Using Lean Start-Up Approach to Integrate Engineering Education with Entrepreneurship Practices at Middle Schools

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Dr. Jidong Huang is an Associate Professor of Electrical Engineering at California State University, Fullerton. His research had been supported by National Science Foundation (NSF), Federal Aviation Administration (FAA) and multiple private companies. Currently, his research interests are focused on innovative approches for STEM learning; robotics; the design of high-precision, integrated navigation system with high integrity; and their indoor/outdoor applications. He is a member of Institute of Navigation (ION); and a senior member of Institute of Electrical and Electronics Engineers (IEEE).

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Jackson is the Director of the Center for Entrepreneurship and the Small Business Institute (SBI) which deploy an applied learning model that engages undergraduate and graduate students with local businesses. These student-led consulting projects challenge the students to practice what they have learned in the classroom. Jackson's student team was recently awarded first place in the nation at the Small Business Institute national competition. (LINK)

John Bradley Jackson is also a Full-time Lecturer in the Management Department. Specializing in Entrepreneurship, Jackson teaches Entrepreneurial Marketing, New Venture Creation, and New Venture Launch. Known affectionately as "Professor JJ", Jackson brings practical marketing and sales knowledge to the classroom from both Silicon Valley and Wall Street.

Jackson is a strong believer in business incubation, which leverages CSUF STEM and business graduates and faculty. He began a pilot program which has launched a mixed use business incubator in Placentia, California. There are currently17 startups in residence at the new CSUF Startup Incubator. The incubator mentors fledgling businesses as they test and launch their business concepts. Student consulting teams support the fledgling startups http://business.fullerton.edu/centers/cfe/StartupIncubator.htm

Jackson is co-principal investigator for a National Science Foundation Grant called I-TEST; this $1,000,000 grant has created an after-school program at Anaheim middle schools which encourages STEM education and entrepreneurship. http://bizblogs.fullerton.edu/blog/2014/09/23/mihaylo-entrepreneurship-collaborates-to-win-1-million-nsf-grant/

As Center Director, Jackson conducts two all-college events: The Business Plan Competition and The CSUF Fast Pitch. Both events reach across the campus to engage students from all disciplines to idea-generate new business concepts, test feasibility, and pitch to a panel of real investors, bankers, and successful entrepreneurs. Jackson personally does the fundraising for the scholarships for both events.

A strong proponent of combining Business and STEM (Science, Technology, Engineering and Math), Jackson was on a team that was recently awarded a $50,000 National Science Foundation grant for the I-CORPS Program that embraces a "Lean Startup" methodology with STEM new ventures. (LINK)

Jackson recently created an innovative class called BUAD 410: "Starting and Managing a Small Business or Professional Practice." Unique to this class is a roster of all non-business students from various disciplines including Kinesiology, Communications, Engineering, Earth Science, Art and others. The class was created in collaboration with the deans from HHD and COMM colleges. The end result is a diverse classroom experience centered on Entrepreneurship.

Jackson also helps coordinate the innovative Dan Black Phys-Bus Program with the Physics department. This program allows students who are earning a BS degree in physics to have an emphasis in business that substitutes certain physics requirements with accounting, marketing, and entrepreneurial courses in Mihaylo College. (LINK)

Jackson was recognized in spring of 2015 by CSUF for his recent book on social media called "Socially Close: Social Media Marketing for Small Business". The book is about how businesses should be using social media in their marketing campaigns.

Also, in spring of 2015 Jackson was recognized by Mihaylo College with the Faculty Award for "Excellence in Service to Students." Jackson's work with student consulting and the CSUF Startup Incubator were cited as evidence of his commitment to service.

Jackson's career began in high technology sales in the semiconductor industry at Signetics Inc., but he soon moved to high technology market research with Dataquest Incorporated. At Dataquest, he served as Vice President for nearly ten years and held a variety of roles in sales, marketing, and research. Later, he joined Bowne and Company, the world's largest financial printer, and served as Senior Vice President responsible for sales, marketing, and operations. Jackson also was Sales Director at Forrester Research Inc., an Information Technology advisory firm.

