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Innovating Education for the Next Generation of Engineers – Results of an NSF-RET Program Focused on Innovation

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Innovating Education for the Next Generation of Engineers – Results of an NSF-RET Program Focused on Innovation

Abstract

Engineering innovation and design continues to be vital to economic success, sustainability, and the creation of jobs in the U.S., and remains at the top of government policy agendas today. For the U.S. to maintain its edge in innovation, our youth must be inspired to pursue STEM fields and must also be exposed to the process of innovation in order to understand the synergism of the methods and approaches used in ideation, discovery and experimentation in the STEM disciplines. This paper describes a unique National Science Foundation – Research Experience for Teachers program that is thematically centered on innovation and engineering design. The overall objectives of this six week program for K-12 STEM teachers and pre-service teachers entitled *Engineering Innovation and Design for STEM Teachers* was to enhance the knowledge of teachers and pre-service teachers about engineering innovation and design so that they can facilitate inspirational engineering and innovation experiences in their classrooms as well as better inform their students of potential career fields and societal needs related to STEM. During the first and second summers of this program, ten teachers and five pre-service teachers were placed on teams with an engineering student, engineering faculty and an industrial mentor or community partner. Each team participated in an introductory engineering innovation and design project as well as a more in-depth project provided by the industrial mentor or community partner. The experience was enhanced through field trips to the industrial mentors' sites, guest speakers, laboratory experiences and tours, technical writing seminars, as well as history and ethics of engineering innovation sessions. Additionally, the participants were guided through a well-structured curriculum writing experience modeled after that used for a highly successful regional STEM teacher professional development program. Through this experience, the teams made use of a curriculum template that was developed to ensure that the resulting lessons provided high quality inquiry based STEM experiences for the students that included concepts of engineering innovation and design and were also aligned with the state curriculum standards. Guided reflections, team presentations of STEM Curriculum, and developed prototypes provided evidence associated with the objectives. Local System Change (LSC), Mathematics Teaching Efficacy and Beliefs Instrument (MTEBI) and Science Teaching Efficacy and Beliefs Instrument (STEBI) surveys were administered to the in-service teachers prior to the program. Follow-up surveys were administered to the 2012 cohort and will be administered to the in-service teachers during the 2013 academic year to identify changes in attitudes, beliefs and practices. Classroom observations of participants delivering developed STEM content provided details regarding transference to K-12 classrooms. A focus group with the engineering students provided feedback regarding their growth and experiences. Results from both qualitative and quantitative assessment suggest that this program was successful at meeting the program objectives.

Introduction

Engineering innovation and design is the cornerstone of economic success, global competitiveness and wage and job growth in the United States (US).[1-5] Additionally, engineering innovation is required to address critical issues that threaten both the environment and global peace.[6,7] As a result, innovation remains at the top of government policy agendas today.[1,6,7] In a 2009 speech, President Obama declared innovation to be critically important and the key to good jobs and economic recovery.[8] For the US to maintain its edge in innovation, the next generation of scientists and engineers must be inspired to pursue these fields at a very early age and must also be introduced to the process of innovation in order to understand the synergism of the Science, Technology, Engineering and Mathematics (STEM) subjects. Additionally, teachers must be able to prepare and inspire a diverse group of students in STEM.[9-10] Unfortunately, the number of students who choose STEM fields continues to decline.[11-14] As such, there is a great need to spark interest among our youth in STEM, and to develop and facilitate quality engineering experiences for K-12 students.[15] However, most undergraduate teacher education programs do not include engineering concepts or engineering design practices in their curriculum. As such, it is unrealistic to expect teachers to teach or promote engineering when many K-12 teachers do not have a good understanding of engineering practices, applications or careers.[16, 17] STEM education at all levels (PK-16+) has been identified as being one of three pillars critical to fostering innovation and to increasing living standards.[1] As stated in a 2010 report from the President's Council of Advisors on Science and Technology, "to improve STEM education, we must focus on both preparation and inspiration."[5]

