
AC 2011-674: LONGITUDINAL EVALUATION OF PROJECT-BASED PROFESSIONAL DEVELOPMENT INSTITUTE: MIXED METHOD ASSESSMENT WITH MBTI TYPE CORRELATIONS

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Longitudinal Evaluation of Project-Based Professional Development Institute: Mixed Method Assessment with MBTI Types Correlations

Abstract

The Design Technology and Engineering for All Children (DTEACH) Professional Development Institute (PDI) at The University of Texas at Austin Cockrell School of Engineering seeks to provide K-12 teachers with engineering design pedagogy and design-based, project-based, hands-on activities for teaching applied mathematics and science. Over the past 18 years, more than 700 educators and 60,000 students have been impacted by the program, which features integration of engineering design challenges into other disciplines of learning from literature to science and mathematics to art. For the past 12 years, DTEACH has focused on teaching automation and control concepts with robotics as the medium. This paper describes an evaluation of recent modifications to the institute implementation and advancements in the design methodology. In particular, changes to the institute feature: (1) contextualization of the design problems within the 21st Century Engineering Grand Challenges; and (2) increased focus on the pedagogy of design-based teaching and learning. These changes were implemented in response to: (1) research that shows females and other traditionally underrepresented groups are more attracted to and interested in design challenges that have a relationship to broader impacts on humanity and (2) indications that participants need more insight into how engineering can be integrated into their classrooms.

A main goal of evaluating the evolution and impact of this program on STEM education is to understand the effect of the changes in content and approach in relation to the improved efficacy of the teachers. The evaluation is based on teachers' responses to daily surveys on the design-based/project-based aspects of the PDI. The evaluation also includes open-ended question assessment throughout the institute and end-of-institute assessment. The mixed-methods evaluation methodology includes correlation of responses with the Myers-Briggs Type Indicator (MBTI) personality types of the participants, which is used in the institute to help form design teams. Data for the 2010 institute were collected using the same instrument employed in the 2004 institute, allowing a longitudinal analysis of the effects of changes to the institute. The analysis indicates that the modifications to PDI have had meaningful impacts across MBTI personality types. The teachers, on average and across the all MBTI types, mostly agreed or totally agreed that the instruction and laboratory aspects of the PDI were relevant to them each day. Multiple teachers commented that they enjoyed the "tag-team" effort of multiple instructors with different specialties. Our results indicate that other PDI developers should consider the NAE Grand Challenges to provide context and relevance to their offerings.

1.0 Introduction

Now more than ever, there is a world-wide need for collaboration to make positive changes to solve major engineering challenges that must be addressed in order to maintain quality of life, national security, and a sustainable future¹. To address these issues, the National Academies of Science and Engineering along with many others agree that the USA needs to produce more engineers and scientists². Therefore, improvements to pre-engineering education are needed to attract more students to major in engineering. One program that has worked to improve Science, Technology, Engineering and Mathematics (STEM) education is Design Technology and Engineering for All Children (DTEACH) offered by The University of Texas at Austin. This program uses active learning with open-ended design projects to improve students' understanding of STEM concepts. This program focuses on assisting teachers and students with generating prototypes during open-ended design projects.

2.0 DTEACH through the years

For over eighteen years, the DTEACH Professional Development Institute (PDI) for K-12 teachers has sought to enhance STEM concepts with active learning techniques^{3,4}. This program has engaged over 700 teachers in engineering design problem-solving processes to help students learn mathematics and science concepts. The DTEACH PDI is offered through the Cockrell School of Engineering at The University of Texas at Austin. The program provides guidance to K-12 teachers on how to use open-ended problems in their classrooms. The institute teaches engineering concepts through the use of everyday technology, directed laboratory activities, and design briefs. Since 1998 DTEACH has used LEGO MINDSTORMS robotics as the focus for hands-on experiences. The program has its roots in engineering design theory and learning methodology research. To clearly demonstrate the effectiveness of this teaching approach, the entire program is taught using the methods the participants are expected to use in their classrooms. The DTEACH website (<http://web.engr.utexas.edu/dteach/>) provides copies of past DTEACH PDI curriculum documents and other content resources.

2.1 Participants

The DTEACH program has been working with educators and students in central Texas for over eighteen years. More than 700 educators and over 60,000 students have been impacted by the DTEACH program. The teachers and students come from broad spectrum of school districts, socially economic classes, races, ages and urbanization. While teachers of all grade levels have enrolled in the DTEACH, the majority of the participants have been K-8 teachers.

