Assessment of Innovative Skill Development in Weekend Challenges

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Mr. Rodney Boehm, Engineering Academic and Student Affairs

Rodney Boehm has joined the Engineering Academic and Student Affairs (EASA) team as an Industry Mentor with very broad experiences, including the creation of a telecommunications standard for the fiber optics industry that is still in use internationally over 25 years later, a wide variety of business experiences in an international company, and start up experience that have helped him hone his ability to quickly determine a direction and execute to it.

He is also formerly the Chief Operating Officer for GroundFORCE, a company that specializes in a unique patented construction technology. His extensive experience in running sales, marketing, manufacturing, and large multi-national organizations was applied to introducing this new technology to the construction industry.

Formerly he was a Senior Vice President of Fujitsu Network Communications, headquartered in Richardson, Texas. With over 30 years of experience in telecommunications, Rodney was responsible for developing partnerships with leading network technology providers and driving marketing efforts for optical, access and data products developed by Fujitsu. Along with Yau Chow Ching, Rodney conceived (and wrote the standards for), the SONET (Synchronous Optical Network) architecture, which served as the base for today's North American telephone network. Rodney was Chairman of the T1X1 Technical Sub-Committee (the organization responsible for SONET standardization) from 1990 through 1994. He has been active in SONET's National and International Standardization since 1985. In addition, Rodney has published numerous papers and presentations on SONET.

Rodney began his career with Fujitsu Network Communications in 1989 as the Director of Strategic Planning. He also held the positions of Director of Transport Product Planning, Vice President of Business Management, Senior Vice President of Sales Management, Senior Vice President of Manufacturing, and Senior Vice President of Business Development. Before joining Fujitsu, Rodney worked for Bell Laboratories, Bellcore (now Telcordia), and Rockwell International. He earned both his bachelor's and master's degrees in electrical engineering at Texas A&M University.

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Assessment of Student Outcomes in a 48-Hour Intensive Innovation Experience

Introduction

Recent reports (1, 2) have highlighted the need to promote development of innovative skills and entrepreneurial mindsets among undergraduate engineering students. This paper will focus on a new extracurricular 48-hour weekend Intensive Innovation Experience (IIE) designed to provide teams of engineering undergraduates opportunities to pursue rapid development of hardware prototypes for needs identified by industry and non-profit organizations. Over the 48-hours, program participants have access to the maker facility, professional staff, and industry and graduate student mentors. At the end of the event, student teams present their designs and compete for awards. After the conclusion of the event, student teams are encouraged to pursue their innovative solutions to further maturation. This paper will first provide an overview of how the program that was launched in Summer 2014, was developed and implemented. It has been offered three times since then. Next, the authors will present data on achievement of student outcomes in five areas: 1) understanding the design process, 2) problem solving, 3) effective communications, 4) team work, and 5) time management. Finally, the paper will present demographics and post-graduation plans of program participants. For program dissemination, the authors will present detailed program information at the poster session hosted at the same conference.

Background

In 2011, the National Advisory Council on Innovation and Entrepreneurship (NACIE) members submitted a letter entitled "*Recommendation to Facilitate University-Based Technology Commercialization*" (1) to Secretary of Commerce Locke. The letter, signed by 146 of America's leading institutions, included in the recommendations the need to develop student programs to provide new opportunities for experiential learning and promote student innovation and entrepreneurship. In response to the above letter, the US Department of Commerce conducted a series of interviews with institutions across the nation in an effort to understand how universities are nurturing and promoting innovation/entrepreneurship and published the "*The Innovative and Entrepreneurial University; Higher Education, Innovation & Entrepreneurship in Focus*" (2). While there is significant research on innovation and entrepreneurship within the formal curriculum (3, 4) there is less focus on extra-curricular programs. Authors believe informal programs offer a great opportunity to engage engineering students in activities promoting innovation and entrepreneurship as it has been shown by the impact of Innovation Challenges on the development of innovative skills (5). Per C. Amelink et al. (5), innovative thinking skills include: a) critical thinking and effective generation of new ideas, b) application and integration of science/engineering content knowledge, c) ability to organize new information/ideas/products articulately, d) ability to communicate ideas to peers and others, effective use of technology/tool selection in design process, e) complex thinking process that transforms a creative idea into useful services/products,