Although most undergraduate teacher education programs do not include engineering as part of their undergraduate curriculum, various professional development opportunities and teacher mentorship programs have been created to help teachers gain a better understanding of engineering careers, principles and practices and to encourage teachers to bring these concepts into their classroom. For example, one very successful two-week program entitled Pre-College Engineering for Teachers (PCET) introduced teachers to engineering concepts and the engineering design process. [18] A slightly different model for professional development entitled STOMP (Student Teacher Outreach Mentorship Program), used undergraduate and graduate engineering students to serve as mentors to teachers and to facilitate engineering design based activities in the classroom. [19] Other engineering education resources for K-12 teachers include the well-known and highly successful Project Lead the Way (PLTW) curriculum. This formalized course curriculum and professional training for middle and high school teachers started in 1986 and currently is used by over 4,200 schools in all 50 states.[20] The other model for teaching K-12 students about engineering is one in which engineering and technology concepts and skills are integrated into other subjects such as science and math.[18] There are a variety of websites available to teachers that have lessons and curriculum in math and science that include engineering principles or concepts. One such website is the TeachEngineering Digital Library which was started in 2003 as a result of a National Science Foundation (NSF) grant. This website hosts a searchable database of engineering related curriculum that is tied to curriculum standards for all grade levels.[21]

The aforementioned efforts are critically important as the inclusion of engineering, particularly engineering innovation and design into the K-12 curriculum, has numerous educational advantages. Among these educational advantages include the fact that engineering, particularly engineer design and innovation, is inherently multi-disciplinary and allows teachers to incorporate different subjects into a single activity. This integration requires students to synthesize their knowledge of STEM while developing their design. Furthermore, in traditional educational models many students fail to see the connection among the "fun" subjects, creativity and STEM. An innovation-based curriculum allows students to bridge this gap which could lead to enhanced interest in STEM subjects. In one study, Baker, et al found the applied and integrative aspects of engineering design to enhance student learning and to increase standardized test scores.[22] This may be due to the fact that engineering design and innovation promotes learning through inquiry, provides an opportunity for structured problem solving and is well suited to team based learning. When done in a classroom setting, the students have the added benefit of learning by observing other teams' projects. This helps students to generalize beyond their own projects and to gain a better understanding of product design and entrepreneurship.[23] The team work, collaboration and potential socially beneficial aspects of engineering innovation and design projects also have been found to engage and attract a more diverse group of students including females and under-represented minorities.[24, 25] Engineering design also has the potential to provide students with a new definition of success and failure when taken in the context of innovation. In the design process an "unsuccessful" design provides an opportunity for learning and can be considered an essential step to the engineering design process that leads to highly innovative and cutting edge designs.[26] As such, engineering design projects integrated into the STEM subjects have the potential to boost the confidence of students in these subjects and to encourage them to embrace educational challenges. Other educational advantages of integrating engineering innovation and design into STEM curriculum include: (a) Positive pedagogical practices are fostered (i.e., inquiry, teamwork, project and problem-based learning, synthesis of knowledge); (b) A broad range of students are engaged and a wide range of curricular standards are accommodated (i.e., teachers can incorporate different subjects into a single activity fostering creativity and synthesis of knowledge, which is appropriate for a wide range of learners; and (c) Students are effectively exposed to a variety of STEM careers (e.g., some projects can dispel narrow perceptions of what an engineer does and demonstrate how engineering is used to help humanity (e.g., designing an assistive device for a handicapped person), which is effective at recruiting females and other underrepresented groups to the field of engineering. [22, 23, 27-29]

Although STEM education has received a great deal of attention in recent years, there does not appear to be a unified voice advocating for a quality STEM educational experience. In 2011, the National Academies Press released a report that identified the need to improve STEM learning and outlined some goals for US STEM education and general criteria for measuring the success of STEM schools. The STEM Education Coalition, an advocacy group that is supported by professional STEM and educational organizations and various companies, outlines core policy principles, which include high quality STEM programs.[30] One resource related to STEM education that has received national attention is the STEM Quality Framework (SQF). Among other things, the SQF articulates a set of principles that outline teaching and learning concepts that lead to a quality STEM educational experience. This tool, developed by the Dayton Regional STEM Center (DRSC) in collaboration with the University of Dayton's (UD) Institute for Technology Enhanced Learning (ITEL), is comprised of ten quality components articulated as rubrics across four performance levels. The quality components were developed over a three-year period of research and development that included an extensive review of the literature and a Delphi Method validation study involving twenty STEM education experts, including leaders from national organizations dedicated to improving STEM education, higher education professors from STEM departments, STEM industry representatives, and classrooms teachers as well, Table 1. The complete SQF including performance rubrics for all ten quality components are described in references 31 and 32.