2.2 Why Robotics?

Robotics technology has been shown to be an effective means of engaging students in meaningful design activities. In a recent study of a summer program using LEGO MINDSTORMS robotics, 10- to 13-year old students built submersible boats over 3.5

hours at a summer camp⁵. Many students let the materials drive their progress and engaged in trial and error designs, becoming frustrated during the process. Some students stayed within the problem but spent time planning and were able to generate designs. Some students spent time planning and worked towards extravagant designs, and were driven by creating designs that somehow outperformed others' designs. One student spent too much time in planning and was not able to engage in the evaluation aspects of design. Many students completed only two aspects of the design process and then proceeded to play with their designs⁵. This is construed as a negative, but has been used to promote redesign with younger children, whose play may be leveraged as an evaluation phase; students would interrupt their play when their design had a structural failure or to accommodate changes in the storyline of their play⁶. In other words, robotics “play” offers multiple teaching and learning opportunities.

2.3 DTEACH Method

The engineering design process provides the foundation for the curriculum and teaching in the PDI. The DTEACH teaching model is based on the Kolb Learning Cycle⁷ of experiential learning and Bloom's Taxonomy⁸. These learning models have been embodied in the DTEACH Method (hands-on technology exploration, interactive discussions, exploratory labs, open-ended design problems, and project reporting process). Figure 1 shows a visualization of the DTEACH Method, which is analogous to the 5 E Learning Cycle model: Engage, Explore, Explain, Elaborate and Evaluate.

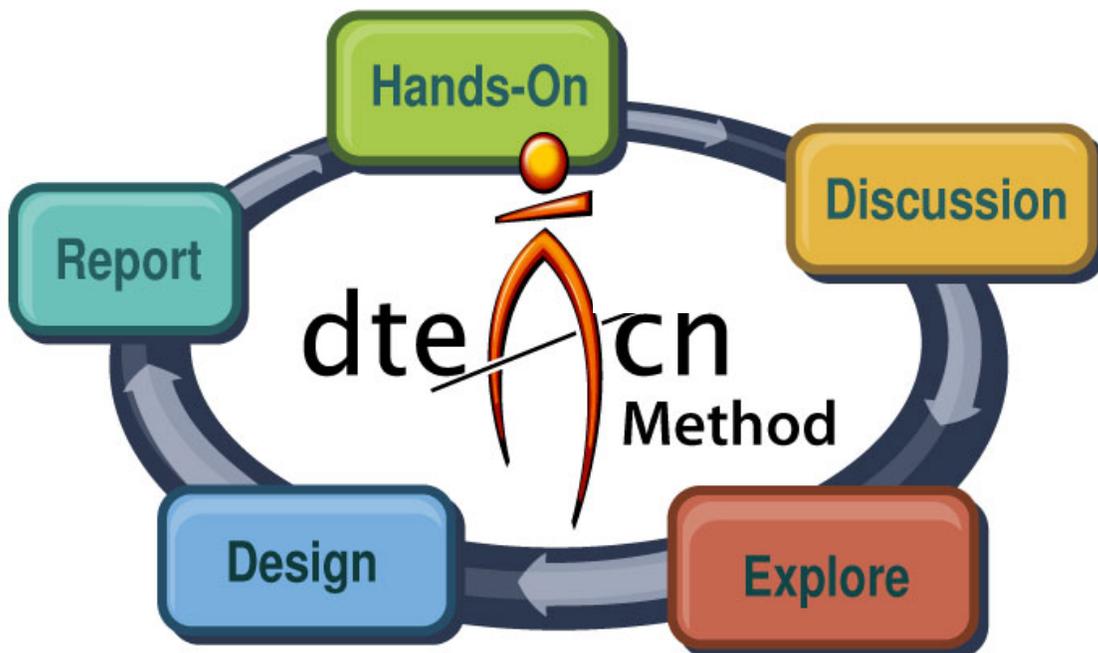


Figure 1: DTEACH Method

The DTEACH PDI is structured according to this model so that the participants experience this method of teaching. In a 2007 survey of teachers who completed a DTEACH PDI between 2000 and 2007, 60 percent of respondents reported that they

routinely use the full DTEACH Method in their classroom⁹. Additionally, more than 90 percent of respondents agreed with each of these statements: “I feel that hands-on activities make it easier for my students to learn new topics” and “I bring real world product examples into my classroom to help me teach a concept.”

2.4 Program Evolution

Throughout human history, imagination has come to fruition through engineering, which has driven immense advances in civilization. These advances can be seen with significant engineering feats that drastically changed societies – ships that created innovative channels for trade and travel; sanitation systems for improved health and quality of life; widespread development and distribution of electricity and water; automobiles and airplanes; telephones; computers; space exploration; and the Internet are but a few of the most notable.

Reflecting on the 20th century and looking forward in our first decade of the new millennium, the National Academy of Engineers (NAE) sought innovative ways to identify formidable challenges as the population grows and its needs and desires expand¹⁰. The NAE gathered a team of leading thinkers with a wide range of experiences who are dedicated to improving the quality of life around the globe. This team explored broad realms of human concern – sustainability, health, vulnerability, and joy of living – and generated 14 specific grand challenges that await engineering solutions, as shown in Figure 2.



