
GC 2012-5625: HIGH SCHOOL TEACHERS ENGINEERING EDUCATION PROFESSIONAL DEVELOPMENT: FOUNDATIONS FOR ATTRACTING AND ENGAGING FUTURE ENGINEERS

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Dr. Christina White completed her Doctoral degree from Teachers College, Columbia University where she studied engineering education. She is the founding director of the National Academy of Engineering Longhorn Grand Challenges Scholars & K12 Partners Program at The University of Texas at Austin. Dr. White is also the director of an outreach program called Design, Technology, & Engineering for All Children (DTEACH) which has reached more than 1000 teachers and 85,000 students. She is the lead inventor on a patent for assistive technology. As an international engineering educator, her current research includes innovative design-based pedagogy, humanitarian engineering, and ways to attract and retain traditionally underrepresented groups in engineering education.

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Joules Webb has a passion and expertise for STEM Education gained through over twenty years of experience serving in both education and industry. In education, she has served as a Texas high school science teacher and campus instructional technologist, a science teacher instructional coach, and currently as a STEM Educational Specialist with Transformation 2013 Texas STEM (T-STEM) Center. She is also a doctoral student pursuing a PhD in Integrative STEM Education through Virginia Tech. She served on the Texas Education Agency (TEA) T-STEM Academy Blueprint design committee. She brings a depth and breadth of STEM education knowledge to the community. As an influential member of the T-STEM Network, she leads STEM professional development design teams, campus instructional coaching programs, and provides STEM technical assistance to district leadership. As a STEM specialist, Joules facilitates K-12 mathematics and science educators' understanding of Design/Engineering/Technology as context for teaching of STEM concepts, including the content required by the Texas Essential Knowledge and Skills (TEKS) standards. Specifically, the design and implementation of innovative interdisciplinary curriculum framed within the National Academy of Engineering's (NAE) identified Grand Challenges of the 21st Century. Curriculum development and implementation is based on scientifically-based models of professional development focusing on best practices, curriculum alignment, project-based learning, design-based learning and instructional coaching support to foster implementation of lessons learned. Equitable access to rigorous content for all students while meeting the mandates of state curriculum standards is a major goal of Joules' work. She supports the development of regional, state, and national STEM innovation networks to stay current with curriculum trends, instruction, technology, assessment, and school systems. Prior to her educational career, she was employed as a chemist in industry which affords her the opportunity to bring the workforce perspective to the education workplace.

High School Teachers Engineering Education Professional Development: Foundations for Attracting and Engaging Future Engineers

Abstract

Increasing engineering awareness and STEM literacy in the Louisiana K-12 community is a regional commitment led by the College of Engineering at Louisiana State University (LSU). LSU's annual High School Teacher Engineering Awareness Program (HSTEAP), a one-week intensive professional development institute, aims to improve and support high school STEM education. This mixed-methods study measures the impact of this professional development for mathematics and science teachers' efficacy in engineering, design-based learning, STEM research and technology, and their ability to teach those principles to their students. Program organizers and curricula professionals developed an innovative curriculum thematically addressing the *National Academy of Engineering 21st Century Engineering Grand Challenges*, and facilitated the HSTEAP community to: a) create and implement engineering design-based projects, b) identify and frame engineering learning within the STATE Department of Education standards for science and mathematics teaching, and c) thoughtfully incorporate team-building and 21st century skill development into their curriculum and teaching. In this paper, the constructs of high school STEM teaching and learning are shown, the critical interworking of our multi-disciplinary and inter-institutional team are discussed, results of a successful design curricula and professional development are presented, and a model is offered for the future ambitions and visions of pre-engineering education.

Introduction

The National Academy of Engineering (NAE) and the US government call upon the K-16 community to develop a strong interdisciplinary expertise and workforce to address and solve the *NAE 21st Century Engineering Grand Challenges*. Scholars and civil leaders laud the notion of improved and integrated science, technology, engineering and mathematics (STEM) learning as goals for a successful society. In response, the High School Teacher Engineering Awareness Program (HSTEAP) administrative team developed and implemented a design-based, standards-based, active learning experience to engage high school mathematics and science teachers in critical thinking and STEM literacy practices and guide them towards fostering integrative STEM learning.

Creation of this professional development and education resource hails from across disciplines and institutions in an effort to design curricula to meet the complex needs of the local and global society starting with high school STEM education. We believe that contextualization of design within the framework of global goals provides the learning communities with opportunities to understand that anyone with an engineering education can be a change agent for society. This professional development program, curricula, and support network developed by the administrative team strives to meet the dynamic and multifaceted needs of high school students by integrating design-based learning through the context of the *NAE 21st Century Engineering Grand Challenges*.