potential for prototyping/commercialization. The program discussed here has been developed to promote innovation with focus on the following learning outcomes: Understanding of Design (a thru e), Problem Solving (a thru e), Teamwork (d), Effective Communication (d), and Time Management (d). Each of the desired learning outcomes are connected to one or more of the innovative thinking skills identified by (5). This paper describes an overview of the development and implementation of a unique informal program and the assessment data from student surveys. The program brings together students from across several engineering majors and classifications to work intensely for 48 hours to develop and build rapid prototypes, solving problems (described by Need statements) sponsored by industry and nonprofit organizations.

Program Development and Implementation

The program is an intense creative and innovative weekend event, which challenges students to solve real world industry and agency problems by using the varied skills of each team member. At times, this process can be chaotic, messy, and tense but incredibly rewarding for the students and sponsors. The program is offered every semester and each time the theme of the program is different thus targeting students with different interests. Because the program is so intense, it requires well-structured approaches in four key areas: preparation, delivery, facility, and follow-up.

Preparation

There are three key threads throughout the process of preparing for the program. The first is establishing the overall theme. The theme is the single item that will rally sponsors, mentors, and students. Past themes include wearable technologies, medical devices, and solutions for first responders. These were considered because of the wealth of opportunities they provide for sponsors to identify problems and also because of student interest. The second thread is gathering need statements, Mentors, and planning for anticipated needs. Need statements define the problem that a sponsoring organization wants solved. Successful need statements are open design problems where students will have a chance to make significant progress towards a solution over the weekend. Because there is little time to obtain additional material during the weekend, it is critical that faculty/staff gain a basic understanding of potential solutions to these needs and gather supplies and support that students might need. Anticipating supply needs beforehand enhances student's ability to create. While certain technologies are important to have on hand, many times the messy creative design experience depends on tape, cardboard, glue, rubber bands, and sticky notes. It is also important to have faculty/staff on hand that are resources for key technologies or construction platforms providing support and answering questions. Finally, the third thread is people. This starts with Sponsors who help fund the event, Mentors who support Need statements, Faculty/Staff who provide the background resources, and Students who brainstorm concept ideas, develop prototypes and present the final solution to the sponsoring organization. Student participants are selected through an application process where applicants list their academic skills,

related experiences, and interest in the theme. The applicant selection process also considers freshmen and sophomores who might not have significant technical skills but demonstrate strong interest in the theme.

Delivery

The program starts with student participants meeting the industry sponsors to learn more about the proposed need statements. Following that, project teams (5-6 students per team) are formed based on student project preferences. Each team meets their industry mentor to discuss the details of the project scope and design requirements to design an acceptable solution. The rest of the weekend is spent in developing and testing prototype solutions, in collaboration with the industry mentors. Table 1 provides a program overview.

Table 1. Program Overview

Activity	Description	Purpose
Overview	Briefly explain the process, resources available (physical and people), facility use, and schedule	Introduce students to full capabilities of the facilities as quickly as possible to maximize results
Motivation	Inspire with videos, music, ice breakers, or innovative people	Foster an environment to break down barriers, try new concepts, push beyond Needs, challenge status quo, set the culture
Team Formation	Students select Needs to work on and self-select team members	Insures students work on something that interests them with people they want to spend the weekend with
Prototype Development	Develop conceptual designs, identify baseline design, develop prototype, test and update design, if needed.	Provides students an opportunity to apply science and engineering skills in solving a real world problem and also practice the engineering design process
Checkpoints	Short checkpoint reviews with faculty/staff to ensure progress, solve roadblocks, suggest additional work/considerations	Provides accountability and identifies teams who are fixated and need to be pushed further
Presentation	Teams present design solutions / products to judges	Encourages effective communication