Figure 2: 21st Century Engineering Grand Challenges¹⁰

The curriculum and pedagogy of DTEACH have evolved over the years to shift with the dynamic nature of engineering education. Our curriculum evolution now incorporates the 21st Century Engineering Grand Challenges as the framework for designs. Our most recent PDI (summer 2010) focused on the challenge of “Restore and Improve Urban Infrastructure.” We continue to develop curricula for other Grand Challenges.

Our curriculum evolution is inspired by the evolving needs of our students as global citizens in the 21st century. This new era calls for students to think differently so that they can effectively learn the skills necessary to be successful lifelong learners. These 21st century skills, such as critical thinking, problem solving, communication, and multiple literacy practices, are key components in our curriculum and are noted in the assessments by the DTEACH participants as important components to integrate into their teaching.

3.0 Mixed Methods Assessment

The assessment methods used in the program are a mixture of qualitative and quantitative measurements. This mixture of assessment methods was a blend of techniques from the education and engineering perspectives. The quantitative assessment was performed as a paper based survey at the end of each institute day. The qualitative assessment was administered as a variety of end of the day and end of course evaluations. The qualitative was created as integrated part of the program including end of the day and end of course feedback.

3.1 Qualitative

Qualitative data are important for evaluating our professional development and curriculum evolution so that we can hear from participants in their own words about their experiences and learning. We garnered qualitative feedback from the participants throughout the professional development in a variety of ways. DTEACH participants reflected on the content, scope, sequence, and pedagogy through multiple literacy practices including ‘Think & Tag’, ‘Parking Lots of Ideas & Inquiries’, ‘Shapes Reflections’, and an open-ended questions evaluation at the culmination of the institute. These qualitative data points are organized by themes that most strongly resonate across participants. Our analyses of the themes that emerge in the data are represented in detail below.

One of the most important items to measure is the ability for DTEACH participants to use the curriculum and professional development in their own teaching practices. In the qualitative data, they share specifically how our PDI and DTEACH Method will inform their teaching. To assess the effectiveness of our program, we prompted each of the DTEACH participants to consider how to effectively use this professional development in their own teaching. When responding to what each would add into their practice, the majority of the participants stated that all of the components of DTEACH will be implemented in their teaching, especially the DTEACH Method. Components of each part of the DTEACH Method were also specified in the qualitative data. Participants indicate that “design- and project-based learning” and the “Grand Challenges” contextualization

will be included in their future teaching experiences. They share that starting with “hands-on exploration”, for example “starting with the flashlight activity,” will be point of access to STEM that they can implement with their students. In teaching strategies, they specified “KWL charts, mindmaps, and Think & Tag” as forms of effective brainstorming, reporting, and reflection. Creating an educational environment that includes “centers, collaborative learning, laboratories, and modeling” is indicated in the data to be a key strategy that enhances engineering education. Providing “curriculum”, developing their “LEGO kit knowledge”, including “programming” pedagogy and exposure to “online LEGO and engineering resources” are all noted as important parts of this professional development that participants will use in their teaching.

One of the main components of the professional development and curriculum is the construction evolution. Our construction evolution is structured to develop building skills, design processes, and engineering concepts. To do this, we scaffolded the construction experiences as depicted in the seven construction descriptions in Figure 3. The pictures associated with the construction evolution capture the participants in action.

