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Maker Fridays: Engaging Rural and Underrepresented High School Students in Pre-Engineering Design and Creativity

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Final Research Report

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Executive Summary

The engineering field struggles to develop sufficient interest and sustained participation across underrepresented demographic groups including women and individuals from rural, Hispanic, or Native American origin. It is critical to foster interest in engineering during formative years when students are deciding career paths. Northeast Community College (Northeast) addressed the shortage of diverse students entering into engineering fields by developing a course to engage rural and underrepresented high school students in maker design and creativity and to determine best practices that attract and retain these students. The Maker Fridays pre-engineering course was part of the Fridays@Northeast program that targets high school seniors, offering them the opportunity to learn from College faculty using Northeast lab spaces and classrooms to earn college credit. Northeast augmented an existing by incorporating a maker design area at the South Sioux City and Norfolk campuses.

There were three cohorts of high school students involved in the EAGER Maker project at Northeast Community College throughout its two-year duration (Fall 2018, Spring 2019, and Fall 2019). Among the three cohorts, twenty-one students were enrolled in the course with eleven students participating in the research component, resulting in a 52% participation rate.

Project Personnel

PI: David Heidt, MS, Instructor for Undergraduate Science Education and Pre-Engineering Academic Advisor at Northeast Community College. Responsible for developing the maker space lab activities for ENGR 1010 Multidisciplinary Design and teaching the enhanced course

Co-PI: Michelle C. Howell Smith, PhD, Educational Researcher and Research Assistant Professor at the University of Nebraska Medical Center. Responsible for developing and implementing the educational research design.

GRA: Kirstie L. Bash, PhD, Associate Researcher, University of Kansas. Assisted with data collection, analysis, and disseminating results.

All personnel on the project completed CITI (Collaborative Institutional Training Initiative) training to ensure compliance with the ethical guidelines established by the US Department of Health and Human Services regarding respect for human subjects.

Intellectual Merit

The Maker Fridays project was designed to engage rural and underrepresented high school students in maker design and creativity and determine best practices that attract and retain these students. Through the Maker Fridays project, high school students were provided with learning activities and career exploration that will help them understand engineering while earning them college credits that will lead right into a program of study upon high school graduation. The researchers worked with the instructor to collect baseline and relevant continuing data on student background, academic preparation, engineering perceptions, career interests, course engagement, and overall student experiences. This was accomplished through a combination of student assessments, recorded class sessions reviews, and in- person class visits. The intent of the research study was to create a theoretical explanation for the development of interest in engineering careers for students from underrepresented demographic groups including women and individuals from rural, Hispanic, or Native American origin. However, the failure of

Northeast to meet enrollment goals resulted in insufficient sample sizes for theoretical development. Thus, we are only able to report descriptive characteristics and general thematic findings from this study. In order to protect participants' confidentiality, we cannot make the de-identified dataset available through the Interuniversity Consortium for Political and Social Research (ICPSR) at the University of Michigan as originally planned. However, the tools developed for this study and related codebooks are available as appendices to this report.

Broader Impacts

There is a continued need to increase the number and diversity of students who pursue and complete engineering degrees to meet current and future national workforce needs. The Maker Fridays project will impact Northeast's rural revitalization efforts due to the significant regional workforce demand for engineers. A major emphasis of this project was the focused partnerships created by inviting college faculty, educational researchers, and industry partners to be genuine colleagues who co-create educational pathways that both excite and encourage students to consider careers in engineering. From the perspective of employers, the project engaged engineering companies in ways that are fundamentally more active than how these partners are typically engaged with higher education. This project not only informed Northeast's program, but it also benefited the students directly by highlighting the ongoing workforce needs of the region's rural employers.

The Maker Fridays project was designed to dispel misconceptions and transform careers in engineering into a tangible and viable option for underrepresented students by engaging high school seniors in a college-level maker course. A student's positive experience in science that is integrated with maker design and creativity has been found to increase enthusiasm and a belief in the ability to pursue a science career (Linder et al., 2002; Feinstein et al., 2016). The Maker Fridays project engaged rural high school students in maker design and creativity. The engineering field struggles to develop sufficient interest and sustained participation across underrepresented demographic groups including women and individuals from rural communities. Through the Maker Fridays project, high school students were provided with learning activities and career exploration that helped them understand engineering while earning college credits that will lead to an engineering program of study upon high school graduation. These experiences were offered early enough in their education to allow changes in their career path. Through activities targeted to a high school audience, the Maker Fridays project dispelled misconceptions and transformed careers in engineering into a tangible and viable option for rural students.

Maker Fridays Project

Background and Project Rationale

There is a continued need to increase the number and diversity of students who pursue and complete engineering degrees to meet current and future national workforce needs. The engineering field struggles to develop sufficient interest and sustained participation across underrepresented demographic groups including women and individuals from rural, Hispanic, or Native American origin. Northeast Community College (Northeast) has made a commitment to addressing the diversity and employment gap in the engineering field in our region by developing an Associates of Science (A.S.) Pre-Engineering program that will transfer to multiple engineering schools. However, the program struggles to attract and retain students from these diverse backgrounds despite a high demographic presence in our region. Northeast developed an initiative to address the shortage of diverse students entering into engineering fields by creating a Maker Fridays project that engaged rural and underrepresented high school students in maker design and creativity and determine best practices that attract and retain these students.

It is critical to foster interest in engineering programs during formative years when students are deciding career paths. Northeast has developed several Early College (EC) offerings to support high school student exploration of career options and acceleration of their paths through earning college credit before their high school graduation. Data from the EC Office indicates a correlation between Early College and Regular Enrollment at Northeast. Northeast also has demonstrated academic success with the EC students with 90% course completion and 83% earning a B or higher (Fall 2013-Spring 2016). To decrease the proportion of incompletes, Northeast developed the Fridays@Northeast program that targets seniors, offering them the opportunity to learn from Northeast faculty as college students using Northeast lab spaces and classrooms. The courses offered through this program allow an introduction to a variety of technical programs and students earn college credit prior to high school graduation. The Fridays@Northeast format improved academic success to 93% course completion and 85% earning a B or higher (Fall 2017-Fall 2019). Maker Fridays used the Fridays@Northeast framework to introduce students to problem solving and engineering design in a project and team based environment.

Northeast created maker space labs for the ENGR 1010 Multidisciplinary Design course for high school seniors at the Norfolk Campus and South Sioux City (SSC) Extended Campus. The Norfolk and SSC campuses were selected for this project due to differences in the diverse populations of students that are served. Whereas the typical SSC EC student population is from a predominantly metropolitan area (23% nonmetropolitan based on Fall 2016 enrollment data & 2013 RUCC) and has a high racial/ethnic diversity with 21% Hispanic and 9% American Indian origin, the Norfolk EC population is 100% nonmetropolitan and has less racial/ethnic diversity with only 11% Hispanic and 1% American Indian origin.

Northeast's Pre-Engineering program provides an experiential education that prepares students with a robust fundamental STEM and engineering background. Northeast created a career pathway for engineers by establishing collaborations with regional industry and educational partners. Northeast has an articulation agreement with South Dakota School of Mines and Technology (SDSM&T). Students complete an A.S. degree at Northeast and transfer the majority of those credits to SDSM&T to complete a Bachelor of Science (B.S.) degree in one of its colleges of engineering. In addition, Northeast has collaborated with UNL to develop four courses that are taught by the community college as part of a pre- engineering initiative for students interested in transferring to UNL.

Northeast has undertaken other STEM education reform projects that position it well for this new effort in pre-engineering education. Northeast participated in the Strengthening Transitions into Engineering Programs (STEP) (DUE 0622274) with UNL. The collaborator and instructor for that grant, Mr. David Heidt, was the PI for the Maker Friday program. Most recently, Northeast completed a MentorLinks project in collaboration with the NSF and the American Association of Community Colleges. The College received previous NSF ATE support (DUE 0501876) to establish a successful model for advancing skills in high school and post-secondary students in Information Technology. Northeast was a key partner involved with the Midwest Center for Information Technology (MCIT) (DUE 1104268) as an ATE Regional Center. MCIT was comprised of 10 community colleges in the northern plains region and the Applied Information Management (AIM) Institute. Through these previous projects, Northeast discovered many challenges created by bringing students to campus, such as transportation costs, schedule coordination, and loss of classroom time, and has developed strategies to mitigate these issues.

Nebraska is the ideal location for students in engineering education programs as it has regional economic impact. The state is home to major input industries tied to engineering, as well as sectors processing value-added products, all of which contribute to its economic significance. The engineering industry has seen rapid advances through emerging technologies and innovation that have had a lasting impact on the region and the nation. The regional engineering workforce has been of extreme demand for over a decade resulting in employers competing to hire and retain employees.

Prior to the beginning of this project, Norfolk expanded its demand for engineering professionals with the construction of a new state-of-the-art Oil Country Tubular (OCT) Pipe mill that will produce approximately 200K metric tons of seamless plain end pipe to supply their 150K metric tons of finished tubing and casing for the nation's oil and gas production market. OCT Pipe selected Norfolk as the location for its new facility due to the U.S. central location in Nebraska and the proximity to Nucor Steel and to drilling and production sites. Similarly, Nucor Steel has had constant demand for the engineering workforce with its facility that produces carbon and alloy steel in special bar, cold heading, and bearing qualities. Overall, steps must be taken to prepare the workforce that will meet the expanding industry demands.

The Maker Fridays Course

The Maker Fridays project consisted of a re-designing the ENGR 1010 Multidisciplinary Design course at Northeast with a maker design area outfitted with a set of tools and equipment at two campus locations. The course content included an introduction to the engineering profession, engineering problem solving, and engineering design with an emphasis on current topics. Course material was taught using projects and group activities including 45 hours of instructor-guided learning. The Northeast instructor/project PI received professional development training to learn maker equipment operation and establish the engagement activities that will foster student design and creativity. The course was initially planned to be delivered to approximately eight students at each campus during the Spring 2018, Fall 2018, and Spring 2019 semesters (48 total students). Delays pushed the project start back to Fall 2018, with the project concluding in Fall 2019.

The project PI, a Northeast faculty member, taught the course which featured engineering career pathways discussions along with regional engineering employers. Northeast's Student

Services division including Northeast's Marketing, Recruiting, Admissions, Veterans' Services, and Disability Services staff members assisted the PI to ensure students were knowledgeable about the Northeast Pre-Engineering program. In addition to the normal marketing initiatives for all Fridays@Northeast courses, the Marketing department was responsible for all of the media that was used to attempt to boost participation. This included designing and coordinating all of the mailers, flyers, posters, and letters that were sent out as well as coordinating and releasing the videos of the makerspace and the course in addition to creating and distributing the electronic media pushes. Some of these went to all of the schools in the project areas. Some of these specifically went to every identified high school junior and senior in the project areas. The recruiters for the project areas were briefed on the grant project and were given additional copies of the materials that had been sent to the schools. Veterans' Services was ready to provide assistance, but none of the students identified themselves as a son or daughter of a veteran and none of the parents/guardians identified themselves as veterans. Disability Services had one staff member look over them Makerspace area to be ready to assist students. None of the students or parents notified Disability Services of a disability or a need of services. The Admissions area assisted the Director of Early College with student admissions and paperwork. The project used two staff who are fluent in Spanish to visit with Hispanic student families when language barriers existed. The staff member for the South Sioux City site is also the recruiter. In addition to her normal visits to the area schools and community events, she accompanied the PI on recruiting visits to the Sioux City school PLTW classroom and to the South Sioux City PLTW class. She and the PI also had an information booth at the Sioux City Makerspace Open House. The staff member for the Norfolk site was not a recruiter, so she was contacted as needed.