Participants

A total of 29 teachers participated in the program. During the one-week HSTEAP professional development, mathematics and science teachers from the same high school are paired together. By having the teachers work in pairs, they are able to connect across their disciplines and plan for ways to enhance their school support system through their partnership. The participants for the second year program were recruited through various media, organizations and agencies, including the Office for Diversity Programs, The Cain Center, Louisiana's Science Teachers Association, Louisiana's Association of Teachers of Mathematics, listserves, websites and by direct mail to high schools in Louisiana.

Ten high school mathematics and science teacher pairs and one single applicant were chosen and participated solely in the 2011 HSTEAP. An additional four pairs, participants selected from a six-week, National Science Foundation RET program, experienced HSTEAP as their inaugural week providing the foundation for development of engineering lessons during and after their subsequent five weeks of work in research laboratories. Each pair was chosen based on certification level, current school assignment, number of years teaching, previous professional development workshops attended, and responses to essay questions.

Curriculum and Teaching Design Team

HSTEAP 2011 facilitators chosen to design and lead the program were brought back from the prior year and integrated lessons learned from the first iteration to refine and enhance the teacher professional development experience. Their role, in collaboration with LSU, was to hone the previous iteration of the week-long curriculum and professional development experience for explicit alignment with the LA state mathematics and science standards. The lead facilitators were also responsible for presenting the curriculum to the teachers, modeling how to incorporate Louisiana standards and 21st century skills through engineering design-based pedagogy.

The program was lead by Dr. Christina White of the University of Texas-Austin and Ms. Joules Webb of Transformation 2013 Texas STEM Center. Dr. White is a recent graduate of Columbia University. She is currently a visiting scholar, co-teacher and curriculum developer in the Department of Mechanical Engineering at UT-Austin. She is also the director, curriculum developer, and instructor with the DETEACH program. Ms. Webb is a doctoral student in Integrative STEM Education at Virginia Tech. She has over 13 years of service in public education in the state of Texas. Currently, Ms. Webb is a STEM Educational Specialist at Transformation 2013, a Texas STEM Center and brings expertise in leadership, coaching, curriculum development, and design-based learning.

To make this HSTEAP program comprehensive and successful, the administrative team was comprised of inter-institutional and multi-disciplinary personnel. Specifically, HSTEAP incorporated significant industry and higher education institutional support and resources into the program. Renowned professors from a variety of engineering and education disciplines from LSU contributed to the curriculum development and program implementation. Highlights of the program week included LSU professors guiding HSTEAP discussions, facility tours, and sharing current research projects with the teachers that directly connected to each of the different

curriculum modules. LSU students from the Office for Diversity Programs were close at hand to support the professional development and represent the strong network of scholars dedicated to HSTEAP and its participants.

The academic resources and network are substantially enhanced with committed industry partnerships. A highlight of the week was visiting the Marathon Oil refinery. The participants learned first-hand about the oil refining process and related career opportunities available to their students. They also toured the oil refinery and participated in an interactive lunch discussion with recent hires and current interns. The panel was comprised of traditionally underrepresented groups in engineering. The panel of recent hires and interns discussed the importance of mathematics and science in high school and the potential impact teachers have on their students' lives. The panel discussion was a turning point for some teachers because they were hearing the needs of their diverse students directly from recent high school graduates.

Rationale

Education policy reports, consumer media, policymakers and government organizations, all levels of educators, and the public in general resoundingly call for improved science, technology, engineering and mathematics (STEM) education. By improving STEM education, there is the potential to attract more and diverse types of students into becoming college-bound and career-ready. Currently, U.S. students are not attracted to STEM fields and are not prepared through our schools for advanced study and careers. The need for improved STEM education and motivation is particularly critical for female and minority students, where participation and achievement gaps between majority and minority and male and female students in STEM disciplines in higher education and careers persist. Providing STEM teacher professional development that integrates interdisciplinary curriculum through design-based learning, directly addresses this need for improved STEM education by providing teachers with the resources and pedagogy to their students, including female and minority students, to pursue STEM careers.

