievement in science and mathematics. *Journal of Engineering Education, 99(2),* 143-157. Informed by Project/Problem Based Learning	Project Lead the Way (PLTW) curriculum—Pathway to Engineering™.	Descriptive for the demographics. Experimental via the standardized test scores in Math and Science (8th and 10th grades)	Students Knowledge (performance in State Standardized Tests)	Experimental group (PLTW group): Seventy students. Control group (non-PLTW group: Seventy students.
Nathan, M. J., Tran, N. A., Atwood, A. K., Prevost, A., & Phelps, L. A. (2010). Beliefs and expectations about engineering preparation exhibited by high school STEM teachers. *Journal of Engineering Education,99(4), 409-426.*	Project Lead the Way (PLTW) curriculum—Pathway to Engineering™.	Experimental –Contrasting two groups. Likert-based questionnaire and comparative vignettes.	Teacher beliefs via the Engineering Education Beliefs and Expectations Instruments (EEBEI).	PLTW group: 43 teachers Non-PLTW group: 182 teachers

Asunda, P. A. & Bill, R. B. (2008). Preparing technology teachers to teach engineering design. *Journal of Industrial Teacher Education, 45*(1), 26-53. Informed by Constructivism and Communities of Practice	National Center for Engineering and Technology Education (NCETE) workshops administered during a year with activities involving: -engineering design -problem solving -analytical skills.	Descriptive-Observations, video footage, interviews.	Teacher beliefs and attitudes.	Fifteen middle school and high school technology teachers.
DeBartolo, E., & Bailey, M. (2009). The TEAK project: Students as teachers. *International Journal of Engineering Education, 25*(3), 468-478.	Traveling Engineering Activity Kit (TEAK) involving engineering concepts developed by students.	Descriptive involving pre-post-test	Students' knowledge and attitudes.	One hundred middle school and high school students.

DISSERTATIONS

Agenda 1: Pathways to increase the number of engineers				
Oware, E. A. (2008). Examining elementary students' perceptions of engineers. *Dissertation Abstracts International*(UMI No. 3344179) Informed by CONSTRUCTIVISM (Vygotsky)	Purdue University's Gifted Education Research Institute (GERI) Super Saturday Spring 2007 program, involving exposure to engineering and engineering problem solving.	Descriptive and Quasi-experimental—Perception Questionnaire, Drawing Analysis, Interviews.	Students' perceptions of engineering and engineers. Instructor and course developers' perceptions.	(1) Nine 3rd and 4th GERI students (2) Nine 5th and 6th GERI students (3) One course developer (4) Two instructors
Martin, B. R. (2011). Factors influencing the self-efficacy of black high school students enrolled in PLTW pre-engineering courses. *Dissertation Abstracts International* (UMI No. 3443823). Informed by Self-efficacy	Project Lead the Way	Descriptive-Motivated Strategies for Learning Questionnaire (MSQL)	Students-Perceptions	Seventy-six high school students.
Lanigan, D. (2009). Increasing student motivation to become a successful industrial engineer. *Dissertation Abstracts International*(UMI No. 1467819). Informed by VIE Theory of Motivation	Industrial Engineering Modules (yearlong course)	Quasi-experimental: Pre-Post Surveys and observations	Student Motivation.	Thirty-six middle school students
Agenda 2: Math and Science achievement improvement				
Marulcu, I. (2010). Investigating the impact of a LEGO™-based, engineering-oriented curriculum compared to an inquiry-based curriculum of fifth graders' content learning of simple machines. *Dissertation Abstracts International* (UMI No. 3419134) Informed by Conceptual development-Piaget	LEGO™-based, design-oriented elementary science curriculum: Design a people mover: Simple machines.	Experimental—Pre and Post-tests and interviews, observations of videos and students workbooks	(1) Students' knowledge and perceptions (2) Teacher s' perceptions.	(1) Fifty-three elementary students and one teacher in the treatment group. (2) Twenty-six elementary students and one teacher in the control group.

Martinez Ortiz, A. (2010). Students' understanding of ratio and proportion within engineering robotics. *Dissertation Abstracts International* (UMI No. 3422310). Informed by Constructivism and Constructionism	LEGO-Robotics integrated engineering and mathematics program, focused on ratios and proportions.	Experimental via post-tests, interviews and observations.	Students' knowledge via the Intra-mathematical proportional test and the Extra-mathematical proportional test.	Thirty fifth grade students, 15 in the treatment group and 15 in the control group.
Agenda 3: Technological literacy improvement				
Portsmore, M. D. (2009). Exploring how experience with planning impacts first grade students' planning and solutions to engineering design problems. *Dissertation Abstracts International* (UMI No. 3396538).	LEGO™-based, engineering-oriented curriculum inspired by Goldilocks and the three bears.	Descriptive involving: (1) Pre-post interviews on engineering design problems (2) Observations and rubrics of artifacts. (3) Observations of videos.	(1) Engineering knowledge (2) Engineering attitudes	Twenty-four first grade students.