As an entrepreneur, Jackson founded The BirdDog Group, a marketing and sales consulting firm that specializes in helping small and medium sized businesses with marketing and sales strategy. In particular, he is an expert in digital marketing including social media, web development and search marketing.

Jackson's other professional activities and accomplishments include: • Faculty Adviser for CSUF Senior Honors Project titled An Analysis of Defense Innovation Unit Experimental in Silicon Valley Innovation. 2015 to present • Faculty Adviser for CSUF Entrepreneurship Students, 2009 to present • Faculty Adviser for the student Club "Entrepreneurship Society", 2009 to present • Faculty Adviser for the student Club "Sigma Epsilon Mu", 2014 to present • Faculty Adviser for the Innovation Fellows program sponsored by NSF, 2014 to present • Mentor at Mihaylo Leadership Academy for Fulltime MBA Students, 2011 to present • Management Department Strategic Goals Committee Leader, 2013 to present • Advisory Board Member at Small Business Development Corporation (SBDC), 2012 to present • Board of Director at Global Vision Holdings, Incorporated, 2012 to present • Advisory Board Member at O2free, LLC, 2015 to April 2016 • Advisory Board Member at BrandMixer, LLC, 2011 to 2015 • Advisory Board Member at Tri-Tech SBDC, 2015 to present • Author of the book "First, Best, or Different", 2007, (wwwfirstbestordifferent.com) • Author of the book "Déjà New Marketing", 2010, (www.dejanewmarketing.com) • Author of the book "Socially Close", 2014 (www.johnbradleyjackson.com) • Author of the book "Your Entrepreneurial Journey – Fifteen Guiding Principles About Your Entrepreneurial Journey", 2014, (www.johnbradleyjackson.com)

Jackson owns a small horse ranch in Norco, California with his wife and daughter.

Dr. Pradeep Nair, California State University, Fullerton

Pradeep Nair received his Ph. D. in Electrical Engineering from the University of Texas at San Antonio in 2009. His research interests include power/performance tradeoffs in the nanoscale domain, leakage power reduction in digital systems, computer performance analysis and evaluation, low Power FPGAs, and biomedical circuits and systems. Dr. Nair is also the co-advisor of the IEEE Computer Society chapter at CSUF.

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Abstract

STEM-Inc is a 3-year NSF ITEST project designed as an after-school program targeting 7th and 8th grade students from traditionally underrepresented groups in Anaheim, California. This project created a simulated technology business 'incubator' in an afterschool program for junior high school students at the Anaheim Union High School District. Its goal is to make middle school students and their parents aware of STEM career paths in addition to engage and attract the students to STEM fields and careers. To this end, the project focuses on getting the students involved in exciting real-world projects that involve Engineering, Computer Science (ECS) and Business concepts.

Toward this goal, the Lean startup approach has been used as a tool to integrate informal STEM learning with Entrepreneurship practices. Lean startup is a method for developing businesses and products. It provides a scientific approach to creating and managing startups; and has the potential for a startup company to deliver a desired product to its potential customers fast and effectively. Using Lean startup method, students in STEM-Inc worked in groups to complete their Engineering and Computer Science projects.

As a design and development project, research questions in STEM-Inc frame formative data collection and analysis to address aspects of the design that are succeeding and others that require revision. Summative measures focus on student learning outcomes, as well as student attitudes toward science and engineering and self-efficacy. Preliminary results from the first two years of STEM-Inc showed positive indicators in both formative and summative data, which supported the use of Lean startup method for integrating Engineering education with entrepreneurship practices.

Introduction

STEM workers drive America's innovation and competitiveness by generating new ideas, companies and industries. But despite their key role in the sustained growth and stability of the U.S. economy (Langdon et al., 2011) and despite growth in STEM jobs that was three times as fast as growth in non-STEM jobs over the past ten years, the United States ranks 27th among developed nations in the proportion of college students receiving undergraduate degrees in science or engineering (*Rising above the Gathering Storm Revisited*, 2010).