Table 1: STEM Education Quality Framework

Components	**Quality Standard**
Potential for Engaging Students of Diverse Academic Backgrounds	Learning experiences are designed to engage the minds and imaginations of students of diverse academic backgrounds.
Degree of STEM Integration	Learning experiences are carefully designed to help students integrate knowledge and skills from Science, Technology, Engineering and Mathematics.
Connections to Non-STEM Disciplines	Learning experiences help students connect STEM knowledge and skills with academic standards from other disciplines.
Integrity of the Academic Content	Learning experiences are content-accurate, anchored to the relevant content standards, and focused on the big ideas and foundational skills critical to future learning in the targeted discipline(s).
Quality of the Cognitive Task	Learning experiences challenge students to develop higher order thinking skills through processes such as inquiry, problem-solving, and creative thinking.
Connections to STEM Careers	Learning experiences place students in learning environments that help them to better understand and personally consider STEM careers.
Individual Accountability in a Collaborative Culture	Learning experiences often require students to work and learn independently and in collaboration with others using effective interpersonal skills.
Nature of Assessments	Learning experiences require students to demonstrate knowledge and skill, in part, through performance-based tasks.
Application of the Engineering Design	Learning experiences require students to demonstrate knowledge and skills fundamental to the engineering design process (e.g., brainstorming, researching, creating, testing, improving, etc.).
Quality of Technology Integration	Learning experiences provide students with hands-on experience in using multiple technologies. (Examples: computer hardware and software, calculators, probes, scales, microscopes, rulers and hand lenses to name just a few).

Program Design and Objectives

In 2010, UD received an NSF – Research Experience for Teachers (RET) award entitled, *Engineering and Innovation Design for STEM Teachers*. The overarching goal of the RET program, in general, is to develop long-term, collaborative relationships with K-12 teachers and university faculty, involve K-12 teachers in engineering research and help teachers translate this research into classroom activities.[35] The *Engineering and Innovation Design for STEM Teachers* program uses engineering innovation as the focus for teacher research experiences in engineering, emphasizing the role of applied research in engineering product design and innovation. Currently, two cohorts have participated in this program during the summers of 2011 and 2012. The program is modeled after UD's well-established first year innovation course and capstone design course offered through the Innovation Center at UD. The innovation focus was selected based on the belief that it would allow the participants and the facilitators to build on regional and university strengths in innovation and because engineering innovation fosters creativity and synthesis of knowledge as described above. As such, curriculum developed with innovation as its theme has the potential to both inspire and inform students about STEM and associated careers. Furthermore, innovation and engineering design can be incorporated into nearly any content area.

Several organizations including UD, the DRSC and local industry and not-for-profit organizations, collaborated on this project to provide a meaningful professional development opportunity for teachers and pre-service teachers and to support teachers in the design, development, and pilot-testing of STEM curriculum under the guiding principles of the SQF. This six week experience included team based engineering design projects that were connected with an industrial sponsor or community partner, tours of engineering facilities, hands-on demonstrations of laboratory equipment and lectures on technical topics, pedagogy, curriculum development, technical writing, project management, library research and the history and ethics of engineering. Additionally, the teachers were guided through a well-structured curriculum development experience which enabled them to write inquiry based curriculum that met academic content standards and included concepts of innovation and the engineering design process. The objectives of this six week experience were to: (1) transfer the program's team-based engineering design and innovation activities to the teachers' classroom activities; (2) spark the interest of the teachers in STEM through exposure to modern engineering tools and technologies; (3) foster collaboration and networking possibilities through interaction with real-world engineering industry, government and not-for-profit project mentors; (4) provide teachers with a greater understanding of the social relevance of engineering; provide teachers with a better understanding of engineering careers; (5) develop and transfer inquiry based curriculum, innovative pedagogy and new engineering knowledge into STEM classroom activities; (6) facilitate the exchange of knowledge, ideas and concepts among team members; (7) enhance leadership opportunities for teachers through the program's professional development for STEM teachers component, including obtaining STEM credentials through on-going engagement with the DRSC; (8) foster long-term collaborative partnerships between K-12 STEM teachers, the university research community, local engineering professionals, and the DRSC through a substantial follow-up plan; and (9) empower teachers so that they will be more likely to provide K-12 students more learning experiences that incorporate engineering innovation and design.