Project Examples

Each weekend experience is designed with an overall theme. Project sponsors include industry, nonprofits organizations such as Red Cross and local hospitals, and government agencies such as NASA, Sandia Labs, and the United States Air Force. Below is a short description of three projects of the program:
- Design a multi-purpose tool which combines the functions of several tools into one tool to be used by first responders dealing with hazardous materials.
- Design a low-cost fire alert network system which can be installed in heavily "populated areas in developing counties to alert occupants in case of fire anywhere in the vicinity.
- Design a system which will monitor at risk neonates and collect vital health information without attaching anything to the infant.

Student Participation

The inaugural program was offered in 2014 summer with forty-three student participants while the fall 2014 program engaged sixty-three students. As it is shown in Figures 1 thru 4, the program attracts students from freshman to graduate students and also participants represent many engineering majors and with a small fraction of participants being from another college.
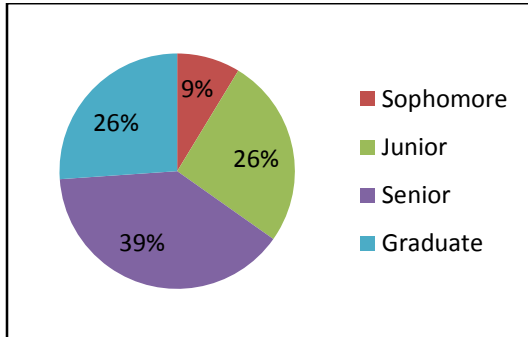

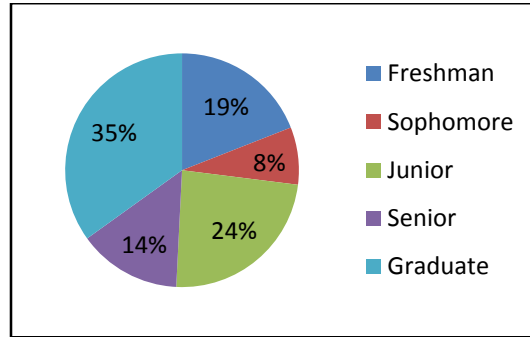**Figure 1. Participant Classification (summer 2014)**
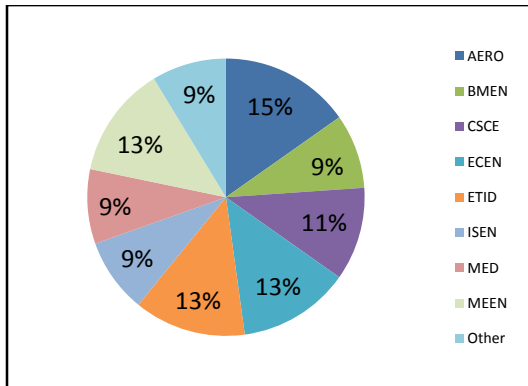

Figure 2. Participant Classification (fall 2014)

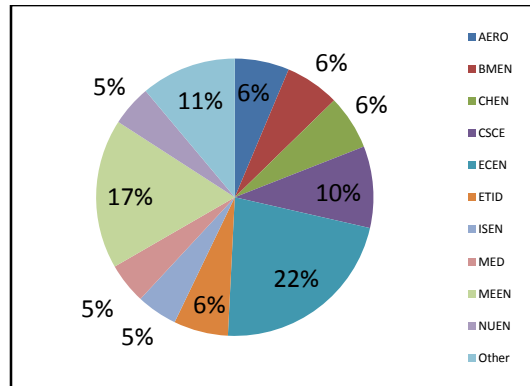**Figure 3. Participant Majors (summer 2014)**

Figure 4. Participant Majors (fall 2014)