The National Science Board (2010) cites longitudinal data showing that intellectually talented individuals who can be identified at an early age and then supported in their learning generate a disproportionate number of Fortune 500 patents, peer-reviewed STEM publications and other creative achievements, and comprise a disproportionate number of tenured academic faculty at top universities. Developing future stem innovators, the board declares, is nothing less than an economic imperative.

Unfortunately, as students go through school, their interest in STEM fields begins to wane, particularly by middle school. This attitudinal decline can begin at age 11, but researchers have found differences between middle school students' attitude toward science generally and their attitude toward formal school science, which may stem from science that is not presented in a way that is culturally or developmentally interesting to students (Osborne, Simon & Collins, 2003). For girls, declining interest in science is especially precipitous. The American Association of University Women (1992) reported that girls begin school with a strong interest in science and mathematics and with similar abilities as boys, but by the time they graduate from high school, they demonstrate less ability and self-esteem in science and math. Females also do not persist at the same rate as males in math courses or in pursuing STEM careers, despite their similar mathematics achievement in middle school and high school (Kerr, 1997; Wiest & Johnson, 2005).

To improve STEM interest, students must be 1) motivated to pursue STEM studies; 2) have time, resources and opportunities to learn and practice STEM skills; and 3) see the connections between STEM knowledge and the real world so they can envision careers for themselves (Thomasian, 2012). The President's Council of Advisors on Science and Technology (PCAST, 2010) recommends inspiring students to learn STEM subjects by creating opportunities for inspiration through individual and group experiences outside the classroom.

Multiple evaluations of STEM-specific afterschool programs show clear benefits for students, including a) increased school attendance, improved grades and graduation rates; b) significant improvement in school engagement, family and parental support for education and behavioral expectations at school; c) more positive attitudes toward science, more confidence in themselves as science students and more awareness of STEM careers; d) higher rates of high school graduation and STEM majors in college; and e) continued pursuit of STEM-related topics in high school and beyond while feeling prepared for STEM careers (Afterschool Alliance, January 2011).

Companies in STEM industries also need employees with backgrounds in other disciplines, particularly business and entrepreneurship. Furthermore, entrepreneurship education can be a fundamental tool for helping low-income young people to see a bigger future for themselves (Network for Teaching Entrepreneurship (NFTE), 2013). Unfortunately, most youth have little or no knowledge of these fields. Fewer than half of US high school graduates take an economics course (Walstad, 2001), and while many educational programs have the goal of teaching engineering and computer science (Malyn-Smith & Colón-Bacó, 2012), fewer teach the connection between STEM fields and business/ entrepreneurship, even though scientists and engineers operate in a global marketplace.

Consistent with the literature, STEM-Inc is an NSF ITEST afterschool program that engages 7th and 8th grade students, especially those from traditionally underrepresented groups, in engineering and computer science with real-world activities that relate to their own lives and inspire them with opportunities for STEM careers. A collaboration between California State University, Fullerton (CSUF) and Anaheim Union High School District (AUHSD), the STEM-Inc concept is to encourage students to think creatively and act as entrepreneurs in an informal, applied learning setting that emulates a technology business incubator. Students will gain engineering and computer science skills as they conceive and develop their own products and learn about the career opportunities available to them if they persist in STEM studies. They will work in teams, strengthening their social relationships, and they will have opportunities to share their enthusiasm with their peers through the outreach required for them to research the markets for their products, potentially generating more interest and participants for subsequent years.

Lean Startup Methodology

Lean startup is a method for developing businesses and products (Ries, 2011). It provides a scientific approach to creating and managing startups; and has the potential for a startup company to deliver a desired product to its potential customers fast and effectively.