Signature pedagogies persist even if they are ineffective due to pedagogical inertia and teachers are likely to conduct their classroom instruction 'business as usual' unless intentional professional development targeting belief systems is implemented. Shulman points out educators most often model their own teaching after that which they received and students upon receiving this 'apprenticeship of observation' then develop the same habits in their own practice. The signature pedagogies are then passed from generation to generation, like an inherited genetic trait. Additionally, personal belief systems and knowledge base play a critical role in how teachers teach. According to Nespor, the affective and emotional nature of beliefs has a more profound effect on how teachers learn and how they apply what they learn than does research based knowledge or academic theory. Teachers must believe that there is a need to adopt a different instructional approach and 'buy-in' to design-based approach as an efficient and effective means of teaching standards-based mathematics and science.

Engineers require integrative education which supports the synthesis of knowledge, strong analytical skills, and a mindset of persistence, perseverance, creativity, imagination, ingenuity, problem definition, solution seeking, teamwork, and effective communication. It is precisely these types of learning experiences—targeting conceptual understanding of STEM topics and

21st century skills—that are emphasized during this professional development. The one-week workshop focuses on the meaning and importance of interdisciplinary STEM content, as well as the differences between each of the disciplines. The teachers discover how engineering can enhance all learning, the importance and value of engineering to society, and how to excite their diverse students to choose a world-changing career.

The world continues to face natural catastrophes. The widespread use of numerous media outlets and venues have brought these catastrophes into almost everyone’s living room, making them vividly real even though they may have occurred several thousand miles away. Because of the media coverage of catastrophes, students have gained a greater understanding of this natural phenomenon and the devastating impact these events have on our societies and communities. Engineering education and design experiences like the ones that are shared with teachers to take into their high schools can provide a sense of hope and urgency to be human rights advocates. The program provides innovative ways to directly impact high school students by engaging them in activities that lead to understanding that engineering is directly connected to three of the primary human needs: health, happiness, and safety. For example, purposely selected teams of students investigate ways to restore and improve infrastructure through creating sustainable structures, alternative energy, and designing green roofs. The design teams are formed through consideration of diversity based on personality types and learning preferences gauged on tools such as the Myers Briggs Personality Type Indicator, 6-Hats, and the Felder Solomon Index of Learning Styles. This consideration and discussion around diverse aspects in socially connecting with others adds a layer of complexity to the ways that students learn STEM and in the way that we face solving the *NAE 21st Century Engineering Grand Challenges*, which are notably linked to our interactions with the world’s citizens.

HSTEAP Professional Development Design and Curriculum

Upon assessment and reflection of prior years of HSTEAP professional development, LSU’s Office for Diversity Programs leveraged the strengths of the program and included new approaches to evolve the program to further enrich engineering education. Three priorities and strengths of Year (YR)1 and YR2 professional development and curriculum were to 1) excite and empower teachers and students through high quality, design- and project-based STEM education 2) attract diverse student populations to the STEM fields and expand the STEM pipeline, and 3) provide more opportunities for underrepresented groups to choose STEM fields and careers in the future.

The HSTEAP *(Re)New Orleans to Restore and Improve Urban Infrastructure* curriculum developed for HSTEAP provides strategies and rationales for teachers to find relevant mathematics and science Grade Level Expectations (GLEs)-alignment with engineering education. Indeed, an important aspect of the professional development was to expose and immerse mathematics and science high school educators in design-based pedagogy as a way to incorporate multiple standards in meaningful and authentic learning experiences. To address and contextualize these standards, the HSTEAP curriculum is framed within the *NAE 21st Century Engineering Grand Challenges* in conjunction with 21st century skill development. The teachers were introduced to and fully immersed in hands-on engineering design-based teaching and learning. This was accomplished through a blended model of project-based pedagogies.

The HSTEAP program’s mission is to work in tandem with the larger community in striving to improve the world’s health, safety, economy, and future through education. As a result, the team uses a wide angle lens to direct the development and implementation of the program. Figure 1 illustrates these guiding principles beginning with the United Nation’s *Education for All* Millennium Goal, and zooming in towards literacy for empowerment, closer towards the *NAE 21st Century Engineering Grand Challenges*, and then to the local education ontological beliefs about high school teaching and learning needs. The curriculum and instruction facilitate design experiences that directly relate to the *NAE Grand Challenges* by integrating inexpensive yet effective household materials, movies, novels, and museums (to name a few) as points of access into student learning through the design-based learning cycle (Fig. 2) based on the award-winning Design, Technology, & Engineering for All Children (DTEACH) program and method (Fig. 3).