Facility

A critical component of any successful program is the space that supports and facilitates implementation. Many have called this a "Maker Space" which describes its function – enable students to "Make/Build" their ideas. The institution has established a 20,000 square feet facility dedicated solely to engineering undergraduates. The facility was developed to provide a multi-functional workspace for undergraduate engineering students. Primary users fall into three categories, senior capstone design teams, various multidisciplinary and vertically integrated teams, and student design competitions. Other students have access to the facility by participating in a variety of programs offered at the facility to promote innovation. These include the 48-hour program described in this paper, training sessions in more than twenty topics, and other special events. The facility provides collaborative

workspace, project storage space, specialty workstations, fabrication facilities, access to electronic components, conference rooms, digital media room, and professional staff. The specialty workstations include: weights and measurements, soldering, industrial sewing, hand tools, electronic measuring, and wet lab. Students have access to an extensive list of components, which include electronic sensors, programmable controllers, and nuts and bolts. The facility includes a 7,000 square feet fabrication center which consists of a machine shop (lathes, mills, sanding, grinding, and cutting), prototyping center (Stratasys and other type 3D printers, laser cutter, and fabrication for printed circuit boards), woodshop, welding lab and paint rooms. In addition, the facility is supported by two full time professional staff and several student workers.

Follow-Up

Based on student feedback, the program offers a follow-up event for students interested in pursuing their project after the program concludes. To facilitate this, interested teams are invited to attend an event where they are presented with campus-wide resources available to them. These include mentors associated with the institution who can support the teams as they continue developing their idea, resources for intellectual property, and access to a university student incubator.

Achievement of Student Outcomes

The program participants were asked to provide feedback in an online survey. The survey, Appendix A, includes questions from several previous studies of student assessment outcomes (6, 7) and also new questions designed to capture student input for areas unique to the program. Overall, 67% of the summer program participants and 68% of the fall program participants participated in the online survey.

<u>*Understanding the Design Process*</u>**:** Participants were asked to rate their growth in a five-level Likert-type scale (*strongly agree / agree/ not sure/ disagree/ strongly disagree)* in their ability to:
- identify critical needs /requirements in an open ended problem (Q1)
- develop and evaluate conceptual designs and select best fits (Q2)
- integrate hardware and software for prototype development (Q3)
- utilize modern rapid prototyping tools for prototype demonstration (Q4)
- apply mathematics, science, and engineering knowledge to evaluate prototype performance (Q5)
- understand the process of design in engineering (Q7)

As shown in Figure 5, more than 90% of participants agree or strongly agree that as a result of their involvement in the program they have improved their ability to identify critical needs/requirements (Q1), develop and evaluate conceptual design (Q2), integrate hardware and software (Q3) and understand the process of design (Q7).
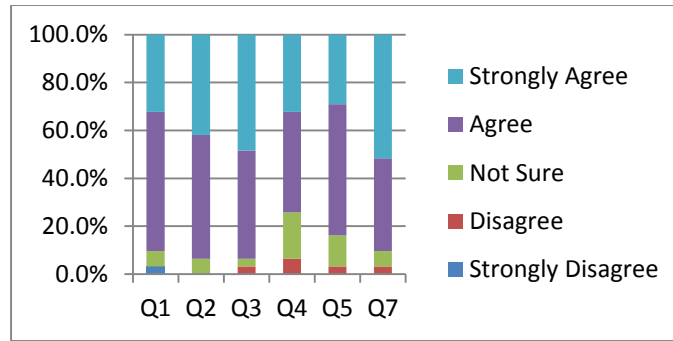
Figure 5. Design Process

Problem Solving: Participants were asked to rate their growth (in a similar five-level Likert-type scale) in their ability to:
- identify what information is needed to solve a problem (Q8)
- apply an abstract concept or idea to a real problem or situation (Q9)
- divide problems into manageable components (Q10)
- develop several methods that might be used to solve a problem (Q11)
- use established criteria to evaluate and prioritize solutions (Q12)