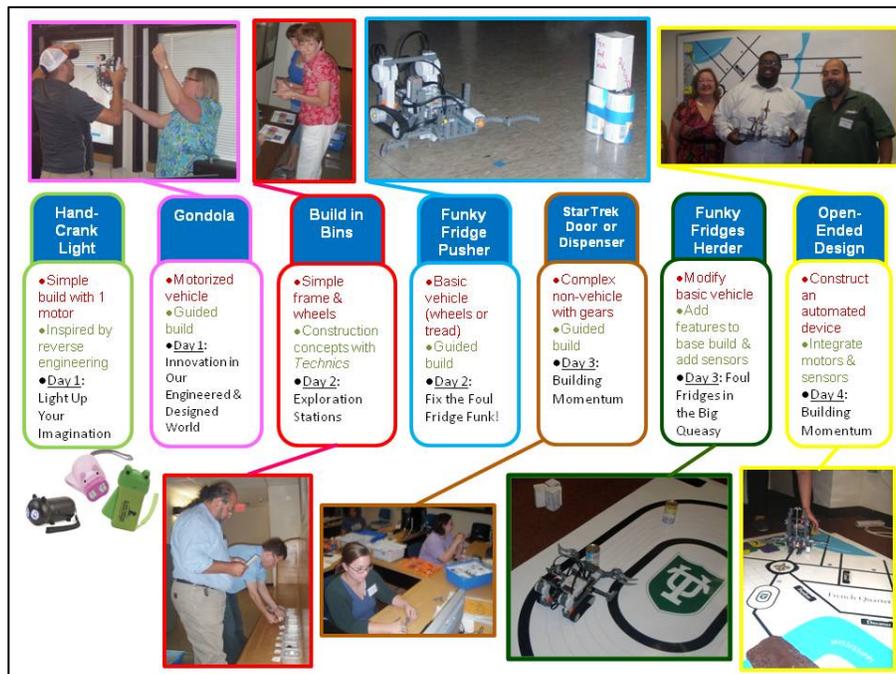


Figure 3: Construction Evolution

3.1.1 Comprehensive Construction of Construction in Our Curriculum

Our curriculum scaffolds construction challenges to provide opportunities for the range of novice to experienced builders. When stating which build was the most helpful, the majority of participants expressed that they find all of the builds helpful and one states, “I loved the building of the different structures and figuring out how they come together.” Participants identified with the social and global relevance of this design-based curriculum and also felt the power of this type of teaching and learning. Teachers tell us that, “I liked the problem/solutions that included Global issues” and want to put “Grand

Challenge in all lesson plans! Help the students realize that they can help solve problems!” We hear the impact of our pedagogy and curriculum as a teacher shares that “All were. Lets me see the frustrations, creativity, & problem solving that my kids will feel and you all illustrated how to handle these situations I will face in teaching STEM.” It is important and exciting to see that the majority of participants found value in every one of the builds and indicated that the construction evolution is well designed. This is further supported by the following qualitative data. Indeed, data show that each of the builds was listed by one or more teachers as being the most helpful.

3.1.2 Hand-cranked Light

Our first icebreaker and hands-on learning exploration focuses on a marketed hand-cranked flashlight. After taking the flashlight apart and participating in an interactive discussion about it, the first construction begins. The first LEGO build is a hand-cranked flashlight. Participants respond that this build is helpful because it offers a “quick sense of accomplishment” and that it “helped to start the lesson better!”

3.1.3 Gondola

The next build sparks excitement in the participants as they construct a LEGO robot that moves – for some, a first! With the design challenge to transport items for aid after a Hurricane Katrina (or other times roads are blocked or inaccessible), the participants built the gondolas shown in Figure 4. The gondola build is noted by a few as being the most helpful build. One participant indicates that the inclusion of alternative transportation and ability to “move on a string” was the reason this was a valuable activity.



Figure 4: Gondolas Galore

3.1.4 Exploration Stations – Build in Bins & Getting into Gears

The goals of the construction curriculum design are to provide exposure to LEGO resources, develop engineering vocabulary, explore engineering concepts with readily available materials, and learn construction techniques. Day 2 of program engaged teachers in these goals through the series of Exploration Stations shown in Figure 5. They listed these hands-on stations as most helpful because of the vocabulary “labeling” and the “build in bins.” One mentions that the gears station is most helpful because it made the conceptual connection to “understand how speed and power are different.”



Figure 5: Exploration Stations

3.1.5 Funky Fridge Pusher and Funky Fridges Herder

We provide participants with a choice of guided build instructions for several vehicles that can push toxic refrigerators out of residential areas into a safe disposal zone, as shown in Figure 6. They can also independently design the Funky Fridge Pusher or Funky Fridges Herder if they feel confident in their LEGO construction skills. Multiple participants posted that the “cars” are the most helpful builds because a vehicle build provides “experience with a basic build” and is the “basic foundation for other activities.” This specifically helped one participant “understand how to apply real world situations to LEGO solutions.”



Figure 6: Constructing Funky Fridge Pushers and Multiple Fridges Herders

3.1.6 Star Trek Door or Dispenser

Another component of the construction evolution in our curriculum is a guided build of an automatic “Star Trek” door, an elevator, or a dispenser. The qualitative data indicate that the majority of participants listed all of the builds as being the most helpful but close behind, data show that the Star Trek door is a favorite and viewed as most helpful. The reasoning is that it is a “great example of how light sensors can be used” and to “show how to work with gears for opening and closing.” One team modified the Star Trek door in their open-ended design to become a wind-powered adjustable and retractable levee wall to help *(Re)New Orleans* when there is flooding (see Figure 7).



Figure 7: Star Trek Door or Dispenser

3.1.7 Open-ended Design

The culmination of the DTEACH PDI is an open-ended design challenge. This experience is of high value to our participants based on their evaluation comments. They mention that the opportunity to work on this as an “individual” designer and then together on “team builds during the final project” are the most helpful construction experiences.

3.1.8 Guided and Independent Building

The scaffolding of the construction curriculum components is meant to meet the needs of a novice builder by providing exposure, support, and improved self efficacy while also inspiring and engaging an experienced builder. There are guided build instructions and options to build independently from scratch. Participants found both important and some participants had completely different views. One participant states that “[t]he most helpful to me were the ones that were prescribed, versus having complete freedom,” supporting the need for guided builds. Other participants shared that the most helpful activity is the “self build because it built confidence in my abilities” and that “all builds done independently that I could finish and independently program” are of most value. These data indicate the rationale for having both guided and independent build options embedded throughout the curriculum.