Due to the exploratory nature of this project, there were substantive changes made after each semester. The paper circuit activity was reduced from a two week project to a one week project. This allowed for two topics (communication and engineering economics) to be expanded for the second and third cohorts. To address the low student enrollment, the format of the course was also changed after the first cohort. Originally, the course was required students to be on campus at Northeast for the full day on Fridays. Beginning with the second cohort, the course was taught using a blended delivery. Lectures were pre-recorded by the instructor for students to watch at their convenience prior to the maker space lab. Students would then spend a half-day on the Northeast campus for the lab activities and a shortened lecture. Although this change was implemented for cohort two, the decision to change the course format did not occur early enough to promote the change when marketing the course. The new delivery mode was fully marketed and implemented for the third cohort. Tables 1, 2 & 3 summarize the Maker Fridays syllabus topics, maker space lab activities, and guest speakers for the three cohorts.

Table 1. Summary of General Topics and Activities – Cohort 1

Week #	Topic	Maker Space Activity	Guest Speakers
Week 1	Engineering Design Process	Drill Press Safety & Paper Tower Projects	
Week 2	Engineering Design Process	Paper Tower Projects	
Week 3	Engineering Design Process	Propeller-Driven Cars, Table Saw Safety & Guest Speaker	Industrial Engineer with Cardinal Health
Week 4	Engineering Design Process	Soldering Safety	

Week 5	Engineering Ethics & An Engineers' Role	Snap Circuit Activity & Propeller-Driven Cars	
Week 6	Engineering Ethics & An Engineers' Role	Snap Circuit Activity & Propeller-Driven Cars	
Week 7	Measurement and Analysis	Paper Circuits Activity, Snap Circuits Activity & Education Station Project	
Week 8	Measurement and Analysis	Wire Wrapping Safety	
Week 9	Fields of Engineering	VCarve Pro Software & Guest Speaker	Electrical Engineer with Continental
Week 10	Fields of Engineering	Paper Circuits Activity, Education Station Project, CNC Machine & Guest Speaker	Metallurgical Engineer with Nucor
Week 11	Fields of Engineering	Paper Circuits Activity & Education Station Project	
Week 12	Conservation of Energy and Energy Conversion	Paper Structure Activity & Hand-Held Drill Safety	
Week 13	Conservation of Energy and Energy Conversion	Paper Structure Activity	
Week 14	Primary and Secondary Energy Sources	Stackable Storage Container & 40-Year Energy Plan Pitch	Civil Engineer with Nucor
Week 15	Patents	Education Station Project, Corkboard / Pine Slate Bridges & CNC Machine	
Week 16	Project presentation and Final Exam	Education Station Project Final Reports	

Table 2. Summary of General Topics and Activities – Cohort 2

Week #	Topic	Maker Space Activity	Guest Speakers
Week 1	Course introduction; Paper structure construction and procedures; (Pretest)	"Hand/Power Tools" section proficiency checkoffs and activities open; Propeller-car build and testing; paper structure	
Week 2	Start of communications, ethics, measurement, engineering design process	Previous checkoffs, activities, and project continued until mandatory aspects completed	
Week 3	Makerspace (instructor at statewide community college course coordination meeting)	"Electronics" section proficiency checkoffs open, paper circuit design; Project: "redesign" of propeller-car to improve performance	

Week 4	Continuation of engineering design process and communications, Snap circuits activity	Previous checkoffs, activities, and project continued until mandatory aspects completed	
Week 5	Introduce primary energy systems presentation and report; continuation of engineering design process and ethics	"CAD-based" section proficiency checkoffs open, (Fusion 360 software, VCarve software, ShopBot Desktop CNC, 3-D printing)	
Week 6	Engineering economics, continuation of measurement; Introduce Engineering current event mini-activity; Instructor presentation of one primary energy source	Previous checkoffs, activities, and projects continued until mandatory aspects completed	
Week 7	Introduce "Client-requested" engineering design project; Students presented current event topic	Client-requested project Research and design a "sectional white-board"-several small white-boards that "store" on the wall to make one large white-board.	
Week 8	Mini-field trip	Previous checkoffs, activities, and projects continued until mandatory aspects completed	Mini-field trip Students met with Northeast employees of different IT/Computer science backgrounds to help students narrow career path focus
Week 9	Fields of Engineering Student primary energy presentations	Work on activities and projects	
Week 10	Fields of Engineering Conservation of energy	Work on activities and projects	
Week 11	Fields of Engineering Propeller-driven car presentation and report	Work on activities and projects	
Week 12	Fields of engineering	Work on activities and projects	
Week 13	Patents and Copyright	Finish projects (work on activities)	
Week 14	Spring Break	Spring Break	

Week 15	Topic wrap-up, review and questions	Work on activities and projects	
Week 16	Presentation of "Client-requested" project; Final Exam		

Table 3. Summary of General Topics and Activities – Cohort 3

Week #	Topic	Maker Space Activity	Guest Speakers
Week 1	Introduction to course, Communication activity (pretest)	"Hand/Power Tools" section proficiency checkoffs and activities open; Propeller-car build and testing; paper structure	
Week 2	Engineering Design Process; communications; paper structure activity	Previous checkoffs, activities, and project continued until mandatory aspects completed	
Week 3	Ethics; measurement and analysis	Previous checkoffs, activities, and project continued until mandatory aspects completed	
Week 4	Introduce Primary Energy Systems activity; Snap Circuits activity; conservation of energy	"Electronics" section proficiency checkoffs open, paper circuit design; Project: "redesign" of propeller-car to improve performance	
Week 5	Makerspace (instructor at NATS/MATM conference)	Previous checkoffs, activities, and project continued until mandatory aspects completed	
Week 6	Force and energy; paper structure rebuild and testing	"CAD-based" section proficiency checkoffs open, (Fusion 360 software, VCarve software, ShopBot Desktop CNC, 3-D printing)	
Week 7	Engineering Ethics activity	Previous checkoffs, activities, and project continued until mandatory aspects completed	
Week 8	Ethics activity. Primary energy systems presentations; Fields of Engineering	Students choose client-requested project, can propose project of their own, or may do additional activities with the tools & equipment that interests them in the Makerspace	
Week 9	Primary energy systems presentations;	One group from same high school had teacher-client request they design a bookcase	Iron Range Engineering Bell Program instructor

		to fit into science room area; one group had PI as client—redesigned the modular whiteboard, third group had Bio instructor as client, designed divider for lab drawer in Microbiology room, remaining students chose additional activities	
Week 10	Fields of Engineering	Work on activities and projects	
Week 11	Fields of Engineering presentations	Work on activities and projects	
Week 12	Current events in engineering	Work on activities and projects	
Week 13	Patents and Copyright	Finish projects	UNL College of Engineering Advisor
Week 14	Topic wrap-up, review, and questions	Work on activities and projects	
Week 15	Presentations on projects, presentation on evaluation of additional activities; final exam		
Week 16			

Note: Questions about the course content and maker space activities can be directed to the PI, David Heidt at daveh@northeast.edu.

Because the Maker Fridays project spanned several semesters, there were revisions and changes to the course structure and assignments at the end of each semester. During the first semester, participants emphasized the need for back-up projects to work on while waiting to gain access to the larger machinery. By adding back-up projects to later semesters, students were able to use class time more efficiently and have less downtime waiting. Participants liked having a big project and a small project to work on at all times. As such, the early suggestion for more projects was implemented for later semesters. In addition, participants in the first semester of the course suggested that the paper circuits activity take less class time to finish. This suggestion was also implemented in later semesters and was not considered a concern during the last semester of the evaluation.

Student Feedback

There was one major suggestion for improvement made by research participants: more detailed descriptions of projects. Participants felt that more information or direction on certain projects was needed. With some projects, participants were unsure whether they should simply test the original design or make changes to the design and retest. One participant shared, “I mean, we build them and then test them, but I don’t know if we were supposed to do anything else on it.” When details were provided to students, participants expressed that:

> "I wish it would have elaborated more on each section that we needed. Some of them were obvious, like 'draw here and put in more detail about how it works,' but then other sections were like, 'define a problem.' Which problem do you mean? A problem with the initial design?"

In other instances, participants felt that written instructions could be "understood different ways," which made it difficult to complete tasks with a certain level of confidence. By providing students with "more structure," (e.g., specific deadlines, more definitive details, clear objectives), participants felt that their experiences within the ENGR 1010 course and Maker Space Lab could be improved.

Other minor but noteworthy suggestions included finding a larger room for students to work on projects, adding a laser cutter to the tools available in the course, and "branch out a little bit more" with engineering types that require more chemistry. In addition to these suggestions, one participant described how having more students in the course would have improved his experience. During this particular semester, only two students were enrolled in the course, which limited their ability to collaborate and problem solve with others. This participant suggested putting the Maker Space Lab itself in high schools, rather than physically at the Northeast Community College location. He reasoned that a more local location might allow more students to learn about the Maker Fridays course and have easier access to participate. Because "most high schools have tools" but no instructors to teach them all, the Maker Space Lab could take place in the high schools with a lab assistant. He continued by saying, "the instructor could hook up a distance learning room" to connect with his high school (and potentially others). Although this suggestion may be outside of the scope of implementations, future iterations of the Maker Fridays course with a Maker Space Lab component should focus much attention on efforts to increase sample size of participating high school students.

External Advisory Board

An external Grant Evaluation Advisory Board comprised of experts in engineering, engineering education, and educational research evaluated the project and determined what changes were needed so the project stayed on track toward achieving its objectives. The Advisory Board was comprised of individuals with expertise in engineering, engineering education, and educational research. Plans were for the board to convene for three virtual meetings to provide both formative and summative assessment of the project. The first meeting was planned for Fall 2017, prior to implementing the first course, to review the proposed syllabus and provide expert review of an adapted Engineering Interest Inventory. The second meeting was to be in Summer 2018 to review preliminary findings from the first course delivery and to provide feedback on suggested changes prior to the second course delivery. The third meeting was planned for Summer 2019 to provide an overall summary of the project. Project delays moved the initial Advisory Board meeting to Summer 2018 and the second meeting was held in the winter of 2018 between the first and second cohorts. The final Advisory Board meeting was not held prior to the completion of this research report.