As shown in Figure 6, more than 90% of participants *strongly agree or agree* that they have improved their ability in problem solving skills associated with questions Q8, Q9, Q10, Q12.
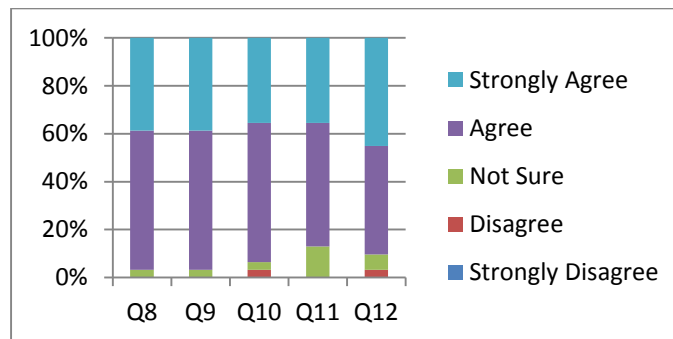

Figure 6. Problem Solving

Effective Communication: Participants were asked to rate their growth (in a five-level Likert-type scale) in their ability to:
- clearly describe a problem orally (Q13)
- clearly describe a problem in writing (Q14)
- showcase their skills to others (Q15)

More than 80% of participants *strongly agree or agree* (figure 7) that they have improved their ability for oral presentations (Q13) and showcasing their skills to others (15) while there is less improvement in describing a problem in writing since the program did not include many opportunities for participants to develop written reports.
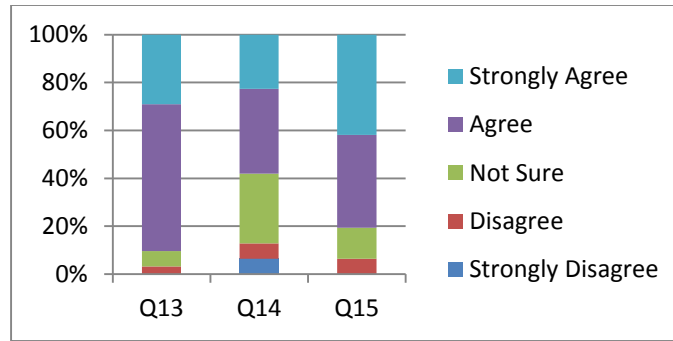
Figure 7. Effective Communication

*Teamwork***:** Participants were asked to rate their growth (in a five-level Likert-type scale) in their ability to:

- develop ways to resolve conflict and reach agreement in a group (Q16)
- be aware of feelings of other members of the group (Q17)
- listen to the ideas of others with an open mind (Q18)
- work on collaborative projects as a team member (Q19)
- ask probing questions that clarify facts, concepts, or relationships (Q20)
- after evaluating the alternatives generated, develop a new alternative that combines the best qualities and avoids the disadvantages of the previous alternatives (Q21)
- evaluate arguments and evidence so that strengths and weaknesses of competing alternatives can be judged (Q22)
- be patient and tolerate the ideas or solutions proposed by others (Q23)
- understand that a problem may have multiple solutions (Q24)
- use discussion strategies to analyze and solve a problem (Q25)
- recognize contradictions or inconsistencies in ideas, data, images (Q26)
- recognize flaws in my own thinking (Q27)
- identify the constraints on the practical application of an idea (Q28)

More than 77% of participants *strongly agree or agree* (Figure 8) that they have improved their ability in all areas of teamwork questions.
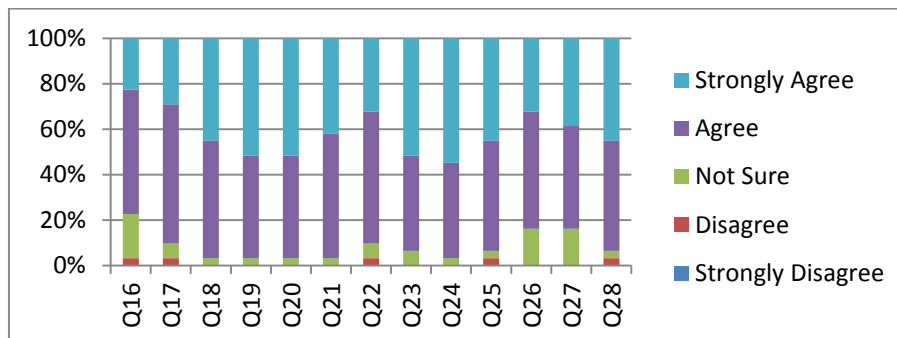