In our qualitative data, we ascertain which aspects of the curriculum and pedagogy connected to participants as learners. The word cloud, shown in Figure 8, illustrates the most frequent themes from our data analysis.



Figure 8: Word Cloud – What Connects Most with Learners

The data analysis and word cloud demonstrate that cooperative learning, hands-on experiences, teaching with and through examples, and multiple literacies (such as videos, read aloud, and written instructions that incorporate pictures) connected most with our participants as learners. They also indicate that interactive discussions using the Socratic method and providing multiple opportunities for students to speak are important. After understanding the most effective connections to our participants as learners during the PDI, we also want to decipher the key components they will incorporate in their classroom. The word cloud shown in Figure 9 creates imagery of the themes in the data most frequently discussed.



Figure 9: Word Cloud – What Teachers Plan to Use in their Teaching

As illustrated in the data analysis word cloud, participants will incorporate design-based learning within interdisciplinary curricula. Participants will include robotics in their teaching as an avenue for students to learn STEM concepts. With the robotics inclusion, they will implement our programming pedagogy to develop the students’ skills and confidence. To frame their interdisciplinary curriculum and make it socially and culturally relevant, they plan to contextualize the design-based learning with the Grand Challenges. In doing so, the teachers indicate that they will be able to enhance 21st

century skills and provide more opportunities for students to explore new ideas. The participants' feedback shows that team formation and development will be important components of their future teaching. In discussing teams, they indicate the importance of considering and including team roles and collaborative work in design-based learning.

3.2 Myers Briggs Type Indicator (MBTI) Personality Types

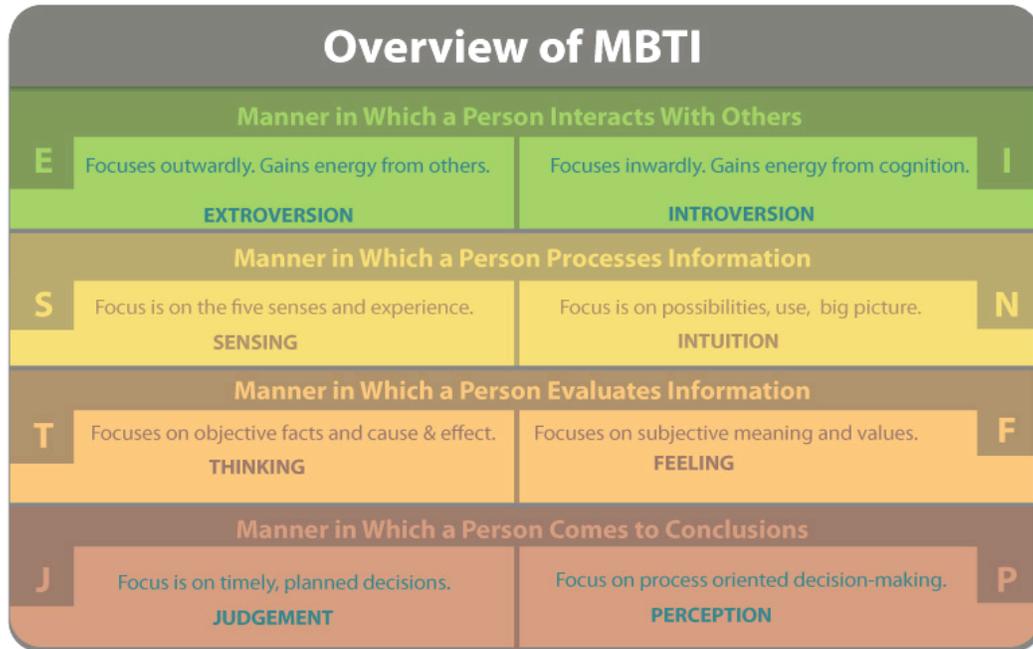


Figure 10: Overview of MBTI Categories¹¹

In an attempt to analyze how different personally preferences respond to the DTEACH PDI, personality type information was collected and correlated to participant responses. The participants are introduced to a team formation strategy based on the Myers Briggs Type Indicator (MBTI), it was natural to use this instrument for this research. MBTI is summarized in Figure 10^{12,13}. MBTI includes four categories that indicate how an individual processes and evaluates information¹¹. The first category describes how a person interacts with his or her environment. People who take initiative and gain energy from interactions are known as *Extroverts (E)*. *Introverts (I)*, on the other hand prefer a relatively passive role and gain energy internally. The second category describes how a person gathers information. People who process tangible data with their senses are referred to as *Sensors (S)*, and persons who prefer theoretical sources of data are called *Intuitors (N)*. The *Sensor* versus *Intuitor* category is an interesting area of study when it comes to engineering education, because professors are historically *Intuitors* while most engineering students are *Sensors*¹⁴. The third category for MBTI preference describes the manner in which a person evaluates information. Those who tend to use a logical cause and effect strategy, *Thinkers (T)*, differ from those who use a hierarchy based on values or the manner in which an idea is communicated, *Feelers (F)*. The final category indicates how a person makes decisions or comes to conclusions. *Perceivers (P)* prefer

to be sure all the data is thoroughly considered, and *Judgers (J)* summarize the situation as it presently stands and make decisions more quickly.