Design Projects

For this six week summer experience, *Engineering and Innovation Design for STEM Teachers*, design teams were formed. The first cohort of teachers participated in the *Engineering Innovation and Design for STEM Teachers* program during the summer of 2011. During this pilot year the design teams were made up of two practicing teachers, one pre-service teacher, one engineering student, a faculty mentor and industry or community partner. Undergraduate and graduate engineering students were hired on a part-time basis to assist each team with their engineering design project. However, based on feedback provided after the pilot year, rising sophomore engineering students were added as full time members of the design teams for the 2012 cohort. The rationale for choosing rising sophomores was that these students had recently completed their first year engineering innovation course, the course that was used as a model in developing this program, the summer between their first and second years of study was one in which these engineering students would likely not have competing opportunities such as co-ops and internships and because it was believed that the summer experience would provide an important professional development for these early career engineering students. Over the course of the two summers, twenty teachers participated in the program representing 14 different schools that included parochial, inner city, alternative charter schools, rural public, a regional career technology center and suburban public schools. Faculty mentors and engineering student participants represented mechanical, chemical, civil, electrical and engineering technology departments.

The first week of the summer experience was used to introduce the participants to concepts of innovation and the engineering design process through inquiry and project based learning. In this introductory project, the teams were guided through the process of ideation and brainstorming, product research and conceptual design, decision analysis and embodiment design, final design, prototype building and testing, product redesign, and project reporting and presentation. The project teams received critical feedback from their faculty mentors, teammates and peers throughout the entire process. For the 2011 cohort this introductory project involved designing, building and testing a table capable of holding 400 lbs that was constructed out of cardboard and glue sticks. The 2012 cohort was challenged with designing, building and testing a prosthetic leg for a Haitian child amputee. The impact of this experience is demonstrated by the fact that several of the participating educators implemented modified versions of these projects in their classes.

After completing the initial design project, the teams were introduced to their industrial mentors or community partners who provided the details of the project that they would work on for the remaining five weeks. Many of the industrial mentors and community partners found the experience to be both enjoyable and beneficial to their organization. As such, many of the organizations sponsored a project for both the 2011 and 2012 cohorts. The five projects that were facilitated during pilot year, 2011, included: (1) design of LED lights to grow algae for bio-fuel applications (industry mentor – Algaeventure); (2) design of calibration tables for force measuring sensors (industry mentor- Bertec Corporation); (3) design of a vision RL power/status indicator system (industry mentor – Persistent Surveillance Systems, Inc.); (4) sustainable energy solutions for the homeless (community partner – St. Vincent DePaul); (5) sustainable water collection and conveyance system for a community garden (Community Partner –Five River MetroParks Community Gardens Program). The five projects that were facilitated during the second year, 2012, included: (1) solar PV laptop charging station for the developing world (Community partner – Dayton Service Engineering Collaborative); (2) portable balance plate kit for assessing concussions of athletes (industry mentor- Bertec Corporation); (3) design of a vision RL power/status indicator system – continued from previous year (industry mentor – Persistent Surveillance Systems, Inc.); (4) low cost resource conservation (industry partner – Capacity Engineering); (5) sustainable water collection and conveyance system for a community garden – additional location (Community Partner –Five River MetroParks Community Gardens Program).

During the six week RET experience, all of the teams toured each of the industry mentors' facilities and community partners' sites. Some of the teams arranged additional tours as part of the product research process. Additionally, the teams were given access to university library resources and provided guidance in using these resources from the library liaison. Teams were also provided with tools and techniques for effective ideation and brainstorming sessions. Most of the teams were in close contact with their industry sponsor or community partner throughout the design process, receiving feedback and ideas related to their designs. The faculty mentors met and worked with their teams frequently throughout the six-week program. Prototype testing was conducted in the laboratory under the guidance of the faculty mentors with assistance from their engineering student. A technical editor provided guidance and feedback on the project reports. On the last day of the program, the teams participated in a Design Symposium where each team gave a 45 minute presentation on their design projects. The campus community, school representatives, community partners and industrial sponsors were invited to this event.