Board members provided input to the chair who prepared evaluation reports following the two meetings. This information was included in annual NSF reporting along with a description of how the input was incorporated into the project. The board addressed the following project evaluation questions:

- To what extent is the project team effectively carrying out the planned activities of this

project?
- Does the course reflect project objectives and anticipated outcomes?
- To what extent is the research being conducted with rigorous methodologies and statistics to answer the identified research questions?
- What lessons are being learned and what changes are being made to improve the project?

The External Grant Evaluation Advisory Board members included:

- **William Todd Abraham, Ph.D., Chair**: Research Scientist and Lecturer - Iowa State University: Research Institute for Studies in Education, Ames, IA; Ph.D. in Psychology with a Statistics Minor; Research Focus: statistical power analysis, psychological research, social and behavior science; Teaching Expertise: Latent Variable Methods and Modeling for Social Psychological Research, Quantitative Behavioral Methods, Educational Statistics, and Research Methods.
- **Ying Deng, Ph.D.**: Associate Professor Biomedical Engineering Program - University of South Dakota: Graduate Education & Applied Research Center, Sioux Falls, SD; Ph.D. in Biomedical Engineering; Teaching Expertise: Biomedical Engineering Experimental Design and Biotechnology.
- **Anne Stephens, B.S.C.E.**: Public Works Director/City Engineer - City of Bel Aire, Kansas; B.S. in Civil Engineering; Professional Expertise: design engineering, commercial and residential site development, municipal works, utilities planning, arterial street design, and aviation planning.
- **Jay Connelly, M.B.A., B.S.M.E.**: Staff Engineer - Continental ContiTech, Norfolk, NE; M.B.A. in Finance; B.S. in Mechanical Engineering; Professional Expertise: engineering management, manufacturing engineering, project coordination, automation design, and industrial HVAC planning.
- **Chad Kehrt, B.S.C.E.**: Project Engineer - Olsson Associates, South Sioux City, NE; B.S. in Construction Engineering; Professional Expertise: civil engineering, storm water and sewer management, drainage and erosion site plans, road and highway site development.

The External Advisory Board evaluation reports are available from the PI, David Heidt at daveh@northeast.edu.

Research Methods

Research Design

The Maker Fridays research design was initially a multi-phase mixed methods-grounded theory design. Mixed methods are appropriate when the research needs to answer multiple questions, address complex facets, satisfy diverse stakeholders, or develop/adapt theory (Plano Clark & Ivankova, 2016). Mixed methods research integrates the individual strengths of quantitative and qualitative methodologies to provide a more comprehensive understanding for the depth of participant's lived experiences and broader impacts. Grounded theory approach builds theory through a "systematic, inductive, and comparative" process (Bryant & Charmaz, 2007) Grounded theory reflects a post-positivist stance that appeals to many quantitatively-trained researchers with its systematic, rigorous, step-by-step procedures (Glaser & Strauss, 1967). Grounded theory is characterized by theoretical sampling that jointly collects, codes, and deeply analyzes data using a method of constant comparative analysis to ensure the saturation of relevant categories. The result of applying this approach to the project would have been a theoretical explanation for the development of interest in engineering careers. Unfortunately, recruitment goals for the course were not met and subsequently, there were not enough participants to conduct a grounded theory analysis. Therefore, the actual research design was a basic convergent mixed methods design. A convergent design is characterized by concurrently collected quantitative and qualitative data that are analyzed separately, and then merged for a deeper understanding of the phenomenon (Plano Clark & Ivankova, 2016).

Research Questions

The original educational research questions for the Maker Fridays project were:

- How do high school students from diverse backgrounds change their perceptions of and interests in engineering careers throughout the Maker Fridays course?
- How do high school students from diverse backgrounds experience the Maker Fridays course?
- How do the activities and strategies in the Maker Fridays course influence diverse high school student perceptions of and interests in engineering careers?

Due to the overall deficits in student recruitment, lack of diversity in the student profiles (only two female students and one Hispanic student), and the failure to enroll students at the SSC site, we did not have the data necessary to answer these research questions. Therefore, we revised the research questions by removing the references to student diversity. The revised questions are:

- How do high school students change their perceptions of and interests in engineering careers throughout the Maker Fridays course?
- How do high school students experience the Maker Fridays course?
- How do the activities and strategies in the Maker Fridays course influence high school student perceptions of and interests in engineering careers?

Participants

Northeast was responsible for recruiting area high school students to the Maker Fridays project in Norfolk and South Sioux City, Nebraska. The recruitment goals were to enroll 8 students in each location for a total of 16 students in each cohort which would be 48 students over the three semesters of the program. Two students enrolled in the course at South Sioux City and attended the first class session. Both students withdrew after the first day, and are therefore not included in this report. Enrollment from high school students at the Norfolk site were also below expectations, with only 19 students total taking the course. Of these students, only two (9.5%) were female and only one (4.8%) was Hispanic. All other students were white (n = 20, 95.2%) and male (n = 19, 90.5%). From this pool of students, 11 volunteered to participate in the research study. Information about research study participants' backgrounds is presented in the findings section. For consistency throughout this report, the term *students* is used to refer to the entire class, whereas *participants* refers to those students who volunteered to participate in the research component. The University of Nebraska-Lincoln's IRB provided oversight of the human protections strategies for this study. The project Co-PI and GRA collected all data except for the engineering knowledge measure, maintained the data securely, and conducted all analyses. The project PI, who was also the course instructor, was not informed about the study participants until after final student grades were posted.

Quantitative Data Collection

We used a student background form to collect demographic variables such as gender, race, ethnicity, county of residence, and free/reduced lunch eligibility along with an inventory of STEM courses and co-curricular activities such as FIRST robotics, Science Olympiad, and Math Bowl.

We designed the Engineering Interest Inventory (EII) to assess pre/post student interests in engineering careers. This tool will incorporated prompts from published STEM interest inventories such as the Persistence Research in Science and Engineering' (PRiSE; Harvard-Smithsonian Center for Astrophysics, 2007), Science Aspirations and Career Choice (ASPIRES; DeWitt et al., 2014), Science Motivation Questionnaire II (Glynn et al., 2011), and STEM Career Interest Survey (Dabney et al., 2012). Relevant concepts from assessments designed for undergraduate engineering majors including the Persistence in Engineering (PIE; Eris et al., 2010) survey and the Academic Pathways of People Learning Engineering Survey (APPLES; Chen et al., 2008) were also featured. We administered the EII pre/post. The EII is included in Appendix A.

Establishing initial and documenting changes in participant perceptions of and interests in engineering careers provided important baseline information. Prior to beginning the course, students may have a lack of exposure to or misperceptions about engineering careers. The first step was to determine how high school students in the target communities perceive engineering careers. The modified Draw an Engineer Test (mDAET) assessed pre/post-understanding of the engineering profession (Thomas et al., 2016; Knight & Cunningham, 2004). The mDAET prompts respondents to "Draw an engineer at work" and to answer illustration specific questions. The assessment was scored for conception levels in four domains: Understanding the work of an engineer, usefulness of science, usefulness of mathematics, and gender stereotypes (Thomas et al., 2016). All drawings were coded at the conclusion of the study by trained raters who were not involved in the study.

We measured participant knowledge of engineering concepts with a pre/post exam based on specific course outcomes. The post measure also served as the final exam for the course grade. The course instructor collected these data and provided them to the research team at the conclusion of the project. Only test scores from research participants were included in our analyses.

The original research plan included post-secondary student enrollment data from Northeast and the National Student Clearinghouse to augment data on participant pursuit of engineering pathways to validate the EII tool. However, Northeast did not provide this information; therefore it was not included in our analyses.

Quantitative Data Analysis

Our initial plan was to conduct hierarchical linear modeling (HLM) analysis to account for the nested data structure in which repeated observations (Level 1) are nested within students (Level 2), which are nested within location (Level 3), and nested within cohort (Level 4). However, given the small sample size (n=11) inferential statistics were not appropriate. Therefore, we our analysis consists of descriptive statistics.

Qualitative Data Collection

Our first strand of qualitative data is comprised of video recordings of naturally occurring classroom data, and as such, all students enrolled in the course, whether or not they volunteered as research participants, were included in these recordings. Because the course was designed to be taught concurrently in two locations (one in person, and one remotely) we had planned to record the remote feed of all maker space labs for analysis. Although the course was ultimately only offered in one location, we were still able to record some of the lab content. The maker space lab in Norfolk was split across two rooms. One room was supervised by the Teaching Assistant and contained the equipment. The other room was a small, L-shaped classroom where students could work on their projects that did not require use of the larger equipment. During the first cohort, the maker space activity in the L-shaped classroom was recorded. However, the awkward shape of the room made it difficult to see all students and to differentiate conversation among the small work groups. The review of the maker space videos ultimately did not yield useful data for answering the research questions.

In addition to the videos, we conducted focus groups with research participants only at the beginning and end of each semester. The interview protocol focused on the participants' interest in engineering as a potential career and discussions about their mDAET drawings. The protocol is included in Appendix B. Focus group interviews were recorded and transcribed by professional transcriptionists at the Bureau of Sociological Research (BOSR) at the University of Nebraska-Lincoln.

Finally, the mDAET drawings themselves were used as qualitative data, independent of the quantitative ratings by external trained coders.

Qualitative Data Analysis

Originally, we had planned to conduct a grounded theory analysis of the qualitative data. Due to the small sample size, this was not possible. Hence, we conducted a general thematic analysis instead. Our coding consisted of an initial phase that identified and coded meaningful segments and a selective phase that synthesized and integrated frequent and significant codes into salient themes. A provisional coding approach was based on key concepts from literature on interest in engineering careers for the initial analysis (Miles et al., 2014). Additional codes were incorporated to reflect new ideas and concepts as they emerge. The qualitative data analysis software package MAXQDA 10 assisted with organization and retrieval of coded data segments for comparison. We relied on triangulating the multiple sources of data to enhance the trustworthiness of our analysis (Creswell, 2013).

Mixed Methods Integration

Integration occurred the conclusion of the study when the overall qualitative findings and quantitative results were merged in a side-by-side visual display to assist in synthesizing the findings. The integrated analysis will identify points of convergence and divergence between data sets.

The relationships between research questions, related outcomes and indicators (instruments) are summarized in Table 4.

Table 4. Project Research Questions, Outcomes, and Indicators

Research Question	Related Outcomes	Indicators
How do high school students change their perceptions of and interests in engineering careers throughout the Maker Fridays course?	Changes in student perceptions of engineering careers Changes in student interests in engineering careers Changes in student knowledge of engineering principles Document student demographic variability and academic preparation	Pre/Post modified Draw an Engineer Test (mDAET) Pre/Post Engineering Interest Inventory (EII) Pre/Post knowledge measure Demographic information
How do high school students experience the Maker Fridays course?	Changes in student perceptions of engineering careers Changes in student interests in engineering careers Changes in student knowledge of engineering principles	Pre/Post modified Draw an Engineer Test (mDAET) and focus groups Pre/Post course focus groups
How do the activities and strategies in the Maker Fridays course influence high school student perceptions of and interests in engineering careers?	Framework for additional analysis of integrated strands	Side-by-side visual data display Integration matrix synthesis

Results

Quantitative Results

The quantitative results are comprised of descriptive statistics from the Engineering Interest Inventory. The results from the quantitative analysis focus on identifying participant characteristics in the sample, previous experiences with science, math, technology, and engineering, connections in student's lives that can impact major and/or career trajectories, and interests and skills related to the field of engineering.