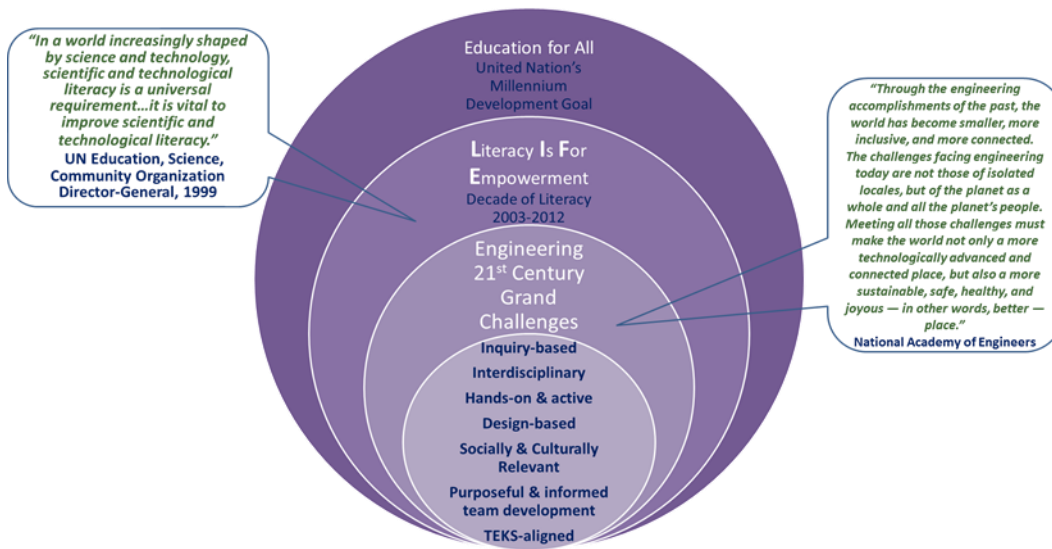


Figure 1. Framework of Curriculum Design for Design Curriculum

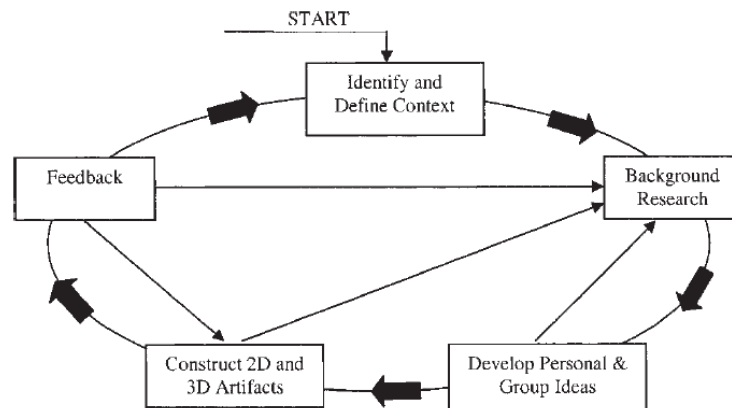


Figure 2. Design-based Learning Cycle



Figure 3. DTEACH Method

Through this intensive immersion, teachers become engineers and designers facing the Engineering Grand Challenges. Of particular relevance to Louisiana is the *NAE 21st Century Engineering Grand Challenge* to “Restore and Improve the Urban Infrastructure,” especially regarding natural disasters. Using the engineering design method, relevant standards, and the needs of their community, the teacher-participants learn and complete two engineering projects, ‘Strong, Sustainable Structures’ and ‘Bioreactor Design’ using everyday classroom items.

Participants are instructed in the use of engineering notebooks at the start of the HSTEAP and required to maintain a notebook throughout the experience. The kickoff of the program begins by framing the experience within the context of the *Grand Challenges*, introducing the teachers to society’s most pressing issues and the call for innovative engineering solutions. The entry event includes viewing a portion of the video ‘When the Levees Broke’ followed by discussions prompted through posing the questions ‘What roles does engineering play in natural disasters?’ and ‘What can be done to minimize destruction from future events?’. Participants are then introduced through a design brief to the first challenge and develop a list of ‘knows’ and ‘need to know’ that drives the instruction during the institute.