Curriculum Development

To ensure that the teachers would be able to bring their RET experience back to the classroom, each team was required to write curriculum for one unit of instruction. The teachers and pre-service teachers, with input from engineering students and guidance from their faculty mentors and a curriculum development coordinator, developed and wrote inquiry based STEM curriculum that focused on engineering design and innovation and aligned with grade band level appropriate academic content standards. To facilitate this, the teams were guided through the curriculum development process using a methodology developed by the DRSC through the STEM Fellows Program.[31] The DRSC supports PK-12 STEM education both regionally and nationally by training and supporting educators, designing, piloting and disseminating curriculum aligned to state and common core standards and workforce needs, training school leaders at the district and building levels and supporting schools and program models committed to STEM teaching and learning. In particular, the DRSC STEM Fellow program brings practicing STEM professionals, PK-12 teachers and university faculty to work together on teams in a well structured environment to support STEM education through the development of curriculum aligned to the academic content standards.

The model used by the DRSC was strategically condensed in order to support the NSF-RET six week program. Efforts were made to ensure that the condensed process did not compromise the quality of the curriculum developed. In particular, efforts were made to ensure the curriculum that was developed was uniquely innovative, mapped to academic content standards and achieved high levels of performance on the SQF. This was accomplished in five interactive sessions. Time between sessions was used by the participants to continue curriculum production.

The first interactive session served as an intensive professional development session in which the teams explored varying levels of inquiry in relationship to the integrity of academic content and quality of the cognitive tasks for multiple scenarios. After initial inquiry discussion, the SQF and the ten components were introduced to participants. The facilitator then discussed previous inquiry scenarios in regards to each component of the SQF. Potential curriculum interventions were discussed in regards to boasting the SQF scoring for each scenario. The teams were then introduced to the curriculum timeline and general expectations of the curriculum. The expectation was that teams would develop a unit of STEM instruction that emphasized innovation, the engineering design process, and career connections that linked to the engineering innovation experience they gained through the RET. The teams were to use the curriculum planning guide and tool designed by the DRSC to generate their unit of instruction.

Session two was used to introduce the SQF based writing template and critical components of this template such as the enduring understandings, essential questions, assessment plan, STEM career connection, and technical brief. The template was created to ensure consistency in formatting, quality and pedagogical information across all generated curriculum. Additionally, the template was created to serve as a professional development tool for the writers. As such, it provided background and content knowledge necessary for properly completing each section as well as additional resources in the form of hyperlinks and references.

The third session focused on quality rubric generation based on the research of Marzano and Brown and Arter and Chappuis.[33, 34] The goal of the session was to equip team members with an understanding of generating a four point rubric for their curriculum. Participants were provided guidance on what their curriculum rubrics were to assess as well as reference material on creating quality rubrics, and general objective/measurable vocabulary. Days later the curriculum was submitted to the Principal Investigator for a technical review.

By the fourth session, the curriculum was nearly complete. The facilitator used this session to aid the teams in assessing their curriculum in regards to the ten components of the SQF. Team members were equipped with an accompanying SQF realignment worksheet and then tasked with using "written" evidence within the curriculum to support the level of proficiency of each component. Through this process, the teams proposed slight modifications to their curriculum that would provide a richer learning experience for the students in regards to the ten SQF components. This curriculum realignment step provided the teams with the opportunity to reflect on the written communication and documentation of the learning experience they envisioned for their students.