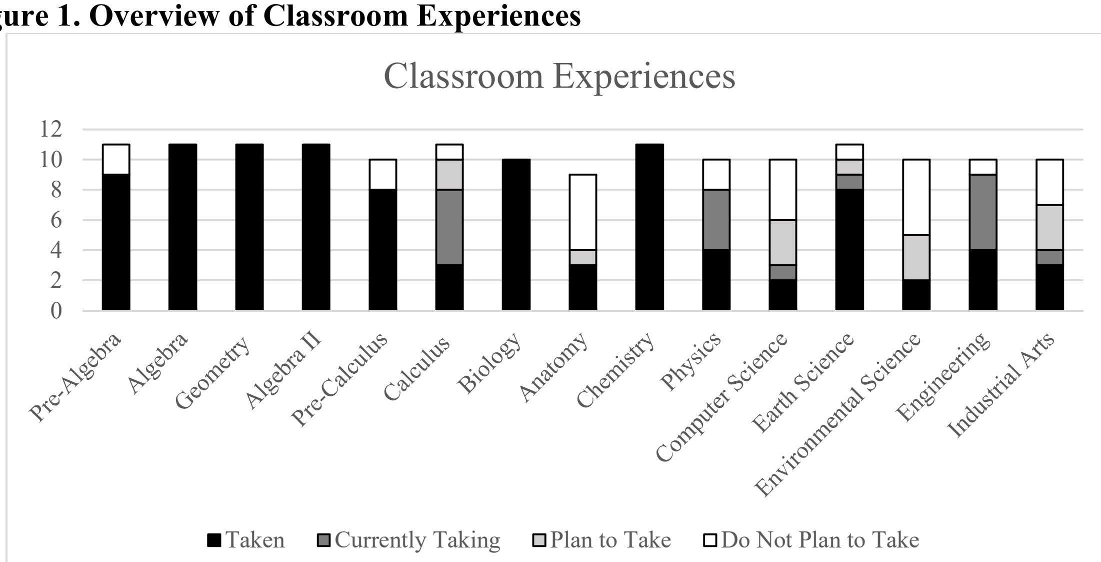
Participant Characteristics

The average age of participating students was 17 years old, and all were enrolled in the twelfth grade. The majority of students were male (n = 9; 82%), with a small number of female students (n = 2; 18%). Most students identified as white or Caucasian (n = 10; 91%) for race and not Hispanic or Latino (n = 10; 91%) for ethnicity. Within the sample of participating students, one student identified as Hispanic or Latino for ethnicity. There was a large proportion of students (n = 9; 82%) who have never qualified for free or reduced lunch.

Previous Experiences

In order to gauge student's previous experiences with science, math, technology, and engineering, students identified previous coursework completed, coursework currently taking, planning to take, or not planning to take. The majority of students reported taking Pre-Algebra (82%), Algebra (100%), Geometry (100%), Algebra II (100%), Pre-Calculus (73%), Biology (91%), Chemistry (100%), and Earth Science (73%). Many students reported currently taking Calculus, Physics, and Engineering while participating in the Maker Space Lab. Students did not plan to enroll in Anatomy, Computer Science, or Environmental Science. See Figure 1 for an overview of these classroom experiences.

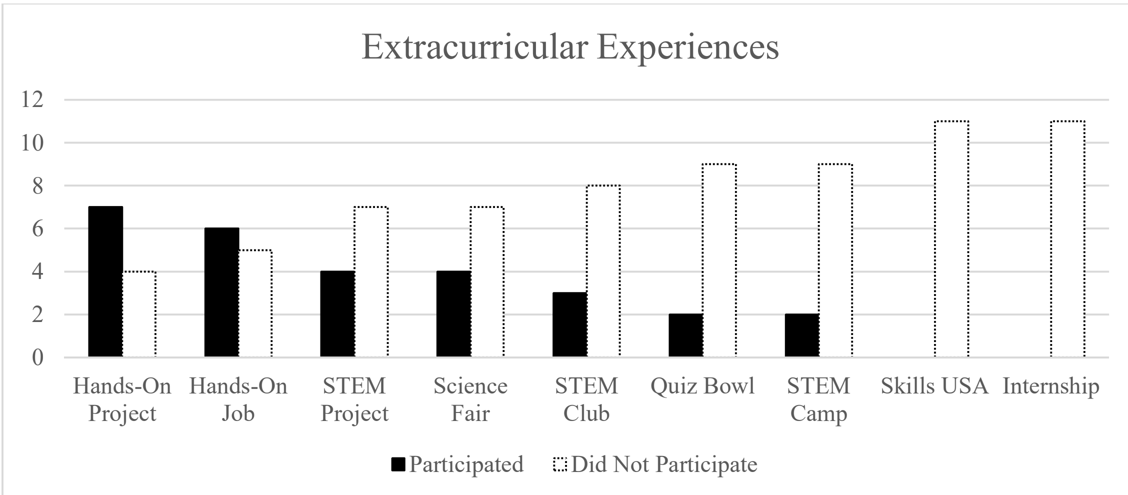
Figure 1. Overview of Classroom Experiences



In addition to coursework, students identified extracurricular experiences related to science, math, technology, and engineering areas. Many students reported participating in hands-on projects (n = 7; 64%) and hands-on jobs (n = 6; 55%) during high school. In general, the majority of students did not participate in many of the extracurricular experiences, such as

STEM club, Skills USA, Quiz Bowl, and so forth. See Figure 2 for overview of extracurricular experiences.

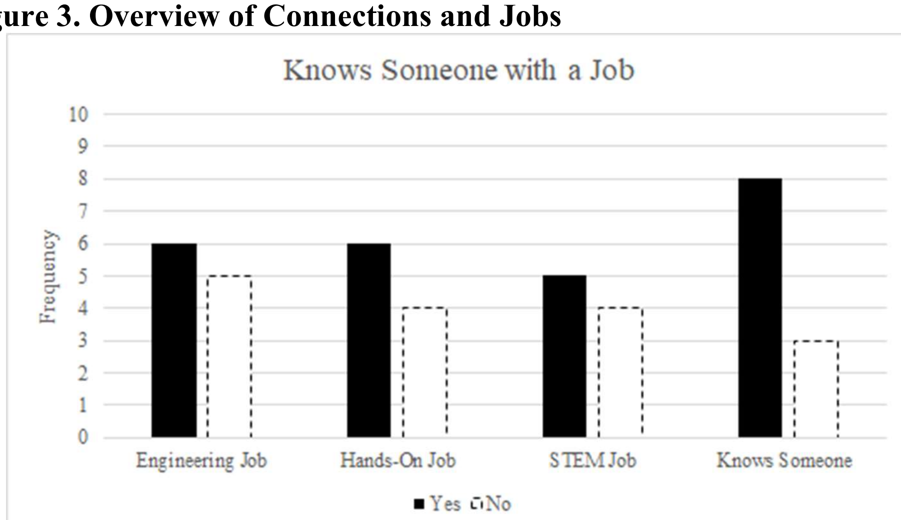
Figure 2. Overview of Extracurricular Experiences



Connections

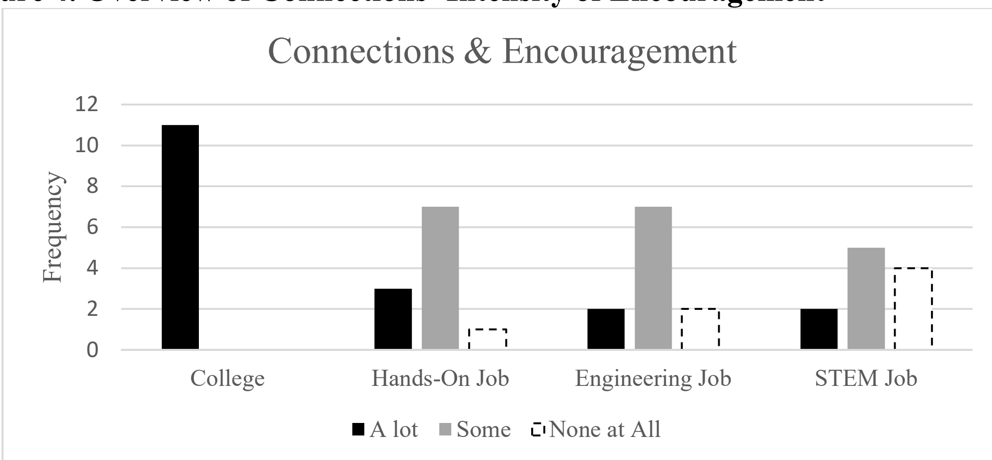
The people and influences in student's lives can have an impact on their interests, majors, and future career plans. In general, approximately half of the students reported knowing someone with an engineering job, a hands-on job, and a STEM-related job. The specific kinds of jobs that their connections worked were quite diverse. With engineering jobs, students shared that they knew someone in metallurgical engineering, metal work, welding, drafting, civil, and electrical. With hands-on jobs, students shared knowing someone in welding, automotive, construction, and mechanic. With STEM-related jobs, students shared knowing someone in drafting, engineering, and teacher. See Figure 3 for overview of student's connections and the jobs they hold.

Figure 3. Overview of Connections and Jobs



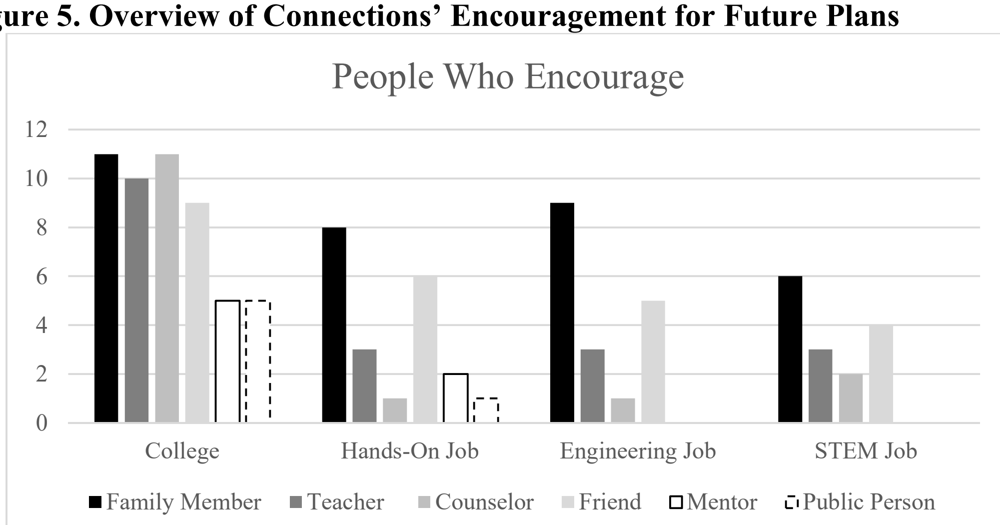
When asked whether someone encourages them to attend college or get a science-based job, students reported that they were encouraged a lot (*n* = 11; 100%) by the individuals in their lives to attend college, and they were encouraged a lot to some to take a hands-on job (*n* = 10; 91%), engineering job (*n* = 9; 82%), or STEM-related job (*n* = 7; 64%). See Figure 4 for overview of student's connections and how much students are encouraged.