Figure 8. Teamwork

*Time Management***:** Participants were asked to rate their growth (in a five-level Likert-type scale) in their ability to:

- estimate required time for each task (Q29)
- prioritize tasks in the order of their importance and relevance (Q30)
- adhere to a timeline (Q31)

The intensity of the program encourages students to practice good time management skills and as shown in Figure 9 more than 80% of participants strongly agree or agree that they have improved their time management skills (questions Q29-Q31).
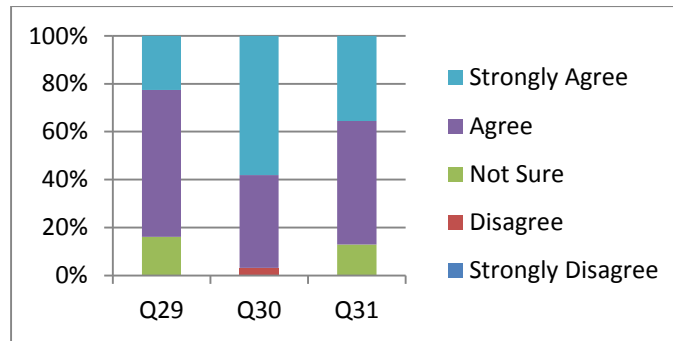

Figure 9. Time Management

Reasons for Participating: Furthermore, authors are interested to investigate the types of students attracted to this program since this type of data will assist efforts to further improve the program. Participants were asked for their reason for participating in the weekend experience:
- have a general interest in program theme (Q32)
- have a general interest in innovation (Q33)
- have a general interest in building prototypes (Q34)
- broaden your career prospects and choices (Q35)
- want to examine my own qualifications (Q36)
- want to become an entrepreneur (Q37)
- have an idea for a business or product (Q38)

As shown in Figure 10, more than 97% of participants *strongly agree / agree* that they participated in the program because they have a general interest on innovation while 87% of participants stated also that the reason for participating was to broaden their career prospects (*strongly agree/agree*).
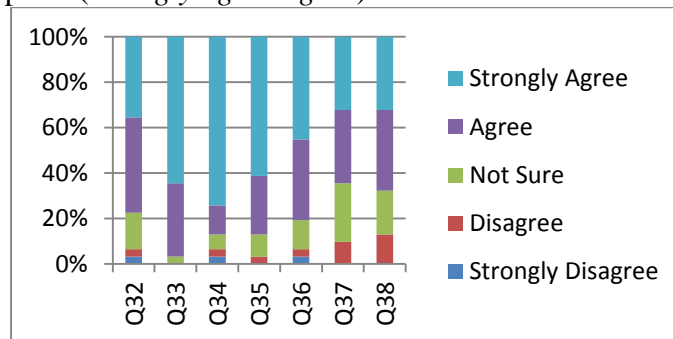

Figure 10. Reason for Participation

Post-graduation Plans: Figure 11 shows participant response when they were asked about Participants were about their post-graduation plans:

- work for a large-sized corporation (Q39)
- work for a medium-sized business (Q40)
- work for a small-sized business (Q41)
- work for a non-profit organization (Q42)
- work for the government (Q43)
- pursue graduate studies (Q44)
- start own business (Q45)