A number of researchers have used knowledge of MBTI types to enhance engineering education¹⁵⁻²¹. In this prior educational research, it is shown that different MBTI types respond in unique ways to distinctive pedagogical approaches. The goal of using the MBTI data is to create an environment for information exchange that facilitates effective learning for all personality types.

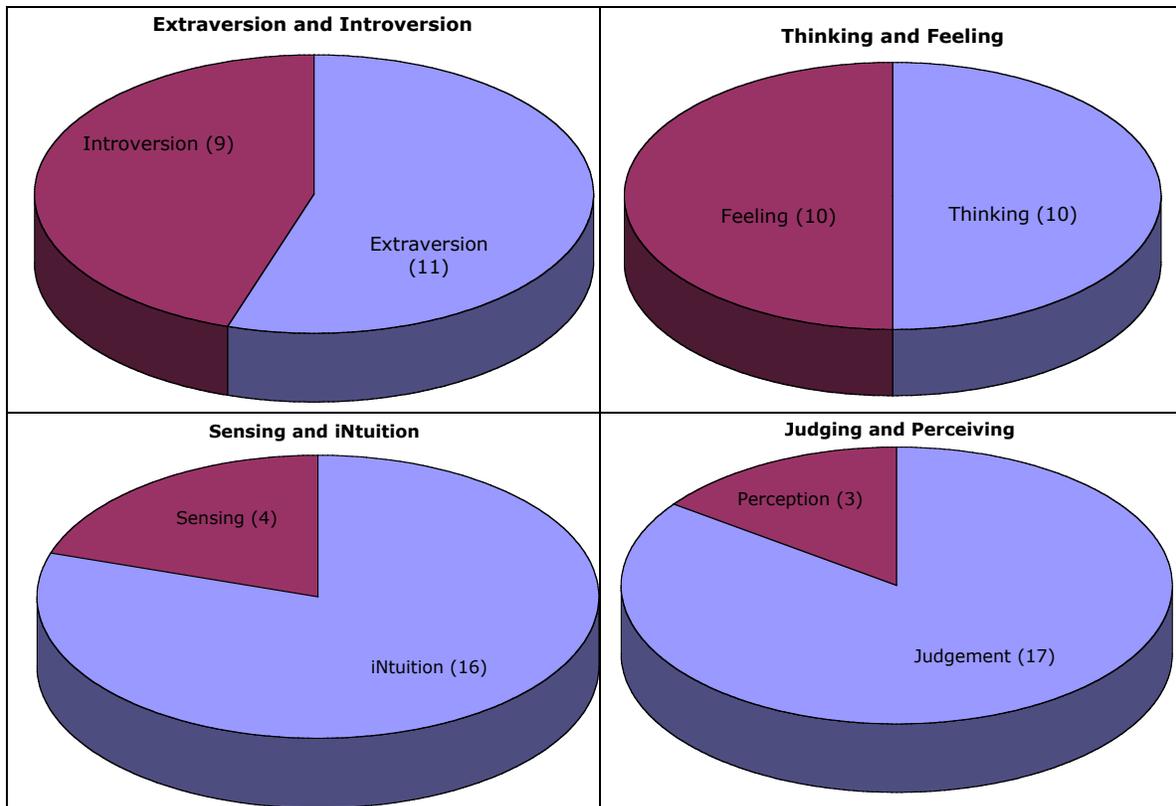


Figure 11: Distribution of MBTI Personality Types for 2010 DTEACH PDI (n=20)