Figure 4. Overview of Connections' Intensity of Encouragement



Examining their connections further, students were asked to identify specifically who encourages them to attend college and/or get certain jobs in science-based fields. Overall, students identified family members, teachers, counselors, and friends as the biggest influences who encouraged them to attend college, and to get a hands-on job, engineering job, or STEM-related job. Although there were a few instances where mentors or public persons provided encouragement, these two connections tended to be less frequent than the other connections. See Figure 5 for overview of people who provided students with encouragement towards a science, technology, engineering, or mathematics field.

Figure 5. Overview of Connections' Encouragement for Future Plans



Interests and Skills

Students were asked to evaluate their interest in common engineering skills during pre-test, then students were asked to assess how their interests and abilities have changed as a result of the Maker Space Lab during post-test. At pre-test, students identified a high interest in making things, helping other people, figuring out how to improve something, and building things. Over time, students reported that the Maker Space Lab aided them in improving their abilities to (a) design something new, (b) keep track of details, (c) define problems, (d) evaluate potential solutions, and (e) communicate recommendations or solutions. See Table 5 for average interest across items from pre-test to post-test.

Table 5. Changes in Skills Interest from Pre-Test to Post-Test

How much do you like to…	Pre-Test (n = 11)	Post-Test (n = 9)	Change (+/-)
Communicate recommendations or solutions	1.18 (0.60)	1.56 (0.53)	+0.38
Design something new	1.36 (0.51)	1.67 (0.50)	+0.31
Keep track of details	1.36 (0.67)	1.67 (0.50)	+0.31
Evaluate potential solutions	1.45 (0.52)	1.67 (0.50)	+0.22
Define problems	1.36 (0.51)	1.44 (0.53)	+0.08
Identify needs	1.36 (0.51)	1.33 (0.50)	-0.03
Brainstorm new ideas	1.64 (0.51)	1.56 (0.73)	-0.08
Solve real-world problems	1.45 (0.52)	1.33 (0.50)	-0.12
Figure out how to improve something	1.82 (0.41)	1.67 (0.50)	-0.15
Figure out how things work	1.73 (0.47)	1.56 (0.53)	-0.17
Make things	2.00 (0.00)	1.67 (0.50)	-0.33
Build things	1.91 (0.30)	1.56 (0.73)	-0.35
Ask questions	1.36 (0.51)	0.78 (0.67)	-0.58
Help other people	2.00 (0.00)	0.89 (0.60)	-1.11

Notes. Raw scores range from 0 (not at all) to 2 (a lot). Table values represent averages, where higher values (closer to 2) indicate higher endorsement of interest. Standard deviations are in parentheses.

Students were also asked to indicate their future plans in STEM and engineering. At pre-test, students reported high interest in taking more courses, majoring in, and having a job in STEM-related, engineering, or similar fields. After participating in the Maker Space Lab, students reported higher interests in (a) taking more engineering courses, (b) majoring in a hands-on or skilled trade program, and (c) having a STEM-related job. In addition, students were asked to indicate how their interests have changed (same interest, more interest, or less interest) in STEM, engineering, and related fields. Overall, students reported about the same level of interest for all items after participating in the Maker Space Lab. See Table 6 for average interest in future plans for courses, majors, and jobs related to science, technology, engineering, and mathematics.

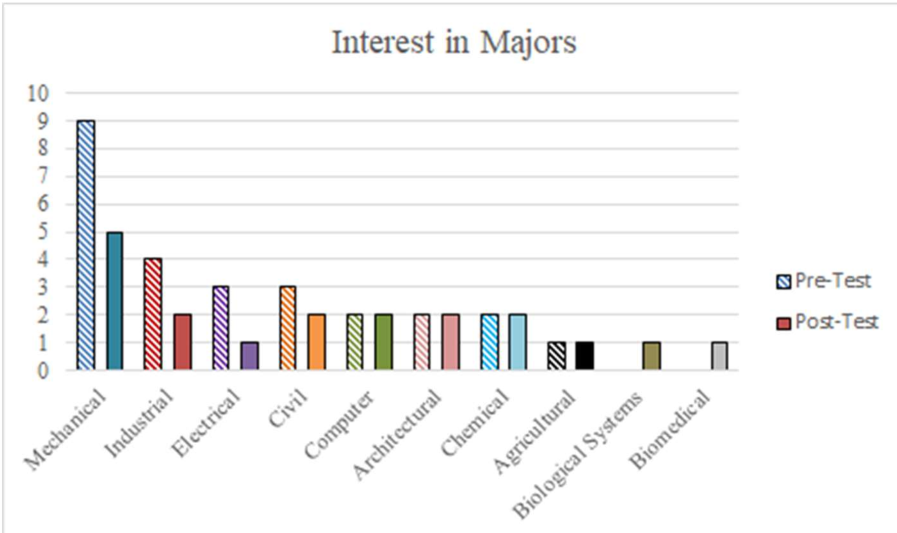
Table 6. Changes in Future Plans from Pre-Test to Post-Test

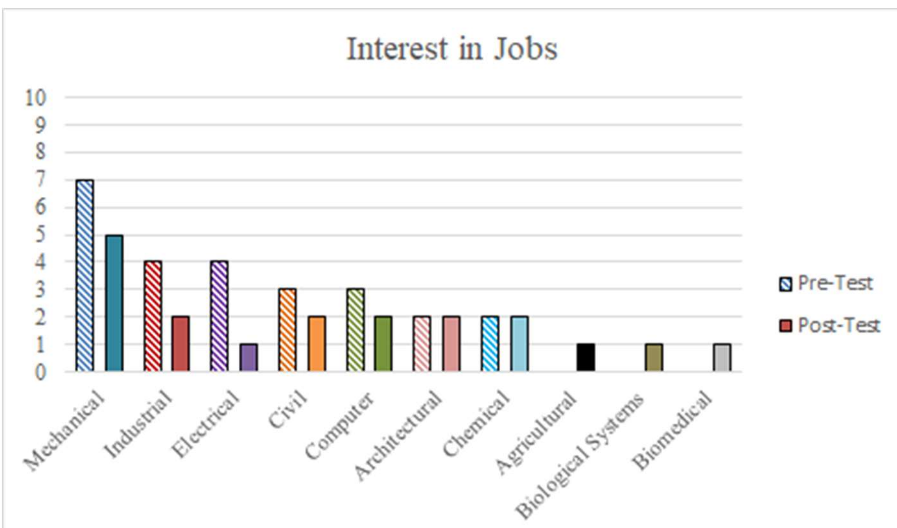
How interested are you in …	Pre-Test (n = 11)	Post-Test (n = 9)	Changes (+/-)
Majoring in a hands-on, skilled trade, or technical program	1.33 (0.71)	1.67 (0.50)	+0.33
Taking more engineering courses	1.78 (0.44)	1.89 (0.33)	+0.11
Having a STEM-related job	1.67 (0.50)	1.78 (0.44)	+0.11
Majoring in a STEM-related field	1.67 (0.50)	1.67 (0.50)	0.00
Majoring in engineering	1.67 (0.50)	1.67 (0.50)	0.00
Having a hands-on, skilled trade job	1.56 (0.53)	1.56 (0.53)	0.00
Having an engineering-related job	1.67 (0.50)	1.67 (0.50)	0.00
Taking more STEM-related courses	1.78 (0.44)	1.67 (0.50)	-0.11
Taking more hands-on, skilled trade courses	1.78 (0.44)	1.56 (0.53)	-0.22

Notes. Raw scores range from 0 (not at all) to 2 (a lot). Table values represent averages, where higher values (closer to 2) indicate higher endorsement of future plans. Standard deviations in parentheses.

Students expressed interest in specific engineering majors at the beginning of the Maker Space Lab and at the conclusion of the Maker Space Lab. At pre-test, Mechanical (35%) was the most prevalent engineering major identified, followed by Industrial (15%), Electrical (11%), Civil (11%), and so forth. At post-test, Mechanical (26%) remained the most prevalent, but students expressed interest in two new engineering majors: Biological Systems (5%) and Biomedical (5%), demonstrating that exposure to different areas of engineering developed new interests for students. See Figure 6 for overview of student's interest in majoring in engineering at pre-test and post-test. Students were also asked to identify the kinds of engineering jobs that they were interested in at post-test. Similar to engineering majors, Mechanical engineering (26%) was the most prevalent interest for future jobs, followed by Industrial (11%), Computer (11%), Chemical (11%), Civil (11%), and so forth. See Figure 6 for overview of student's interest in getting an engineering job at post-test.

Figure 6. Overview of Interests in Engineering Majors and Jobs





Finally, in the post survey only we asked students to retrospectively reflect on how their interest in engineering and related fields and skills had changed compared to before they enrolled in the Maker Fridays course. Table 7 provides the actual counts of their responses. Across most items, student did not indicate a change in interest, with the exception of "taking more engineering courses."

Table 7: Retrospective Interest Change

Compared to before you took this class, how has your interest changed in…? (n = 9)	Less	Same	More
Taking more STEM-related courses	0	7	2
Taking more hands-on, skilled trade courses	0	6	3
Taking more engineering courses	1	3	5
Majoring in a STEM-related field	0	7	2
Majoring in a hands-on, skilled trade, or technical program	0	6	3
Majoring in engineering	0	6	3
Having a STEM-related job	0	7	2
Having a hands-on, skilled trade job	0	6	3
Having an engineering-related job	0	6	3

Perceptions of Engineering (mDAET)

The Draw-An-Engineer-At-Work activity was administered to participants at the beginning and end of the semester during data collection. Participants were asked to draw three different engineers at work during the pre- and post-focus groups. Eight participants (out of 11) completed the mDAET at both data collection points. The mDAET activity was scored by a trained professional on four dimensions: the use of math in engineering (0-9), the use of science in engineering (0-6), gender stereotypes (0-9), and the work of an engineer (0-9).