The premise of lean start-up is that businesses must form a hypothesis, then talk with potential customers before coming up with a solution. Based on those interviews, the company then creates specifications for a product that meets a confirmed need and keeps returning to customers for feedback to refine it through a series of prototypes, starting with a “minimum viable prototype.” Lean start-up favors experimentation over elaborate planning, customer feedback over intuition and iterative design over traditional “big design up front” development (Blank, 2013).

Prior to embarking upon the projects, the students will be asked to justify, based on economic and business factors, the perceived user need and their solutions, using lean start-up methodology. In this way, they will become aware of the factors that affect business outcomes, such as demand, supply, infrastructure, resources, etc. The aim of this activity is to motivate students to learn STEM content by making real-life connections with the activity, as observed in Thomasian (2012).

Program Design

The STEM-Inc regular after-school program was offered at four participating junior high schools (2 schools using traditional new venture creation methods; and 2 schools using the Lean Startup methods) in AUHSD, twice a week, two hours each time from early-October to early-May, for academic years 2014 – 2015 and 2015 - 2016. At each school site, about 30 to 40 students from 7^{th} and 8^{th} grade were recruited to participate in STEM-Inc program activities.

It offered participating students a way to see engineering and science from two interconnected perspectives. One is the engineering side in which they identify a real-world problem and seek practical solution to the problem that requires the engineering design, assembly and testing of a product; and the other is the business side in which they identify the business value of the product that is targeted to a specific market and seek ways to promote the product through new venture creation. Along this process they learned the different stages that are required for both Engineering design and Business venture creation.

For the Engineering and Computer Science (ECS) part, students went through a series of tutorials and trainings to learn about a) Mobile App development through the use of MIT App inventor (http://appinventor.mit.edu); b) 3D Modeling, Design and Printing using Sketchup (http://www.sketchup.com); and c) Design of Robotic Cars using Arduino-based platforms. As a cumulative experience, students were asked to work in groups to identify real-world problems and seek engineering-based solutions to these problems. They were also challenged to make prototype products to meet both engineering and business requirements.

Just like the engineering piece, the entrepreneurship side of STEM-Inc also followed a rigorous curriculum to help students develop business entrepreneurship skills. The students were encouraged to think “out of the box” about new ways to do things and new products to invent. They formed teams of 3-6 students and shared ideas. Each team was empowered to choose a single business concept and then research its feasibility through an intensive interview process, especially for the two schools guided by the Lean Startup approaches. From there, the students

created product specifications and moved toward the creation of prototypes. Prototypes were built, tested and modified as necessary.

Student Demographics

Student participants for the project were recruited through multiple efforts. A recruiting flyer was created and distributed to the classes at the four participating schools via STEM-Inc teacher participants when the school year started. In addition, the recruiting flyer and application packages were always available at the school front offices during STEM-Inc enrollment period. Furthermore, a STEM-Inc open house and live engineering/computer science project demonstrations with Q&A session was held at each one of the four schools, mostly during the lunch hours in September for recruiting students. Through these efforts, a large number of applications were turned in; and were then screened by the STEM-Inc teachers and their school principals to ensure that underrepresented applicants were given higher priority.

Figure 1 shows STEM-Inc student race information for both years 1 and 2. Apparently, STEM-Inc in 2015-2016 had a higher proportion (49%) of African American and Latino students in comparison to the 2014-2015 school year (30%).