More than 61% *strongly agree / agree* that their post-graduation plans include starting their own business while 52% *strongly agree / agree* that they will pursue graduate studies (participants provided input for multiple post-graduation plans).
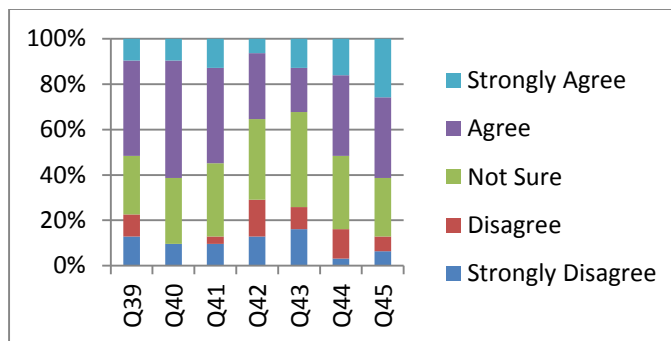

Figure 11. Post-graduation Plans

Value to Professional Career: Participants were also asked (Q46): *what were the most valuable aspects of your experience with the program for your professional career?* Below are some of participant responses related to the above learning outcome categories:

- Understanding the Design Process – One student wrote: *"The most valuable aspect of this event was learning how to apply the engineering method to a real life issue with completely random strangers and producing a prototype in a minute amount of time. Then finally cap it all off, being able to communicate and present this idea and prototype to an audience"* while another student wrote: *"I learned how to navigate the design process under very limited time constraints".*
- Teamwork – One student wrote: "*Learning to grow up and accept that my idea wasn't the best while keeping my full effort in the project"* while another student wrote: *"Being able to collaborate with others from different fields of study than myself allowed me to grow and be able to express what I want in a way that makes sense to someone other than myself".*
- Effective Communication – One student wrote: "*Usually I am not the one to get up in front of people to give a presentation but the program helped me step out of my comfort zone. After presenting, I feel more confident with presenting in front of people. I am also more comfortable opening my ideas up*

to the group, because some of my ideas were actually implemented into our design" while another student wrote*: "Ability to do oral presentations and sell an idea".*

- Problem Solving – One student wrote: "*Gaining experience developing ideas to solve complex problems that can positively affect the lives of others*" while another student wrote*: "Being able to apply what I learned in the classroom to a real life scenario with all modern technology and support".*
- Time Management - One student wrote: "*Managing the project and keeping everyone on task and focused on the actual problem, not the variety of solutions available*" while another student wrote*: "The ability to look at the need and organize time and resources to get the task accomplished".*
- Other - One student wrote: "*The experience afforded me the opportunity to network and establish my own confidence in myself by taking on a challenge that was widely outside my comfort zone*" while another student wrote*: "I had a blast, and what made all of the time and work worth it, the hours upon end of drafting it and finally assembling it, was walking out at the end of the day with the 1st place title. With that said, everyone walked out of ...with a smile on their face, because I know from first-hand experience that everyone had a great time".*

Discussion

Student survey data demonstrate the value students see in participating in this informal weekend Intensive Innovation Experience program with industry sponsored needs, mentors, and access to resources for rapid prototyping development and testing. The program has been very successful with students and the authors are considering to offer a longer version of the program between fall/spring or spring/summer semesters to accommodate student needs. The authors would like to express their appreciation to all the industry and nonprofit sponsors and mentors who greatly contributed to the success of the program.

Authors have received IRB approval for this study.