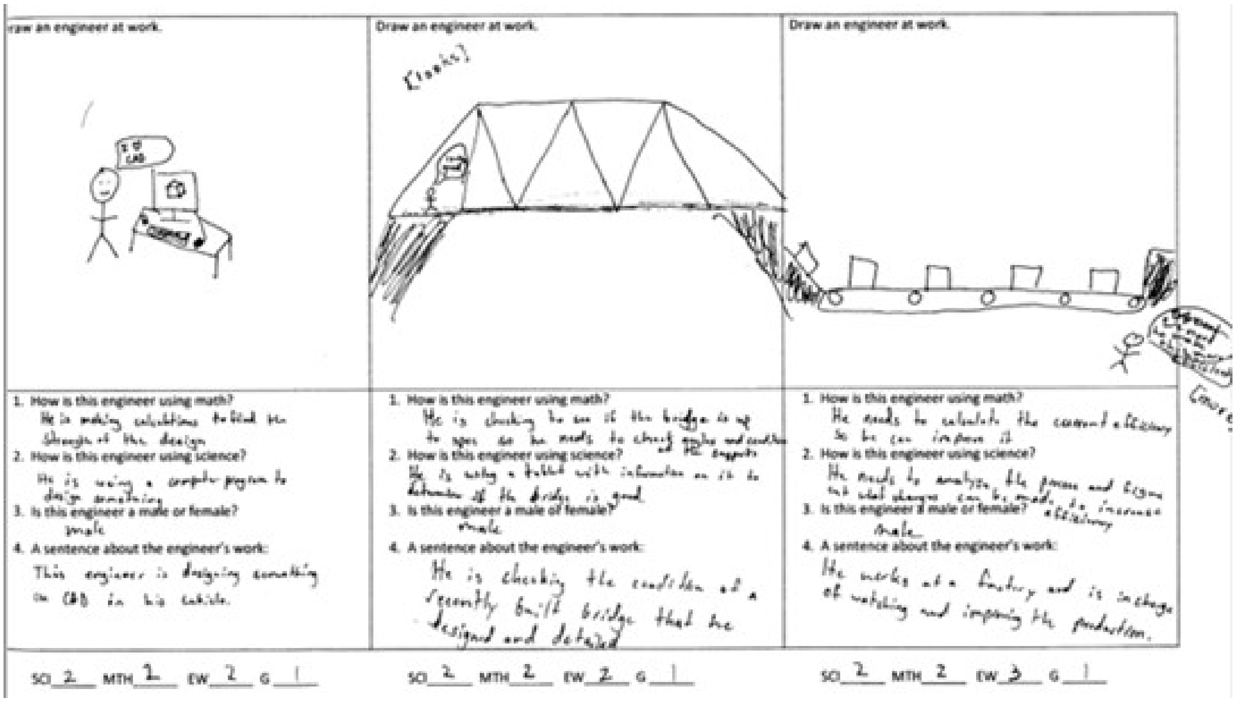
Overall, participant scores decreased as well as for the math, science, and gender dimensions, indicating that the accuracy of students' perceptions of engineers decreased over the course of the Maker Fridays experience. The only gain was observed in perceptions of the work of an engineer (+0.43), illustrating that after completing the ENGR 1010 course participants were drawing engineers with higher detail about the work of an engineer. Table 8 summarizes the pre- and post-mDAET scores for each dimension (math, science, gender, and engineering) for the three drawings. Figure 7 shows an example of a scored mDAET for one participant in the sample.

Table 8. Pre and Post mDAET Scores

	Pre (n = 8)	**Post** (n = 9)	**Change** (+/-)
Math (0-9)	3.88 (2.11)	3.77 (1.97)	-0.11
Science (0-6)	3.26 (2.56)	2.89 (2.27)	-0.37
Gender (0-9)	5.13 (3.02)	4.44 (2.77)	-0.69
Engineering (0-9)	6.01 (2.70)	6.44 (2.02)	+0.43
Total	18.28 (10.39)	17.54 (9.03)	-0.74

Notes. Raw scores for each dimension are identified in the table. Table values represent averages with standard deviations in parentheses.

Figure 7. Example of Participant's Scored mDAET



Engineering Knowledge (pre/post exam)

The ENGR 1010 pre/post exam was administered to students at the beginning and end of each semester by the course instructor. The pre/post exam consisted of five key components related to engineering: (1) ethics and canon, (2) energy sources, (3) engineering design process, (4) fields of engineering, and (5) project design. Each of the five components were evaluated based on a corresponding rubric created by the course instructor. The ethics and canon rubric focused on whether students could state the six National Society of Professional Engineers (NSPE) canons discussed in the course. The energy sources rubric focused on whether students could compare and contrast primary energy sources, where students picked three primary energy systems, listed the basic information for each, and provided the advantages and disadvantages. The engineering design process rubric focused on whether students could list the steps in the engineering design process, either by generating a complete list or state the steps in one of the detailed models discussed in the course. The fields of engineering rubric focused on whether students could compare and contrast the different fields of engineering, where students were tasks with listing five different fields and providing a brief description of what each involves. Finally, The project design rubric included procedures, evaluation, and cost, such that students were evaluated based on their ability to (a) write clear, duplicable procedures, (b) identify and describe multiple strengths and weaknesses in their prototype, and (c) generate a complete, organized list of costs. For all five rubrics, students were scored from one (unacceptable) to four (good).

Table 9 summarizes the results of the pre/post exam for participants. Overall, the results demonstrate that students scored higher on all five rubrics at post-test after completing the course. The highest gains were shown in the ethics and canon component, the energy sources rubric, and the engineering design process rubric. These results suggest that the ENGR 1010 course and Maker Space Lab increased students' knowledge on the five key components related to engineering.

Table 9. Pre/Post Exam Results

Rubrics	Pre-Test (n = 11)	Post-Test (n = 10)	Change (+/-)
Canons	0.94 (0.52)	1.88 (0.79)	+0.94
Ethics	0.71 (0.82)	1.59 (0.48)	+0.88
Energy Sources	1.06 (0.51)	1.88 (0.42)	+0.82
Engineering Design Process	1.47 (0.79)	2.12 (0.52)	+0.65
Five Engineering Fields	1.00 (0.52)	1.35 (0.67)	+0.35
Project Design			
Procedures	1.29 (0.77)	1.76 (1.05)	+0.47
Evaluation	1.18 (0.75)	1.59 (0.95)	+0.41
Budget	1.18 (0.75)	1.58 (0.82)	+0.40

Notes. Raw scores range from 1 to 4. Table values represent averages with standard deviations in parentheses.

Qualitative Findings

Using the same sample of high school students (n = 11), the qualitative findings are derived from focus groups with students at the beginning and end of each semester for all three cohorts. The qualitative findings are organized in three primary sections: *Maker Space Lab Experiences*, *Perceptions of Engineers*, and *Interest in Engineering*, which are based on pre- and post-focus group themes and subthemes.

Maker Space Lab Experiences

In this first section, we examined the research question of *How do high school students experience the Maker Fridays course?* To answer this question, four main components were explored: (1) student's perceptions of the Maker Space Lab during pre-test, (2) student's highlights of the Maker Space Lab at post-test, (3) any meaningful activities that students completed as part of the Maker Space Lab, and overall benefits of the Maker Space Lab.

Perceptions of Maker Space Lab. Although participants only had one week of experience in the Maker Space Lab during the pre-focus group, we wanted to gauge their initial perceptions of the Lab component to the Maker Fridays course. In general, participants were positive and expressed excitement about the anticipated projects throughout the semester. Participants were especially enthusiastic about projects that were more hands-on and allowed them to experience building something either by themselves or collaborating in teams. For some participants at their high schools, "we don't usually get to do shop or anything. We come here on Fridays and we get to do hands-on stuff, and that's really cool." 3D printing, soldering, welding, and CNC machines were some of the main tools and skills that students were excited to learning. Overall, participants were looking forward to these and other experiences that would help them in their future goals.

Highlights. Upon completion of the semester, we wanted to determine what some of the highlights were for students from the Maker Fridays course. Participants identified two related highlights from the Maker Space Lab component of the Maker Fridays course. First, participants appreciated completing different activities that required learning a variety of new tools, which included "a lot of different stuff from saws to soldering." Over the course of the semester, Maker Fridays students had access to tools including not but limited to a screwdriver, table saw, 3D printer, wire strippers, ratchets, solders, and V-CARB machine. One participant shared his highlight:

> "I would say having access to the tools and letting my mind creatively flow through the Maker Space stuff that definitely is what piqued my interest the most. I get to really think and put into perspective and design things that are in my head. I get to use their tools and use that little budget to get the stuff we need to either benefit the college or benefit ourselves."

Participants also liked the variety in project magnitude, where some projects included one to two people and other projects included the whole group working together to "figure out what worked best." Although favorite activities varied, participants shared that building the bookshelf, making a paddle boat, and designing the wooden car were highlights among several participants. The variety of activities and tools allowed participants to learn how to think critically on their own as well learn how to work collaboratively in a group; therefore, simultaneously learning skills necessary to be an engineer. One participant summarized, "We did different projects for different things of engineering. That's kind of the stuff that you're going to have to be dealing with when you're going into that line of engineering."

Extending the first highlight, the second major highlight from the Maker Space Lab was learning new skills in the course, which included hard skills and soft skills. For hard skills, participants enjoyed learning how to weld, how to solder, and working with computer-aided draft (CAD). One main soft skill emerged from participants' feedback, such that participants enjoyed the process of problem solving, particularly with the wooden car project. During this project, participants were tasked with building an efficient car using rubber bands and wooden pieces. By designing and testing their cars, participants had to problem solve how many rubber bands to create the right amount of tension, how many cranks to create enough energy, and so forth. This project, in particular, highlights the importance of problem solving and the capability of the Maker Space Lab to help students in developing these skills.

Meaningful Maker Space Activities. Throughout the semester, students were tasked with completing many engineering activities in the Maker Space Lab. There were two activities that especially stood out to participants as meaningful in some way: the car project and the education station project. For the car project, students worked in small groups to take a basic design of a wooden car and problem solve how to make the car more efficient and race faster than the other groups. Participants shared their experiences with redesigning the car, which included testing and retesting the number of rubber bands, the number of cranks, the overall design of the car, and so forth. They enjoyed problem solving with other students in the class, identifying what worked and what needed improvements, and seeing the end result of their work. For the education station project, students designed education activities such as a water wheel to teach the concept of electrical flow and a hands-on balsa wood bridge building project. Participants liked being able to take a basic template and redesign the structure to be more efficient. One participant shared, "I feel like everybody liked that more because you could use your ideas rather than looking at a piece of paper and saying, 'oh, I've got to do that.'" These two projects highlight that, in general, participants seemed to find projects more meaningful when they had a degree of autonomy and authority to be active contributors in the design and building process. As one participant summarized:

> "That's what I really love is the whole when you're done with it. You can be proud of what you've done and that came from my mind, and I made it into reality."

Benefits of Maker Space Lab. For many participants, the primary benefit of the Maker Space Lab was gaining the opportunity to better understand engineering, as related to the daily work, kinds of skills needed, and a broad understanding of the different types of engineering. As one participant shared,

> "The only things I knew about engineering were really what my brother and dad told me. Being in the Maker Space and in the classroom and seeing what I will learn once I get to college. I think [the Maker Space Lab] really helped me because it made me realize that I could actually do this for a living, and I'd like to do this for a living."