During a sustainable structures challenge, the teachers design and build an affordable community with innovative ideas for restoration, improvement, and sustainability through natural disasters. To inform their designs, we integrate Active Learning Products (ALPs) so that teachers experience a variety of hands-on instructional strategies to explore the concepts of load, bending, center of mass, and shape strength. An emphasis is placed on introducing and reinforcing academic STEM vocabulary and inquiry. Classroom research is conducted to meet the designed structures’ requirements of 1) use sustainable materials, 2) have low-carbon emissions footprint, and 3) achieve the ‘green ideals’ of energy efficient building. A variety of text-based and internet resources provided by the facilitators guide the teachers’ research. Through facilitated discussion, the participants define and assign community structures to teams for development. The community includes a state-of-the-art church, high school, police station, library, hospital, boutique, grocery store and model-home, all designed to survive hurricane winds and flood waters. The teacher teams construct a model, develop a rubric, and present their designs as a culminating experience.

During a bioreactor design challenge, the teachers collaborate to design a biofuel system for alternative fuel production. The challenge is introduced by a guest lecturer (Dr. Michael Benton, faculty member) and connected to research currently taking place at LSU followed by guided field trips to the campus research facilities. The instructional model described for the sustainable structures challenge is applied to the bioreactor design challenge to meet the designed bioreactor systems requirements of: 1) Characterize the organism(s) is/are used in the solution; 2) Explain the rationale behind selecting this particular organism; 3) Describe the growth requirements of the organism(s) used in your solution; 4) Identify and explain those parts of the system providing the necessary growth requirements; 5) Detail the characteristics of your technological system--the parts and how they work; 6) Provide an explanation of any/all mechanisms (sensors, etc,) used to monitor your system; and 7) Provide a rationale of why the system you designed is the best solution to the problem based on scientific and mathematical reasoning. The teachers presented their designs in a culminating Pecha-Kucha style presentation format.

Pedagogical Considerations

The curriculum design was guided using the Texas STEM panning tool for STEM project-based learning (Appendix 1) and considers the following instructional design elements:

Student Engagement

- Organizes activities around a driving question or challenge
- The complex, open-ended question or challenge provides a meaningful focus for student work
- Entry event is designed to capture student interest and prompts the inquiry process beginning with Knows, Needs-to-Know, and Next Steps

Focuses on Authentic Issues

- Students address problems and issues from *Engineering Grand Challenges of the 21st Century* and community needs
- Students complete tasks in a simulated or real STEM work environment in which they are working like STEM professionals
- Students are exposed to STEM careers
- Students collaborate with professionals beyond the classroom
- Includes an intentional instructional focus on helping students develop the interpersonal skills valued in real-world environment such as 21st Century Skills /Habits of Mind

Focuses on Significant Academic Content

- Students learn important knowledge and skills derived from standards
- Focuses on helping students acquire deep understanding of the ‘big idea’ or ‘foundational skill’ critical to their future learning
- Students integrate knowledge and skills from two or more of the STEM subject areas, at least one of which must be the ‘T’ or ‘E’ in STEM

Connections to Non-STEM Disciplines

- Connects STEM knowledge and skills with non-STEM disciplines
- Includes instructional support for quality performance in non-STEM Discipline (ex: Teaching/assessing quality technical writing)

Quality of the Cognitive Task

- Project requires students to use higher order thinking skills
- Students frame the problem, design the procedures, and make decisions that affect the course of the project
- Students ask further questions as they generate answers and solutions
- Students develop their solutions, evaluate the feasibility of their solutions, and defend their choices
- Students generate new answers and/or create unique products that address Challenge/Driving Question
- Students generate one or more possible solutions to the problem
- Students have opportunities to take significant responsibility and work independently from teacher

Application of the Engineering Design Process

- Students use the engineering design process to develop their project
- Students demonstrate thinking skills across multiple steps in the engineering design process
- Students experience the recursive nature of the process

Quality of Technology Integration

- Students use multiple technology tools and resources to enhance their capacity to complete tasks, solve problems, or manage projects

Nature of Formative Assessments

- Students use feedback to make choices to improve the quality of their work prior to the final submission of their products
- Students peer reflect to constructively critique each other's work in progress
- Students use feedback to request additional resources and instruction to meet their current individual and team needs
- Students provide feedback to teachers on assessments and learning activities which helps teachers improve the project quality

Nature of Summative Assessments

- Assessment requires students to demonstrate knowledge or skill through a performance-based task evaluated via a rubric
- Students work in formally structured teams with clearly defined expectations for team and individual accountability

Conclude with a Public Presentation/Exhibition

- Students present culminating products and defend them in detail and in depth by explaining their reasoning behind choices they made
- Students Respond to Content-and Process-Focused Questions
- Students present/exhibit to audiences from both within and outside the school in F2F and/or online formats

Project Reflection

- Students and the teacher engage in thoughtful, comprehensive reflection about what students learned and the project's design and management at key checkpoints and after the project's culmination

A mandatory component of the program is the participation of mathematics-science teacher pairs from a given high school to allow for the development of team teaching scenarios and the development of class exercises that cross- link the science and mathematics to engineering.