Appendix A – Survey Questions

	Skills / Knowledge	Question
Please rate your growth in the following.		
As a result of my involvement in the program, I improved my ability to:		
Q1	Design Process	Identify critical needs /requirements in an open ended problem
Q2	Design Process	Develop and evaluate conceptual designs and select best fits
Q3	Design Process	Integrate hardware and software for prototype development
Q4	Design Process	Utilize modern rapid prototyping tools for prototype demonstration
Q5	Design Process	Apply mathematics, science, and engineering knowledge to evaluate prototype performance
Q6	Societal Impact	Understand what engineering can contribute to society
Q7	Design Process	Understand the process of design in engineering
Please rate your growth in the following.		
As a result of my involvement in the program, I improved my ability to:		
Q8	Problem Solving	Identify what information is needed to solve a problem
Q9	Problem Solving	Apply an abstract concept or idea to a real problem or situation
Q10	Problem Solving	Divide problems into manageable components
Q11	Problem Solving	Develop several methods that might be used to solve a problem
Q12	Problem Solving	Use established criteria to evaluate and prioritize solutions
Please rate your growth in the following.		
As a result of my involvement in the program, I improved my ability to:		
Q13	Communication	Clearly describe a problem orally
Q14	Communication	Clearly describe a problem in writing
Q15	Communication	Showcase my skills to others
Please rate your growth in the following.		
As a result of my involvement in the program, I improved my ability to:		
Q16	Teamwork	Develop ways to resolve conflict and reach agreement in a group
Q17	Teamwork	Be aware of feelings of other members of the group
Q18	Teamwork	Listen to the ideas of others with an open mind
Q19	Teamwork	Work on collaborative projects as a team member
Q20	Teamwork	Ask probing questions that clarify facts, concepts, or relationships
Q21	Teamwork	After evaluating the alternatives generated, develop a new alternative that combines the best qualities and avoids the disadvantages of the previous alternatives
Q22	Teamwork	Evaluate arguments and evidence so that strengths and weaknesses of competing alternatives can be judged
Q23	Teamwork	Be patient and tolerate the ideas or solutions proposed by others
Please rate your growth in the following.		
As a result of my involvement in the program, I improved my ability to:		
Q24	Teamwork	Understand that a problem may have multiple solutions
Q25	Teamwork	Use discussion strategies to analyze and solve a problem
Q26	Teamwork	Recognize contradictions or inconsistencies in ideas, data, images

Q27	Teamwork	Recognize flaws in my own thinking
Q28	Teamwork	Identify the constraints on the practical application of an idea

Please rate your growth in the following.
As a result of my involvement in the program, I improved my ability to:

Q29	Time Management	Estimate required time for each track
Q30	Time Management	Prioritize tasks in the order of their importance and relevance
Q31	Time Management	Adhere to a timeline

Please indicate your reasons for participating in Aggies Invent:

Q32	Reasons for Participating	Have a general interest in program theme
Q33	Reasons for Participating	Have a general interest in innovation
Q34	Reasons for Participating	Have a general interest in building prototypes
Q35	Reasons for Participating	Broaden my career prospects and choices
Q36	Reasons for Participating	Want to examine my own qualifications
Q37	Reasons for Participating	Want to become an entrepreneur
Q38	Reasons for Participating	Have an idea for a business or product

Please indicate your plans post-graduation:

Q39	Post-Graduation Plans	Work for large-sized corporation
Q40	Post-Graduation Plans	Work for medium-sized business
Q41	Post-Graduation Plans	Work for a small sized business
Q42	Post-Graduation Plans	Work for a non-profit organization
Q43	Post-Graduation Plans	Work for government
Q44	Post-Graduation Plans	Pursue graduate studies
Q45	Post-Graduation Plans	Start own business

Overall Questions: Please help us understand your experience at Aggies Invent in depth,

Q46	Other	What were the most valuable aspects of your experience with the program for your professional career?
Q47	Other	What was the most valuable asset Facility asset for your design project?
Q48	Other	What were the benefits of your interactions with industry / nonprofit sponsors?
Q49	Other	Are you planning to pursue your project after today?
Q50	Other	Are you planning to keep in touch with any of the industry sponsors in the future?
Q51	Other	Are you planning to pursue your project after today?
Q52	Other	Would you be interested to have access to the Facility and for which reason?
Q53	Other	What Improvements would you make to the program to make it more valuable to undergraduate engineering students?
Q54	Other	Please list any themes you would like us to consider for future program events

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