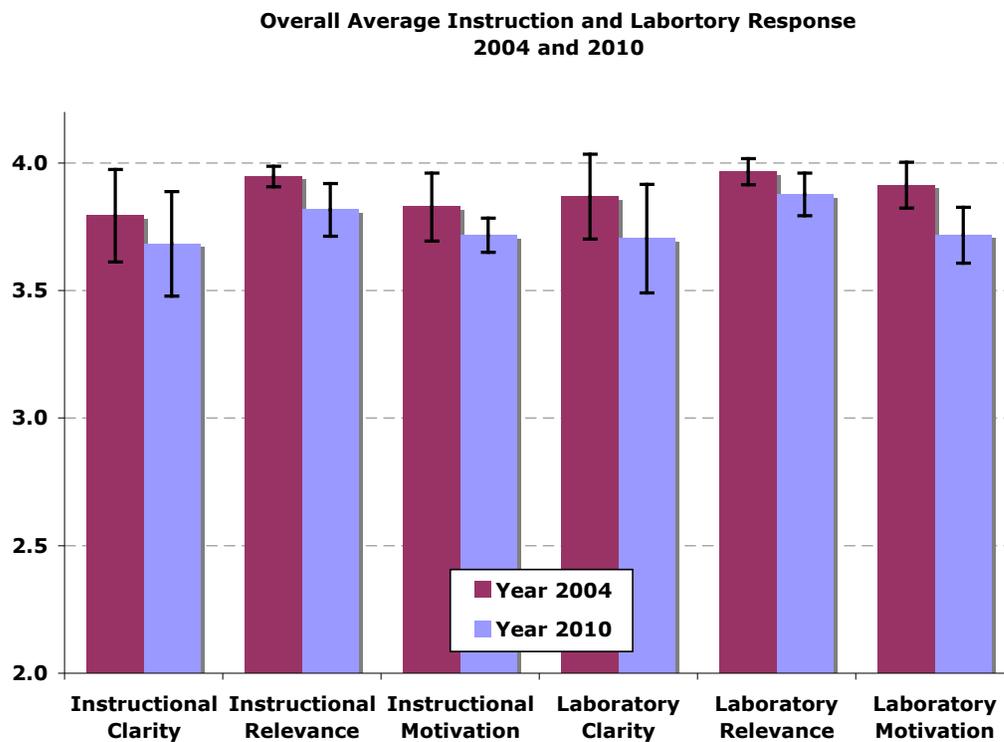
Figure 11 shows the distribution of the personality preferences that the participants exhibited in 2010 DTEACH PDI. The data indicates a large percentage of the participants exhibited preferences toward judgment over perception. Research as shown that the majority of practicing engineers have a tendency to prefer judgment and thinking²¹. The participants MBTI preferences look seminal to engineering students. MBTI type indicator information was collected for the participants with a web based on-line survey. The personality data was correlated with the quantitative survey data.

3.3 Daily Quantitative

The quantitative assessment was based on the same paper instrument that was used in the 2004 program to provide continuity in the assessment. The survey has six question assessing the clarity, relevance and motivation of the instruction and laboratory portions

of the program. The survey was scaled 0 to 4, indicating whether the participant agreed or disagreed that each day's instruction and laboratory were clear, relevant and motivating (0=disagree, 1=very slightly agree, 2=somewhat agree, 3=mostly agree, 4=totally agree).

Overall, both years were ranked by the participants on average, across all questions, between mostly agree and totally agree (3.89/4.0 for 2004 and 3.75/4.0 for 2010). With the small size of 20 participants the two overall scores were within one standard deviation. The consistent high scores show that the program is still perceived to be very clear, relevant and motivating across Instruction and laboratory. Across all six areas in both years the lowest rating was (3.7/4.4), demonstrating that the participants mostly agreed or totally agreed with the statements, as shown in Figure 12



**Figure 12: Overall Average Instruction and Laboratory Response
(one sigma error bar)**

To gauge the impact of the program on different MBTI preferences, the survey data were separated by personality preferences. Figure 1314 shows the overall laboratory and instruction results separated into the four personality preferences. As discussed previously the average scores in 2004 were higher than the 2010 scores but were within one standard deviation. Note particularly that all personality types responded relatively uniformly across personality types.