Every day, the teachers were introduced to teambuilding activities and team formation through individual results from the 6-Hats, ILS, and MBTI assessment tools. These three tools are used to understand and evaluate learning styles and communication preferences. The Felder-Soloman Index of Learning Styles is comprised of four dimensions (active/reflective, sensing/intuitive, visual/verbal, and sequential/global) (Figure 4). The Myers-Briggs Type Indicator (Figure 5) includes four dimensions: 1) introvert/extrovert, 2) sensing/intuition, 3) thinking/feeling, 4) judgment/perception. The 6-Hats models (figure 6) group thinking and is a detailed, cohesive way to assist teams in working together more efficiently. The tools that have been chosen continue to have significant advantages. These advantages include the availability, reproducibility, cost, and quantity of background research. The professional development tools are designed to meet a range of learning and communication styles and are used to form diverse teams based on individual's style. Particular approaches to teaching often favor a certain learning preference. Therefore it is important to incorporate a variety of teaching approaches and expose students to value of diversity in developing innovative solutions from multiple perspectives.

The end result of the latest learning styles collaboration, in addition to a useful online version of a learning style index, is a set of teaching techniques to help address all the learning styles present in any classroom. Even with varying opinions, there are numerous efforts to use the ideas of learning styles and communication approaches to further understand how students differ, how educators can reach all students, and how to enhance learning. It is our goal to increase approaches to understanding and forming teams that are diverse in a variety of areas and provide educators tools to use for classroom teach formation. By integrating these methods into team formation, students become metacognitive about ways that they learn and communicate. These teaming tools are aids in structuring diverse design teams that can learn to effectively work together.

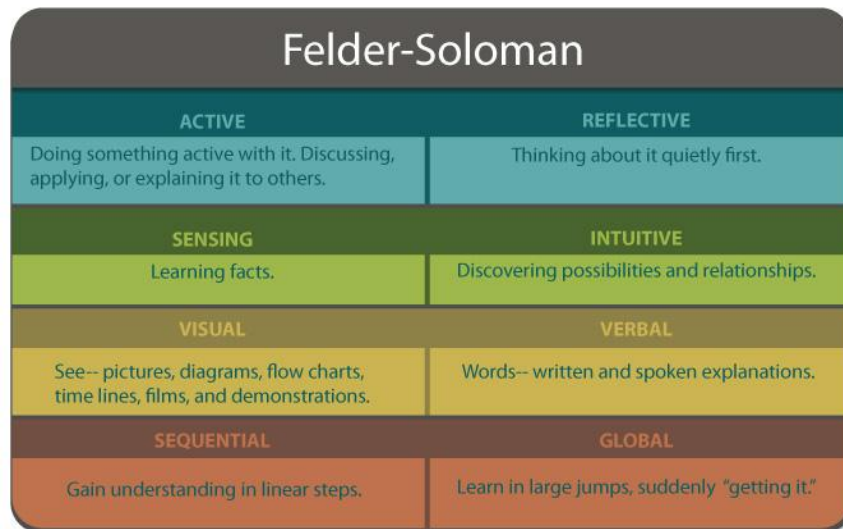


Figure 4. Felder-Soloman learning styles' categories.