The final session was used to provide final feedback on the curriculum and to allow the teams to address any issues with their lessons. During a Curriculum Sharing Day, each team had the opportunity to present the curriculum they developed to the rest of the participants and invited guests. Each team was required to provide an overview of their lesson and then facilitate a short sample hands-on activity. A question and answer period was facilitated at the end of each teams' presentations which provided the audience an opportunity to provide feedback and give ideas to the presenting team. The curriculum developed through this experience was then subjected to a vetting, editing and piloting process. A majority of the curriculum developed during the summer of 2011 has been piloted and published on the DRSC website.[31] The curriculum developed during the summer of 2012 is undergoing the piloting and editing process and will be published on this website in the summer of 2013. As a result of this program, ten curricular units that target academic content standards in grades ranging from 4-12 have been developed. A majority of these units include multiple lessons. Upon completion of the six-week experience, RET teachers were selected to either continue working on curriculum development through the DRSC STEM Fellow program or to pilot additional STEM lessons.

Program Assessment

The objectives of this program as listed above were assessed both qualitatively and quantitatively. Groups presented the STEM curriculum developed, the final prototype developed and provided regular guided reflections regarding their activities during the six week program. The qualitative data for both cohorts has been analyzed. Local System Change (LSC), Mathematics Teaching Efficacy and Beliefs Instrument (MTEBI) and Science Teaching Efficacy and Beliefs Instrument (STEBI) surveys were administered as pre and post assessments to identify changes in attitude and beliefs. Additionally, the in-service participants were required to implement one of the STEM curriculum units in their classrooms. Student pre and post unit assessments were used to determine the average content gained for students of participating teachers.

Qualitative results were gathered for both cohorts of NSF-RET participants. All cohort one (2011) and cohort two (2012) participants created and presented STEM curriculum designs at the conclusion of the program as described above. During the follow-up year, the external evaluator conducted classroom observations and teacher interviews which provided specific examples of the transfer of summer activities to classroom activities. Participants named new knowledge and STEM interest regarding spatial visualization skills, decision making matrix, engineering design process, awareness of ethics and engineering, conservation methods, green technology, and engineering design process, to name a few. The program was also successful at enhancing the participants' understanding of the social relevance and historical impact of engineering inventions. All curriculum designed through the summer program included the social relevance and history of engineering as elements.

Participants listed more than 20 engineering careers that were new to them: Materials Engineering and Creativity and Innovation, Electrical Engineer, Industrial Engineer, Green and alternative energy research being a few. Participants indicated that group work provided an appreciation for skillsets needed to work in teams. Many cited the importance of diversity within the group. All indicated plans to share the team work skills development process with students in their classrooms. Classroom observations to date have confirmed that team work skills are being reinforced in the K12 classrooms.

Although not a specific objective of this program, qualitative results were gathered to assess the impact that this program had on the participating engineering students for Year 2. During the first year of this grant, the engineering students for each team were juniors, seniors and graduate students who worked with the teams on a part time basis. These students had other obligations such as class, work or lab responsibilities not related to the NSF-RET projects. Recommendations from Year 1 faculty mentors and participants included having the engineering student team member involved daily during the entire six week summer experience.

In response to this suggestion, first year students from the Engineering Innovation class were recruited for Year 2. The NSF-RET summer experience was designed based on the Engineering Innovation class. From the first day brainstorming/team effort, informal observations of team activities indicated that the engineering students were leaders for their teams. As the teams evolved, the leadership qualities became more apparent. It appeared that an unintended consequence for the engineering students in the NSF-RET experience was the development or enhancement of leadership skills. For that reason, it was decided to investigate the attitudes and beliefs of the engineering students regarding their participation and perceived benefits of participating in the program. A focus group was conducted two days before the summer experience ended. The focus group was recorded and transcribed. Results of this focus group confirmed that the experience did provide leadership opportunities for the engineering students, helped them to develop closer relationships with professors, helped them to understand the importance of diversity for innovation and teamwork, having the opportunity to teach teachers about engineering and to participate in the curriculum development process.