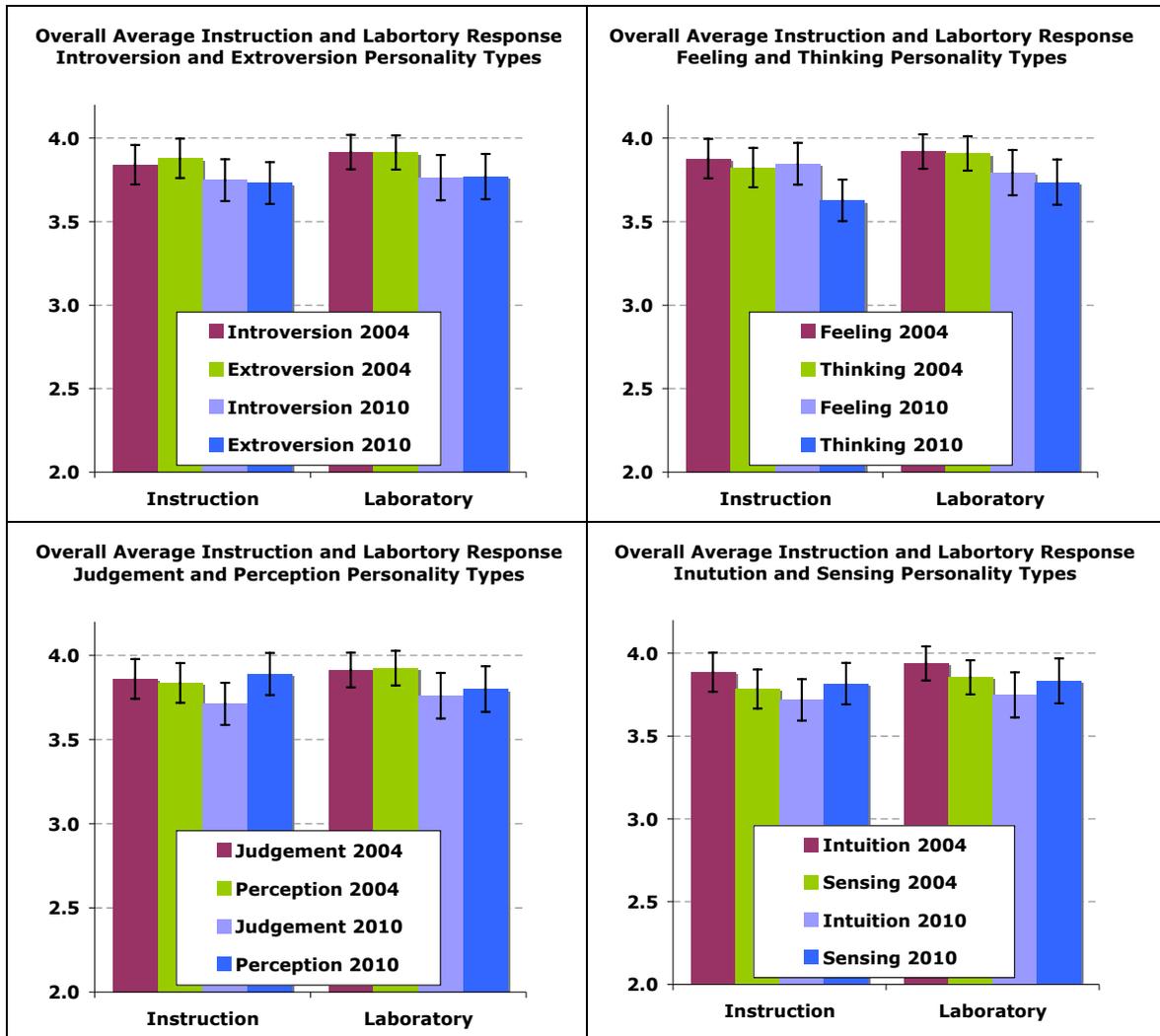


Figure 13: Average Instruction and Laboratory Response Separated by Personality Type²² (one sigma error bar)

From our qualitative results teachers indicate that the funky fridge pusher and multiple fridges herder are some of the most valuable and helpful activities. Yet we note from the data that on the day of these activities the clarity of the instruction and lab received lower rankings on the survey scale. We interpret these results as being related the discomfort level of teachers undergoing the design-based learning process where there are limited specific step-by-step instructions, pushing their comfort zone. As indicated in the qualitative data, teachers state that experiencing the challenges and pushing the boundaries of their traditional comfort zones helps them better relate to their students' learning experiences. Ultimately, we will continue to strive to improve strategies to maximize clarity while being true to the design-based learning process and pedagogy. Overall, we are excited to see high results across both years and very slight variations across MBTI types as our curriculum has continued to evolve.

4.0 Discussion

From our mixed methods assessment of the professional development and curriculum, we confirmed that our design-based learning reaches across different MBTI types and improves teacher efficacy about STEM education. The participants indicate that every curriculum component is helpful to their future teaching, which means that our evolution is relevant and successful. The NAE calls for curriculum and pedagogy to integrate the Grand Challenges into K-12 to inspire the coming generation to face these pressing global issues with innovative solutions. Our program answers that call with design-based learning that takes into consideration diversity, ways to contextualize engineering design in our everyday lives, and interdisciplinary learning. Indeed, we consider these components carefully as we embed strategies for team formation and development into our PDI, assess and align learning experiences across MBTI types, and contextualize curriculum. Overall, we find in this longitudinal evaluation of our program that the DTEACH method, design-based learning, and curriculum evolution enriches engineering education and provides teachers with the resources and experiences to increase their self-efficacy to teach STEM and design.

A major challenge for the DTEACH program has been getting detailed assessment of the implementation of the program on the student's learning. This challenge leads us to a new, more thorough study that focuses on the detailed assessment of the program on students, teachers, and undergraduate DTEACH mentors. This study of our program implementation includes researchers from education, engineering, and sociology to gain multiple perspectives on the evaluation of the impact of design-based learning and the evolution of the curriculum and pedagogy. Our future work will include analysis of this evaluation of the implementation of the program which will inform ways that we evolve and disseminate the curriculum and pedagogy to meet the needs of teachers, students, and undergraduate mentors.

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