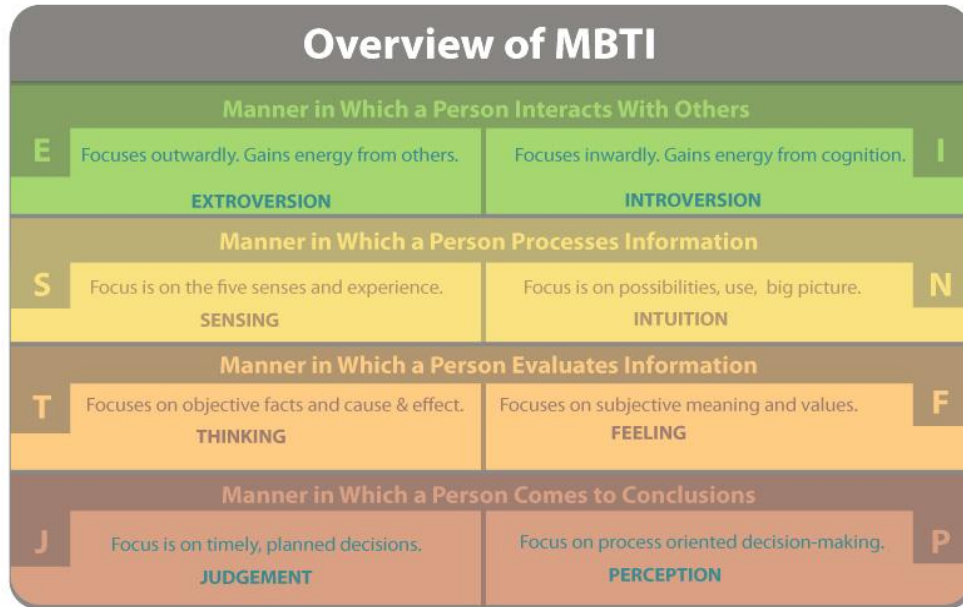


Figure 5. Overview of MBTI

<p style="text-align: center;">White Hat</p> <ul style="list-style-type: none"> I focus on objective facts. I enter into a discussion without preconceived ideas on a solution I seek to know that facts of a situation I seek to know the statistical evidence concerning a decision I try to think totally objectively about a situation I seek to differentiate between facts and opinions I am more interested in facts than opinions 	<p style="text-align: center;">Red Hat</p> <ul style="list-style-type: none"> My feelings sway my decisions I have good intuition I often have hunches about the best decision My personal opinions play a significant role in my decision making process I listen to my emotions when making decisions I am suspicious of other people's decision making process I think emotions should play a significant role in decision making
<p style="text-align: center;">Yellow Hat</p> <ul style="list-style-type: none"> I usually see the positive side of things I can often see the good parts of even a bad idea I am usually optimistic that a new idea will work I tend to see the valuable contributions in people's ideas I believe that most new ideas have significant value I usually "look on the bright side" of a problem My comments are usually positive and constructive 	<p style="text-align: center;">Black Hat</p> <ul style="list-style-type: none"> I can quickly see why an idea will not work I often can tell an idea will not work by judging from past experience I like to play the "devil's advocate" I can usually see the pitfalls in an idea I can readily detect poor logic in someone's argument I find it easy to be critical of other's ideas I am often pessimistic of others ideas
<p style="text-align: center;">Green Hat</p> <ul style="list-style-type: none"> I am creative I often generate new ways of thinking about a problem I easily think "outside of the box" I am good at finding new approaches to solving a problem I am constantly thinking of alternatives I am not likely to settle for the "status quo" I can easily generate new concepts 	<p style="text-align: center;">Blue Hat</p> <ul style="list-style-type: none"> I like to lead the problem solving process I tend to think as much about the problem solving process as the problem itself I focus on the big picture, summarize and draw conclusions I find myself trying to keep the group focused I tend to try to optimize the group problem solving process I often help the group clearly define the problem I often find myself orchestrating the group

Figure 6. 6-Hats categories

Evaluation

This mixed-methods study measures the impact of this professional development for teachers' efficacy in engineering, design-based learning, STEM research and technology, and their ability to teach those principles to their students. An external evaluator administered surveys at the beginning and end of the week-long institute to measure the change in intended classroom behavior. The categories of questions were 1) emphasis on goals and objectives, 2) teaching methods, 3) learning activities, 4) assessment, 5) teacher type, and 6) areas of growth. A Wilcoxon signed ranks test was used to calculate the number of teacher who showed significant gains on the content knowledge test. The W value was calculated as 4.71 ($p < .001$). All twenty-

nine teachers showed statistically significant gains. The average gain was 10.5 points on a 19 point test.

A survey was administered at the beginning and end of the week-long Institute to measure the change in intended classroom behavior. The largest change was observed in the emphasis that teacher intend to give to integrating the NAE 21st Century Engineering Grand Challenges into curriculum. Other categories that showed an increase in emphasis were 1) facilitating design-based learning, 2) integrating team formation strategies and community development tools, 3) increasing students' interest in the subject and in pursuing further study, and 4) integrating course curriculum with other subjects or fields of study.

The intention to use the following teaching methods increased slightly 1) student-led whole-group discussions or presentations, and 2) students doing design-based learning projects. The intention to use the following learning activities increased substantially 1) reflect on course material by writing in a journal, 2) use primary sources to investigate current issues or new developments in STEM, and 3) design or implement their own engineering challenge, scientific investigation, or mathematical theory of proof.