Other participants shared different realizations, such as engineers not only designing but also doing the work and finishing the project themselves or that engineers are much more hands-on than participants initially thought. One participant admitted that "I didn't quite understand what engineering was" before enrolling the Maker Fridays course. He further explained that:

> "I understood kind of what the process was and that you get paid a lot. Now I understand that there's a way bigger process to it than I first realized. There's so much information that you have to gather, that you have to write down, and you have to work in team groups. You have to learn about ethics, you have to learn about all these different things that are societal. It's not just 'Hey, I'm gonna build something. I'm a crazy scientist.' It's a completely different process than what I thought."

In addition, the Maker Space Lab set more realistic "expectations of what I'm going to be getting into" for participants interested in pursuing an engineering major and/or career. By participating in the Maker Space Lab, some participants felt that "it's made it surer that I want to go into one of the fields of engineering," highlighting that students' first-hand experiences with engineering concepts and activities can facilitate greater confidence in their abilities as well as their interest to continue pursuing this academic and professional route.

Perceptions of Engineers

The next section helps to address the research question of *How do high school students change their perceptions of engineering careers throughout the Maker Fridays course?* There were four components that emerged from the focus groups related to student's perceptions of engineers: (1) overall perceptions of engineers at work during pre-test, (2) thoughts on how students can become at engineer during pre-test, (3) any changes in student perceptions of engineers at work during post-test, and (4) any changes in their understanding of engineers during post-test.

Perceptions of Engineers at Work. The modified Draw-an-Engineer-at-Work (mDAET) exercise asked participants to draw what they think of when an engineer is at work. The purpose of the mDAET was to gauge participants' initial perceptions of engineering prior to the Maker Fridays course, including activities that engineers are tasked with, the environment they work in, how the engineers use math or science, whether the engineer is male or female, and a brief sentence bout the engineer's work.

During the pre-focus group, participants shared a variety of tasks that their engineers were engaged with, illustrating how participants consider engineering to be a multi-faceted job. The main task that participants described their engineers doing was thinking and problem solving, either an as individual or team-based. Participants envisioned their engineers either sitting at a desk or being more hands-on with the tasks, but in both settings, participants drew their engineers thinking, problem solving, and figuring things out. For example, one participant shared that their engineer was working on "how could they improve, how they could brainstorm something new, something different, something that could work more efficiently." Participants also described that the engineers were busy designing and testing their designs to ensure that their designs were efficient and as close to perfect as possible. One participant shared, "in each of my drawings, the engineer is designing something. They're either using blueprints or computer models for what they're doing." Another participant described the engineer testing different materials to assess the structural integrity of the materials. In addition, participants described several work environments for their engineer, including a temporary workspace, sitting in a cubicle, out in the field, in a factory, and at a construction site.

Becoming an Engineer. There were two primary components that participants felt were necessary to become an engineer. First, most participants agreed that engineers needed a lot of math and science courses, including physics and chemistry. Participants also shared that internships and a bachelor's degree in an engineer-related major were important for engineers. Second, participants shared several skills that engineers should learn, which included communication, working as a team, remaining calm under pressure, good leadership, not being afraid to start over, and hard work.

Changes in Perceptions of Engineers at Work.Next, research participants were asked to describe their Draw-an-Engineer-at-Work drawing during the post-focus group data collection for the purpose of identifying any changes after participating in the Maker Space Lab. Although there was a small subset of students who said their engineers changed only minimally, most students identified that their drawings were either more detailed or had more variety in the jobs that engineers were tasked with. By participating in the Maker Space Lab, participants were more aware of the "subproblems, or what could possibly go wrong with what they're trying to do," so their engineers were included more details about diagrams and measuring things. In addition, by having the opportunity to hear from guest speakers and engineers out in the field, participants included more variety in their drawings to illustrate that engineers "sit at a desk for some time but a lot of the time they're out doing stuff too." The activities and guest speakers provided participants a more well-rounded understanding of engineer's day-to-day tasks as well as the different work environments that often occur within their jobs. **Understanding of Engineering.** One purpose of the Maker Space Lab was to enhance high school students' understanding of engineering about the different types of engineering as well as the engineering process. Participants identified several components of the Maker Space Lab that enriched their understanding of engineering. First, participants emphasized the importance of each step in the engineering process, such that "you don't really realize that you're doing it, but you are.

Especially with redesign, you go through the entire [process] again." Their participation in the Maker Space Lab helped participants to "realize it's a little more complicated. You actually have to do testing and trying different solutions to make it better." As one participant explained, "it's not just one solution and you're done. You have to come up with several solutions." Overall, participants agreed that the Maker Space Lab not only taught them the explicit steps in the engineering process but demonstrated the importance of each step. Similarly, participants felt that the Maker Space Lab helped them to slow down and think, such that

"You have specific things that you have to do in order to get your finished product. I think that [the Maker Space Lab] really helped because it slowed everything down and made you think about what exactly has to go into this to make it work."

A couple of participants noted that the Maker Space Lab also (a) encouraged them to develop more hands-on skills needed of engineers to complete common tasks and (b) promoted collaborations with classmates in order to learn how to work with people with a "variety of different opinions." By emphasizing each step, slowing down to think, working hands-on, and collaborating with others, participants felt that the Maker Space Lab matched the type of work and skills needed to work as an engineer in the field.

Interest in Engineering

The final section focuses on answering the research question of *How do high school students change their interest in engineering careers throughout the Maker Fridays course?* To achieve this purpose, there are four subsections related to interests in engineering before and after completing the Maker Fridays course: (1) overall interest in Maker Fridays at pre-test, (2) students backgrounds that motivate their interests at pre-test, (3) student's interest in certain branches of engineering at pre-test, and (4) student interest in engineering at post-test.

Interest in Maker Fridays. Enrolling in the Maker Fridays pre-engineering course stemmed primarily from two motivations. First, participants had a genuine interest in engineering and saw the course as an "opportunity to learn more about engineering that I'm interested in." A couple of participants commented that, "I've been looking forward to engineering." Second, participants saw Maker Fridays as a chance to see "if this was my type of field," and "which kind of engineering, if any of them, that I wanted to pursue." By enrolling in the course, participants believed they would be able to explore different kinds of engineering (e.g., mechanical, agricultural, etc.) in order to make plans in the future regarding their majors and/or careers.

Backgrounds. For many participants, the reasons for enrolling in Maker Fridays dealt with their backgrounds in engineering and engineering-related fields. Several participants shared that family members, such as dads, uncles, brothers, and sisters, were employed in an engineering-related field. One participant noted a family member who was an engineer would "talk about how people should have made it like this, or people should have made it like that." One participant shared that his dad, sister, and brother all went into metallurgical engineering, "so I figured I'd give it a shot." Other participants shared that their interest and enjoyment in engineering started "when I was younger." Helping family members, working on their own projects, and gaining that experience for themselves at a younger age guided participants to wanting to seek additional opportunities to better understand the engineering process.

Branches of Engineering. Participants were asked at the beginning of the semester to identify which branch (if any) of engineering that they were currently interested in pursuing. Mechanical engineering as the most cited branch, with participants sharing that "I'd be cool to work with machines, knowing how they work and how to improve them" and "mechanical is such a broad field and they give you a lot of options, like aerospace or automotive." Chemical engineering was the second most cited branch of engineering, such that participants were drawn to the ability to "improve formulas and stuff people use in their daily lives, like pesticides." Finally, civil was the last branch of engineering that participants were considering in order to "work on things people use and need."

Interest in Engineering. As a part of understanding engineering, participants were asked to reflect on whether they experienced any changes in their preferred engineering type over the semester. A small subset of participants shared that participating in the Maker Space Lab, in fact, solidified their decision to study and/or pursue a specific type of engineering. The remaining participants expressed that their interests had changed over the semester, given the new information learned in the Maker Fridays pre-engineering course. For example, some participants transitioned from civil to mechanical, whereas other students were able to eliminate which type(s) of engineering that they were uninterested in. One student shared that "I'm still very interested in engineering and architecture, but I'm looking to everything a bit more closely," highlighting that the breadth of engineering types covered in the course opened up more possibilities for participants. In the end, student experiences in the Maker Space Lab either allowed them to be more confident in their major and/or career plans or be clearer about the engineering type(s) they are not interested in pursuing.

Mixed Methods Integration

Table 10 provides a side-by-side integration matrix of the quantitative results and qualitative findings. This visual joint display addresses the research question, *"How do the activities and strategies in the Maker Fridays course influence high school student perceptions of and interests in engineering careers?"*

Table 10: Mixed Methods Integration via Joint Display of Results

How much do you like to…	Change (+/-)	Participant Quotes
Communicate recommendations or solutions	+0.38	"Engineers need to be able to communicate with people and work as a team."
Design something new	+0.31	"I get to really think and put into perspective and design things that are in my head."
Keep track of details	+0.31	"You're keeping a notebook with all of your tabs, you're making budgets, you're making all of this stuff just so you can do a step by step process on how to solve a solution for a client."
Evaluate potential solutions	+0.22	"It's not just one solution and you're done. You have to come up with several solutions."
Define problems	+0.08	"My engineers are more aware of sub problems or what could go wrong with what they're trying to do."
Identify needs	-0.03	"My engineer is in a team-based manner working with somebody to figure out what needs to be done and how best do to it."
Brainstorm new ideas	-0.08	"My engineer is figuring out how they could brainstorm something new, something different."
Solve real-world problems	-0.12	"This class definitely taught me a lot of things that I hadn't had in a real-life situation. The process has also taught me real life qualities and things that I can put into effect."
Figure out how to improve something	-0.15	"My engineer is figuring out how could they improve something that could work more efficiently."
Figure out how things work	-0.17	"I like seeing how things work. Like how things turn, how things move in a system and all that kind of stuff."
Make things	-0.33	"I like to get to do something, make something and see how it works."
Build things	-0.35	"My highlight was the prototypes you're building, seeing if they can support a certain amount of weight and seeing how good the material is that they're using."
Ask questions	-0.58	
Help other people	-1.11	"My engineers want to help people. Make life easier for other people that need it."

Discussion

The participation in the Maker Fridays course, and therefore participation in the research project, was well below the initial expectations. This makes drawing any conclusions from this study tenuous, at best. Ceiling effects of the quantitative responses certainly impact the analysis, as student responses indicated a strong interest in engineering at time one. This leaves little room for students to indicate an increased interest in engineering. The results themselves are difficult to interpret. For example, the largest gain in future plans pre/post was interest in majoring in hands-on, skilled trade, or technical program, while the largest decrease was in taking more hands-on, skilled trade courses. Although the quantitative pre/post results, in general, suggest a possible decrease in interest in engineering, the retrospective (post only) responses indicate a no change in the interest levels. The qualitative findings present a slightly more positive picture. Participants articulated greater refinement in their engineering interest. The integration of quantitative results with qualitative findings in the joint visual display illustrates is dissonance of small decreases in interest juxtaposed with generally positive comments.