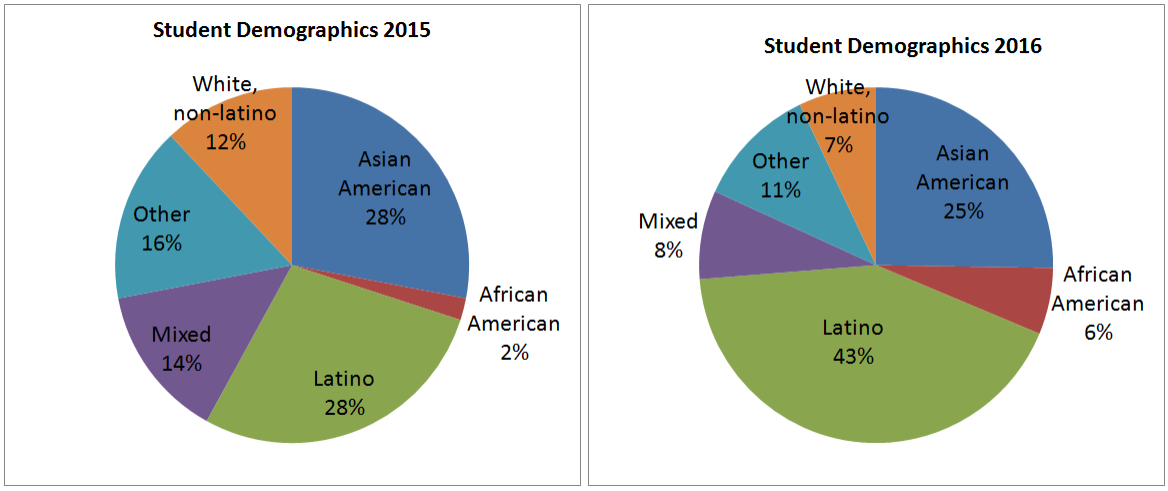

Figure 1. Race of STEM-Inc. student participants, by year

Figure 2 shows STEM-Inc student gender information for both years 1 and 2. Clearly, STEM-Inc in 2015-2016 had a higher proportion (49%) of female students in comparison to the 2014-2015 school year (32%).

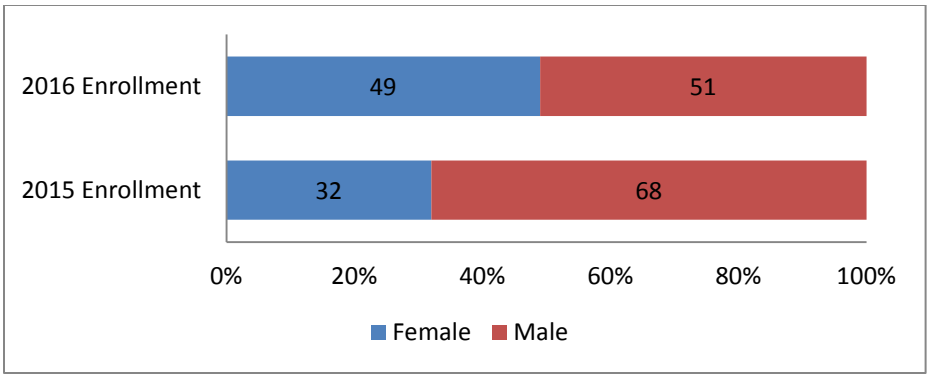

Figure 2. Gender of STEM-Inc. student participants, by year

Apparently, STEM-Inc is increasingly recruiting students from historically underrepresented groups in STEM careers.

Evaluation Method and Analysis

The Arroyo Research Services (ARS) served as the external evaluator for STEM-Inc. In particular, ARS developed multiple instruments for evaluating: 1) the quality and fidelity of program development and implementation, and 2) the effectiveness of the program in terms of student outcomes.

The STEM-Inc evaluation instruments were built from psychometrically sound instruments and scales that include the Career Interest Questionnaire and Modified STEM Semantics Survey (Tyler-Wood et al., 2010), Entrepreneurial Self-Efficacy and Intention (Wilson et al., 2007), Student Attitudes toward STEM Survey (Mahoney, 2010); STEM Semantics Survey (Tyler-Wood et al., 2010), Sources of Self-Efficacy Scale (Britner & Pajares, 2006), and a 21st Century Skills Assessment/Rubric.