Many of the teachers said they intended to use different assessment methods more often. The highest changes were seen in 1) written explanations of through processes (e.g. journals), 2) Project- and design-based learning, 3) student portfolios, and 4) student presentations/projects. In the post test, teachers were asked, "To what extent has the week's activities changed how you feel the following statements describe the kind of teacher you are?" In all the categories, the teachers reported they were changed to a significant extent.

In the Pre-survey, the teachers were asked "In what areas would you most like to develop and grow in your teaching?" The responses were categorized and used to create the responses for a question in the post survey. The post-survey question was "In what areas have you developed or grown in your teaching as a result of the week's training?" The largest increases were seen in 1) project-based learning (PBL), 2) design-based projects, 3) how to increase the relevancy of lessons, 4) ways to increase group work.

Finally, the teachers were asked to rank the session and the facilitators. They strongly agreed that the facilitators were knowledgeable and have credibility and sessions were designed for adult learners, relevant to their teaching situation, and likely to have a positive and lasting impact on their classroom instruction. When asked how the sessions could be improved, many of the teachers said that nothing should be changed or the session should be longer. Other suggestions were to give more instructions with better communication before the workshop, to slow down, to present more projects for the classroom and more math hands-on activities, to allow more collaboration with the other participants, and to give more impression of preplanning.

The external evaluator used the Horizon Professional Development Observation Protocol to rate the quality and effectiveness of HSTEAP 2011 and the indications are as follows. Collaboration, respect for each person's ideas, and effective group work were observed. Facilitators mixed the groups for each major activity. Positive effect was predicted for 1) Participants' understanding of how students learn; 2) Participants' ability to plan/provide high quality mathematics/ science

classroom instruction; 3) Participants' ability to use the designated instructional materials to develop students' conceptual understanding. Overall this session got the highest ranking: Level 5: Exemplary Professional Development - Facilitation is skillful, and participants are highly engaged in purposeful work (e.g., investigations, discussions, presentations, reading) designed to deepen their understanding of important mathematics/science concepts; enhance their pedagogical skills and knowledge; increase their ability to use the designated instructional materials; or to enhance their leadership skills. The session is artfully implemented, with flexibility and responsiveness to participant needs/interests. The session is highly likely to enhance the capacity of participants to provide high quality mathematics/science education or to be effective leaders of mathematics/science education in the district(s).

Conclusion

The innovative curriculum framework developed provides a model for pre-engineering professional development programs targeting high school mathematics and science teachers. Key programmatic elements include 1) contextualization of mathematics and science subject content through *NAE 21st Century Engineering Grand Challenges*, 2) implementation using a design-based learning approach modeling multiple instructional strategies, 3) explicitly and repeatedly making the connection to the Louisiana Department of Education standards for science and mathematics, 4) inclusion of teambuilding and team formation strategies based on learning styles, and 5) meaningful industry-based experiences and interactions with higher education faculty. The collaborative nature of the program leveraging the multi-disciplinary and inter-institutional team are critical aspects resulting in the successful design curricula and professional development and is offered as a model for the future ambitions and visions of pre-engineering education.

Appendix 1

XXX STEM PBL OVERVIEW					
AUTHOR(S)/AFFILIATION					
PROJECT TITLE					
DURATION					
CONTENT ORGANIZATION					
REAL WORLD CONTEXT					
WORKFORCE CLUSTER					
CAREER CONNECTION(S)					
GENERAL SUBJECT		COURSE			
KEY CONCEPTS					
SETTING THE STAGE					
DRIVING QUESTION					
PROJECT ABSTRACT					
PROJECT LAUNCH/ENTRY EVENT					
PROJECT ASSESSMENT BLUEPRINT					
STANDARDS <small>XXX(T), STL(S), ELPS(E), CCRS(C), HABITS OF MIND(H), 21ST CENTURY SKILLS(21)</small>	MEASURABLE OBJECTIVES <small>(OBSERVABLE DEMONSTRATIONS OF STUDENT LEARNING)</small>	LEARNING ACTIVITIES <small>(NEEDED TO ACQUIRE KNOWLEDGE & SKILLS ADDRESSED IN PROJECT)</small>	FORMATIVE ASSESSMENT <small>(PROCESS THAT INFORMS INSTRUCTION)</small>	SUMMATIVE ASSESSMENT <small>(EVALUATES LEARNING)</small>	
STANDARD DESCRIPTION	CODE				
PROJECT RESOURCES NEEDED					
PERSONNEL					
INSTRUCTIONAL TECHNOLOGY					
MATERIALS					
FACILITIES					
BIBLIOGRAPHY					

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