What is clear from this study is that the instructor was responsive to student feedback and the participants enjoyed the maker space activities. Additional studies are needed to determine if maker space lab activities have a meaningful impact on students' interest in engineering. We would encourage future studies to obtain a larger and more diverse sample.

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Appendix A: Engineering Interest Inventory

Classroom Experiences

1. Here is a list of science, math, technology, and engineering courses offered in many high schools. Mark the courses you've taken (or plan to take) **before you graduate high school**.

   Check one answer for each course.

	Taken	Plan to take	Do not plan to take
Pre-Algebra	☐	☐	☐
Algebra I	☐	☐	☐
Geometry	☐	☐	☐
Algebra II	☐	☐	☐
Pre-Calculus	☐	☐	☐
Calculus	☐	☐	☐
Biology	☐	☐	☐
Anatomy	☐	☐	☐
Chemistry	☐	☐	☐
Physics	☐	☐	☐
Computer Science	☐	☐	☐
Earth Science	☐	☐	☐
Environmental Science	☐	☐	☐
Engineering	☐	☐	☐
Industrial Arts (Shop, Automotive, etc.)	☐	☐	☐

Extracurricular Experiences

2. Here is a list of science, math, technology, and engineering extracurricular experiences that you may have participated in during high school.

Mark the activities you have participated in <u>**during high school**</u>.
Check one answer for each experience.

	Participated	Did not Participate
Participated in a STEM-related club (robotics, coding, math, rockets, etc.)	☐	☐
Participated in Skills USA	☐	☐
Competed in a STEM-related quiz bowl competition (Science/Math Olympiad, etc.)	☐	☐
Completed a STEM-related project	☐	☐
Completed a hands-on project (shop projects, fixing cars, etc.)	☐	☐
Attended a STEM-related camp	☐	☐
Participated in a Science Fair	☐	☐
Had a STEM-related internship or job	☐	☐
Had a hands-on job (construction, automotive, welding, plumbing, etc.)	☐	☐
Other (please specify)	☐	☐

____

Connections

3. Do you know someone who has an engineering job?
☐ Yes
☐ No
☐ Not sure

3a. If yes, what kind of engineering job does that person have?
____

4. Do you know someone who has a hands-on, skilled trade job?
☐ Yes
☐ No
☐ Not sure

4a. If yes, what kind of hands-on, skilled trade job(s) does that person(s) have?
____

5. Do you know someone who has a STEM-related job?
☐ Yes
☐ No
☐ Not sure

5a. If yes, what kind of STEM-related job(s) does that person(s) have?
____

6. How much has someone encouraged you to go to college?
☐ A lot
☐ Some
☐ None at all

6a. If a lot or some, who has encouraged you? (check all that apply)
☐ Family member
☐ Teacher
☐ Counselor
☐ Friend
☐ Mentor
☐ Public Person
☐ Other (please specify) _____________________

7. How much has someone encouraged you get a hands-on, skilled trade job?
☐ A lot
☐ Some
☐ None at all

7a. If a lot or some, who has encouraged you? (check all that apply)
☐ Family member
☐ Teacher
☐ Counselor
☐ Friend
☐ Mentor
☐ Public Person
☐ Other (please specify) ________________________

8. How much has someone encouraged you get an engineering-related job?
☐ A lot
☐ Some
☐ None at all

8a. If a lot or some, who has encouraged you? (check all that apply)
☐ Family member
☐ Teacher
☐ Counselor
☐ Friend
☐ Mentor
☐ Public Person
☐ Other (please specify) ________________________

9. How much has someone encouraged you to get a STEM-related job?
☐ A lot
☐ Some
☐ None at all

9a. If a lot or some, who has encouraged you? (check all that apply)
☐ Family member
☐ Teacher
☐ Counselor
☐ Friend
☐ Mentor
☐ Public Person
☐ Other (please specify) ________________________

Interests

10. How much do you like to figure out how things work?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

11. How much do you like to design something new?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

12. How much do you like to figure out how to improve something?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

13. How much do you like to make things?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

14. How much do you like to solve real-world problems?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

15. How much do you like to keep track of details?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

16. How much do you like to build things?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

17. How much do you like to help other people?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

18. How much do you like to ask questions?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

19. How much you do like to define problems?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

20. How much do you like to identify needs?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

21. How much do you like to brainstorm new ideas?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

22. How much do you like to evaluate potential solutions?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

23. How much do you like to communicate recommendations or solutions?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

Abilities

24. How much has participating in the Maker Space Lab improved your ability to figure out how things work?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

25. How much has participating in the Maker Space Lab improved your ability to design something new?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

26. How much has participating in the Maker Space Lab improved your ability to figure out how to improve something?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

27. How much has participating in the Maker Space Lab improved your ability to make things?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

28. How much has participating in the Maker Space Lab improved your ability to solve real-world problems?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

29. How much has participating in the Maker Space Lab improved your ability to keep track of details?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

30. How much has participating in the Maker Space Lab improved your ability to build things?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

31. How much has participating in the Maker Space Lab improved your ability to help other people?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

32. How much has participating in the Maker Space Lab improved your ability to ask questions?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

33. How much has participating in the Maker Space Lab improved your ability to define problems?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

34. How much has participating in the Maker Space Lab improved your ability to identify needs?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

35. How much has participating in the Maker Space Lab improved your ability to brainstorm new ideas?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

36. How much has participating in the Maker Space Lab improved your ability to evaluate potential solutions?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

37. How much has participating in the Maker Space Lab improved your ability to communicate recommendations or solutions?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

Future Plans

38. How interested are you in taking more STEM-related courses?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

39. Compared to before you took this class, how has your interest in taking more STEM-related courses changed?
    - ☐ I have more interest
    - ☐ I have about the same level of interest
    - ☐ I have less interest

40. How interested are you in taking more hands-on, skilled trade courses?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

41. Compared to before you took this class, how has your interest in taking more hands-on, skilled trade courses changed?
    - ☐ I have more interest
    - ☐ I have about the same level of interest
    - ☐ I have less interest

42. How interested are you in taking more engineering courses?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

43. Compared to before you took this class, how has your interest in taking more engineering courses changed?
    - ☐ I have more interest
    - ☐ I have about the same level of interest
    - ☐ I have less interest

44. How interested are you in majoring in a STEM-related field?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

45. Compared to before you took this class, how has your interest in majoring in a STEM-related field changed?
    - ☐ I have more interest
    - ☐ I have about the same level of interest
    - ☐ I have less interest

46. How interested are you in majoring in a hands-on, skilled trade, or technical program?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

47. Compared to before you took this class, how has your interest in majoring in a hands-on, skilled trade, or technical program changed?
    - ☐ I have more interest
    - ☐ I have about the same level of interest
    - ☐ I have less interest

48. How interested are you in majoring in engineering?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

49. Compared to before you took this class, how has your interest in majoring in engineering program changed?
    - ☐ I have more interest
    - ☐ I have about the same level of interest
    - ☐ I have less interest

50. Which types of engineering are you interested in majoring? (select all that apply)
    - ☐ Chemical
    - ☐ Civil
    - ☐ Computer
    - ☐ Electrical
    - ☐ Industrial
    - ☐ Mechanical
    - ☐ Other (please specify) ________________________________

How interested are you in having a STEM-related job?

- ☐ A lot
- ☐ Some
- ☐ Not at all

51. Compared to before you took this class, how has your interest in having a STEM-related job changed?
    - ☐ I have more interest
    - ☐ I have about the same level of interest
    - ☐ I have less interest

52. How interested are you in having a hands-on, skilled trade job?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

53. Compared to before you took this class, how has your interest in having a hands-on, skilled trade job changed?
    - ☐ I have more interest
    - ☐ I have about the same level of interest
    - ☐ I have less interest

54. How interested are you in having an engineering-related job?
    - ☐ A lot
    - ☐ Some
    - ☐ Not at all

55. Compared to before you took this class, how has your interest in having an engineering-related job changed?
    - ☐ I have more interest
    - ☐ I have about the same level of interest
    - ☐ I have less interest

56. Which types of engineering jobs are you interested in? (select all that apply)
    - ☐ Chemical
    - ☐ Civil
    - ☐ Computer
    - ☐ Electrical
    - ☐ Industrial
    - ☐ Mechanical
    - ☐ Other (please specify) ________________________________

Demographics

57. How old are you?
- ☐ 15
- ☐ 16
- ☐ 17
- ☐ 18
- ☐ 19
- ☐ Other (please specify) _________

58. What grade are you in?
- ☐ 10th grade
- ☐ 11th grade
- ☐ 12th grade
- ☐ Other (please specify) _________

59. Which of the following best describes your gender?
- ☐ Male
- ☐ Female
- ☐ Prefer not to say

60. Which of the following describes your race? (select **all** that apply)
- ☐ Asian
- ☐ Black or African-American
- ☐ Native American
- ☐ Native Hawaiian/Other Pacific Islander
- ☐ White or Caucasian
- ☐ I don't know
- ☐ Prefer not to say

61. Which of the following best describes your ethnicity?
- ☐ Hispanic or Latino
- ☐ Not Hispanic or Latino
- ☐ I don't know
- ☐ Prefer not to say

62. Have you ever qualified for free or reduced school lunch?
- ☐ Yes
- ☐ No
- ☐ I don't know
- ☐ Prefer not to say

Appendix B: Focus Group Protocols

Pre Focus Group Protocol

1. Please introduce yourself and share why you registered for this course.
2. Describe your drawings of engineers.
    - What are your engineers doing?
    - How do engineers spend their time?
    - What kinds of tools are your engineers using?
3. What do you imagine the engineers in your drawings think about the work that they do?
    - Why do engineers like doing engineering?
    - How much money do you think engineers make?
    - How does that compare to other careers?
4. How would you describe what non-engineers think about engineers?
    - How accurate are those descriptions?
5. Tell us about your experience in the Maker Space lab?
    - What did you like?
    - What didn't you like?
    - What do you hope you get to do?
    - How could we make it better?
6. What kinds of engineering work would you be most interested in doing? Least interested?
7. What would you need to do if you wanted to get a job in engineering?

Post Focus Group Protocol

1. Please introduce yourself and share a highlight from the course
2. Describe how your drawings of engineers has changed from the beginning of the semester?
3. Tell us about your experience in the Maker Space lab?
    - Which activities were the most meaningful?
    - Which activities were the least meaningful?
4. How has the Maker Space lab helped you understand the engineering design process?
5. We have been watching the videos from the Maker Space lab, but we don't get to see what happens in class after the lab. I'd like to hear about the discussions you had after the Maker Space lab activities.
6. What have you learned about careers in engineering as a result of participating in this course?
    - Review list of guest speakers…which did they like/not like
7. How has the Maker Space lab changed your interest in a career in engineering?
    - What kinds of engineering work are you most interested in doing now?
    - How did the Maker Space lab help you identify what kind of engineering you are interested in?
8. How have you benefited from participating in the Maker Space lab?
9. What suggestions do you have to improve the Maker Space lab?