Specifically, the process evaluation was designed to measure both quality and intensity of STEM-Inc activities in order to monitor the short-term and formative results of activities and services, validate program components, and determine whether activities were of sufficient quality and intensity to influence intended outcomes. The process data were collected through project documents (e.g., program descriptions, recruitment plans), attendance logs, a site visit with observations and interviews of an afterschool activity, and participant surveys. Post-, or end-of-program, surveys with students, mentors, teachers and parents also included formative items designed to inform next year's program development.

To assess program outcomes, ARS employed a number of measures (such as those for student interests and self-efficacy) and evaluation activities (such as those for student learning

outcomes) across the four participating schools and between the two different interventions (a, traditional new venture creation approach at two schools; and b, Lean Startup approach at two other schools), including survey data from students, college mentors, and teachers; as well as STEM-Inc advisory board members.

Results

Data collection from STEM-Inc included after-school site visits consisting of interviews and focus groups; fall (pre)/spring (post) surveys with participating students; and student learning outcome assessments consisting of engineering/computer science and business concepts measured by students' end of year self-assessment and rubric scores from advisory board members, mentors and teachers. Please note that, for research purpose, the lean startup method was not introduced until year 2 of STEM-Inc (AY 2015-16). Therefore, the results below were mostly obtained from data collected from AY 2015 - 2016.

According to STEM-Inc data, students reported that they have generally enjoyed the STEM-Inc afterschool program activities. For example, figure 3 shows the results from mid-year 2016 evaluation. Over 80% agreed or strongly agreed that they enjoyed working in groups, creating projects, and working on and learning about new technologies. Over 70% agreed or strongly agreed that they were given time to research ways of solving problems, spent time testing ideas and/or plans, developed software or other products on a computer, and talked about STEM subjects to family and friends. Over 50% agreed or strongly agreed that they enjoyed developing a business plan, spent enough time working on projects, and created documents on a computer.

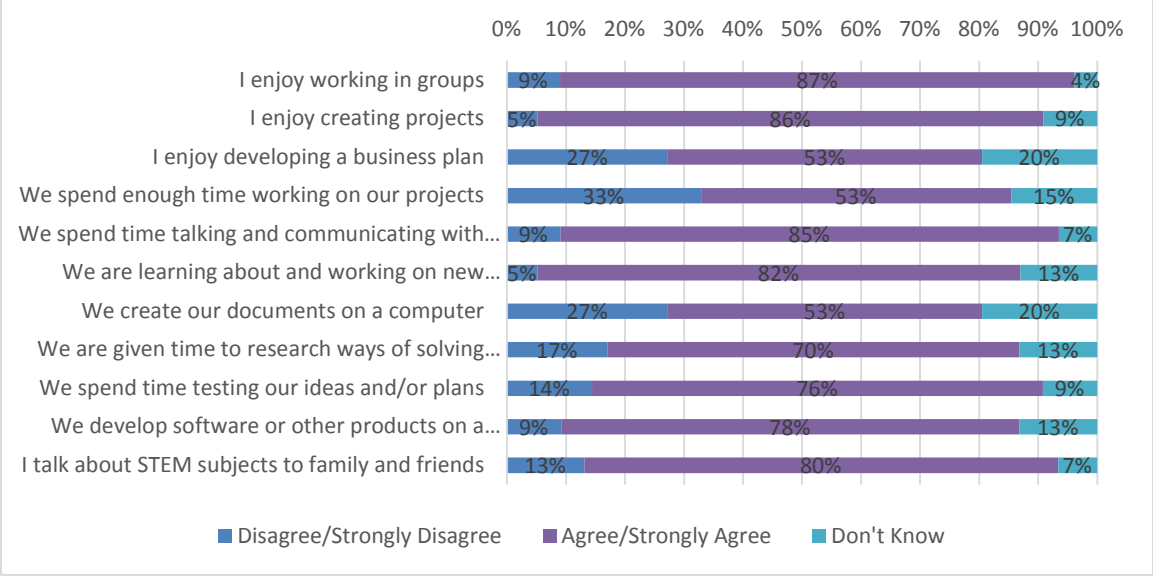

Figure 3. Student involvement with and experience of STEM-Inc, mid-year 2016.