Quantitative results for cohort one (2011) in the form of pre and post data are included in this paper. The pre and post K12 student content assessment data for cohort two is still being collected. The post Local Systemic Change (LSC) surveys and the post Mathematics/Science Teaching Efficacy and Beliefs Instrument (MTEBI/STEBI) surveys for the second cohort have not been collected at this date. The Local Systemic Change (LSC) teacher questionnaire was developed in 2000 through an NSF funded contract with Horizon Research Incorporated. The intent was to develop instrumentation to track systemic change in teachers' attitudes and perceptions regarding their mathematics and/or science content preparedness, pedagogical preparedness, classroom practices, and principal support for math and science teaching. Expert reviews established the validity of the instrument.[35] The questionnaire contains 29 questions, all of which have from four to 24 sub-questions. Respondents have a choice of five Likert style choices of Strongly Disagree to Strongly Agree; or four Likert choices of Not adequately Prepared to Very well prepared or four Likert choices of Not important to Very important. The items on the questionnaire were combined into composite variables through factor analysis to provide more reliable estimates of teachers' preparedness and classroom practices.[35]

The composites of interest for this study were:

- Perceptions of pedagogical preparedness;
- Perceptions of mathematics/science content preparedness;
- Use of traditional teaching practices;

- Use of practices that foster an investigative culture;
- Use of investigative teaching practices;
- Perceptions of principal support

Internal reliability estimates for these composites have been calculated using Cronbach's alpha and are in the acceptable to very good range (.67 - .76 , p. < .05).[35]

Respondents completed the questionnaires the first day of the workshop and three to six months later, after having returned to the classroom. For the first cohort, six of the participants completed both the pre and the post questionnaire. For the composite regarding teacher perceptions of mathematics/science content preparedness, complete data was available for five participants. Using the respondents' total scores (ordinal data) for each composite, the Wilcoxon Rank Sum tests results indicated no significant differences in pre and post responses. Different from the total score, the composite score for each respondent is the percent of total points possible for a composite. For example, if a composite consists of five questions, each with a choice of four Likert responses, the composite score is calculated by totaling the responses to the five questions and dividing by 20. Using a paired *t* test with the five respondents' composite scores (ratio data), the composite related to respondents' perceptions of mathematics/science content preparedness was significantly higher in the post questionnaire administration ($t = -1.76$, $n = 5$. $p = .08$). The significance should be viewed with caution due to the small sample size. The sample size prevents confirmation that the distributions are normal, an assumption for the *t* test. The reason the questionable result is presented here is because it is the only composite that may be significantly different post program. There are many factors that could have contributed to the increase; the professional development experience could be one of those factors. Analyses from future summer programs may confirm or weaken this finding.

The STEBI-A instrument measures personal science teaching self-efficacy (PSTE) and science teaching outcome expectancy (STOE) for in-service science teachers. The instrument was developed based on Bandura's theory of social learning.[36] The theory posits that people are motivated to perform an action if the outcome expectation (STOE) is high and they believe they can perform the action successfully (PSTE). In other words, if teachers believe their teaching will contribute to greater student achievement and if they have the confidence they can teach effectively, they are more motivated to invest time in developing engaging lessons. Given that the professional development was designed to increase participants' skills and awareness of Engineering Innovation and Design, the STEBI-A was used to collect participants' baseline belief and attitudes about teaching science. Administration of STEBI-A to participants after returning to the classroom allowed any changes in beliefs and attitudes to be measured.

The STEBI-A contains 25 items measuring the two scales (PSTE and STOE). Items such as, "I will typically be able to answer students' science questions," are presented with five options of agreement or disagreement ranging from strongly agree to strongly disagree. An overall average over the 25 items provides a measure of participants' self-efficacy beliefs. The PSTE construct includes 13 of the questions; the STOE construct includes 12. The reliability of the PSTE construct is calculated at 0.90; for STOE, 0.76; the internal validity was re-evaluated in 2004 and determined to be strong.

For the first summer cohort, nine in-service teachers completed the STEBI-A before the professional development began. (There was only one Math Only participant). Participants were asked to complete the STEBI-A again three to five months after the professional development ended. Six cohort one teachers completed the post-program STEBI-A. For the second summer cohort, a total of 12 participants completed the pre STEBI/MTEBI; post STEBI survey results are not yet available.

Descriptive statistics are presented in Table 2 and 3.

Table 2. STEBI-A Average Values from 2011 Summer Professional Development

	N	**Overall**	**PSTE**	**STOE**
Pre-test	9	3.03 (1.32)	2.74 (1.49)	3.41 (0.93)
Post-Test	6	3.11 (1.32)	2.70 (1.45)	3.68 (0.83)

*One of the 10 in-service teacher participants only taught math.
**Standard deviation provided in parenthesis

Table 3. STEBI-A Average Values from 2012 Summer Professional Development

	N	**Overall**	**PSTE**	**STOE**
Pre-test				
Math	4		3.3(1.6)	2.2(.81)
Science	8		3.2(1.4)	2.4(1.0)

**Standard deviation provided in parenthesis*

For the six participants in the 2011 cohort for whom pre and post STEBI scores were available, a Wilcoxon Rank Sum test using the respondents total scores indicated the increase in overall scores of Science Teaching Efficacy and Belief was significant at the .05 level, W (pre-n=5, post-n = 5) = -17, p = .05. This means that overall, the participants increased their self-efficacy and beliefs regarding their science teaching. A Wilcoxon Rank Sum test using total scores indicated the increase in STOE scores was significant, W (pre-n = 6, post-n = 6) = -17, p = .05. This means that the participants have a greater confidence that their science teaching will have positive outcomes. There are many factors that could have contributed to the increase in overall STEBI scores and specifically STOE; the professional development experience could be one of those factors. There was one participant from the 2011 cohort who only taught math at the high school level. There was no change in that participant's MTEBI pre and post scores.

Participants developed STEM curriculum that reflected the program's team-based engineering design and innovation activities. The curriculum is available on the DRSC database for K12 STEM curriculum. Involvement with DRSC as STEM Fellows or Ambassadors during the follow-up year includes implementing at least one of the DRSC STEM projects within the participant's classroom.

Quantitative data was also gathered to assess the impact of the RET experience and the curriculum developed through this program on the K-12 students. The participants' student scores were used to calculate a normalized gain by dividing the amount gained by the difference between the total possible score and the pretest score (Amount Gained/(Total possible – Pretest Score). According to Hake (1998), normalized gains are in three categories: "high" for a normalized gain greater than 0.7, "medium" between 0.3 and 0.7, and "low" below 0.3.[38] Pre and post content tests were given to students of the 2011 participants. The grade levels represented from this data include kindergarten, fourth, and seventh grades. The normalized gain was found to be between 0.6 and 0.8, which is considered medium to medium high.[38] Although this data is preliminary, it suggests that student learning is enhanced by teacher participation in this program and the curriculum developed through this program. Student gains will continue to be assessed for this program for the 2012 cohort.

Summary

The pilot year for the *Engineering and Innovation Design for STEM Teachers* provided an integrated and real world engineering design and innovation experience for ten in-service and five pre-service teachers. Teams were developed to include the in-service and pre-service teachers, an engineering student, faculty mentor and industrial mentor or community partner. The teams were guided through the process of ideation and brainstorming, product research and conceptual design, decision analysis and embodiment design, final design, prototype building and testing, product redesign, and project reporting and presentation for a short term introductory project as well as a more significant industry or service innovation project. Additionally, the teams worked collaboratively to develop inquiry-based and innovation centered curriculum. The experience was enhanced by field trips, lectures, and significant follow-on activities.

Qualitative data suggest that the pilot program was successful at developing collaborative relationships with university faculty and students, other teachers, engineering professionals and community service representatives. Program participants also attained new content knowledge regarding engineering and engineering design as well as exposure to numerous modern engineering technologies and techniques and careers. The program was also successful at enhancing the participants' understanding of the social relevance and historical impact of engineering inventions. Through this program, five inquiry based curriculum that aligns with state standards and are centered around an engineering innovation project were developed and piloted and will be published on the DRSC website for wide distribution. Additionally, the participants gained a better understanding of team work and group dynamics which should aid them in facilitating team based activities in the classroom. An unintended consequence of this program was a beneficial professional development experience for the rising sophomore engineering students who participated as full team members during the 2012 cohort. These students experienced leadership, networking and greater understanding of effective teamwork through this experience.

Although the quantitative data for cohort two is still being gathered and assessed and the sample size is too small to determine the significance of change, initial data from cohort one suggests that the teachers gained confidence through their participation in this program that their science teaching will have positive outcomes. Assessment of the pre-service teachers suggested that they came into the program with a high level of self-efficacy regarding teaching science as inquiry. Preliminary data from pre and post content tests suggests that the experience and curriculum is effective at positively impacting student learning.

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