When it comes to how STEM-Inc program activities helped students build up knowledge and interests in STEM and Entrepreneurship, the majority of STEM-Inc students reported either "satisfied" or "very satisfied". As an example, figure 4 demonstrates student's overall satisfaction level with STEM-Inc in the semester of Spring 2016.

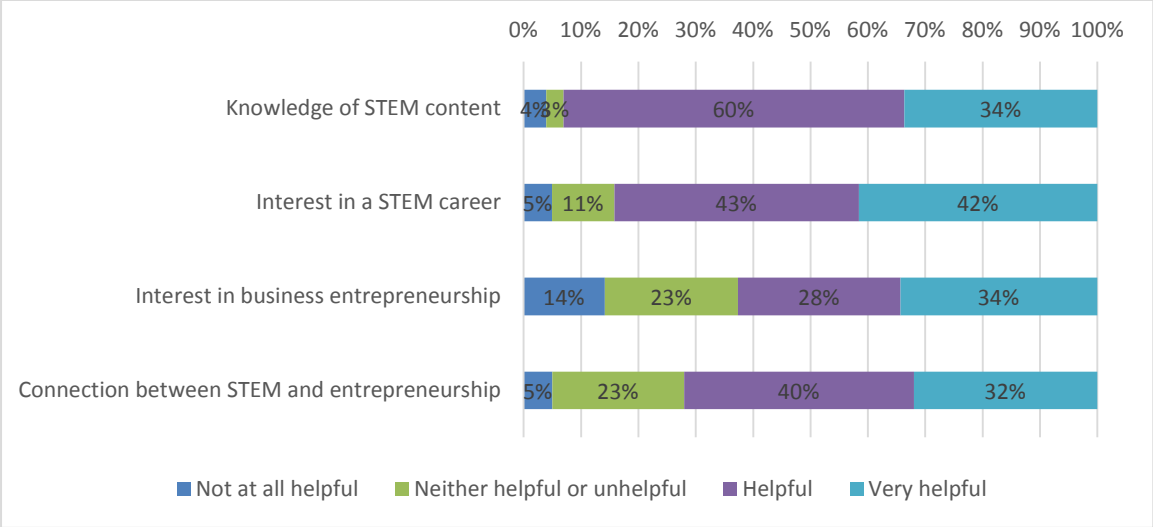

Figure 4. Spring 2016 student responses to "Please indicate the degree the event/activity helped you in the following:"

For STEM-Inc year 2, across all students, field interest in Engineering, Computer Science or entrepreneurship was high during program entrance and did not significantly change from fall (pre-) to spring (post-) as shown in table 1. Within just the Traditional group, however, students' engineering field interest did significantly decrease from fall to spring; while for the Lean Startup group, there is little change. Each field interest construct was measured using 5 net promoter items on a 0 to 10 scale, with 0 reflecting the highest positive value ("Interesting," "Appealing,") and 10 indicating the closest negative value ("Boring", "Unappealing").

Table 1. Change in STEM-Inc Student Interest in Computer Science, Engineering & Entrepreneurship, Fall to Spring, 2015-2016

	Total 2016		**Traditional 2016**		**Lean 2016**	
	Mean (Pre-)	Change (Post-)	Mean (Pre-)	Change (Post-)	Mean (Pre-)	Change (Post-)
Computer science field interest (construct)	2.37	0.13	2.22	-0.19	2.47	0.37
Engineering field interest (construct)	1.79	0.33	1.18	0.66	2.27	0.07
Entrepreneurial field interest (construct)	3.26	0.02	3.64	-0.06	2.97	0.08

Students, however, did report having more of an interest in STEM activities in the spring than prior to the program. Seventy-nine percent of students reported that they had an increased interest in STEM activities then in comparison to their interest before the program (Figure 5). Sixty-nine percent of students also reported they were now more effective in solving science and math problems than prior to the program.

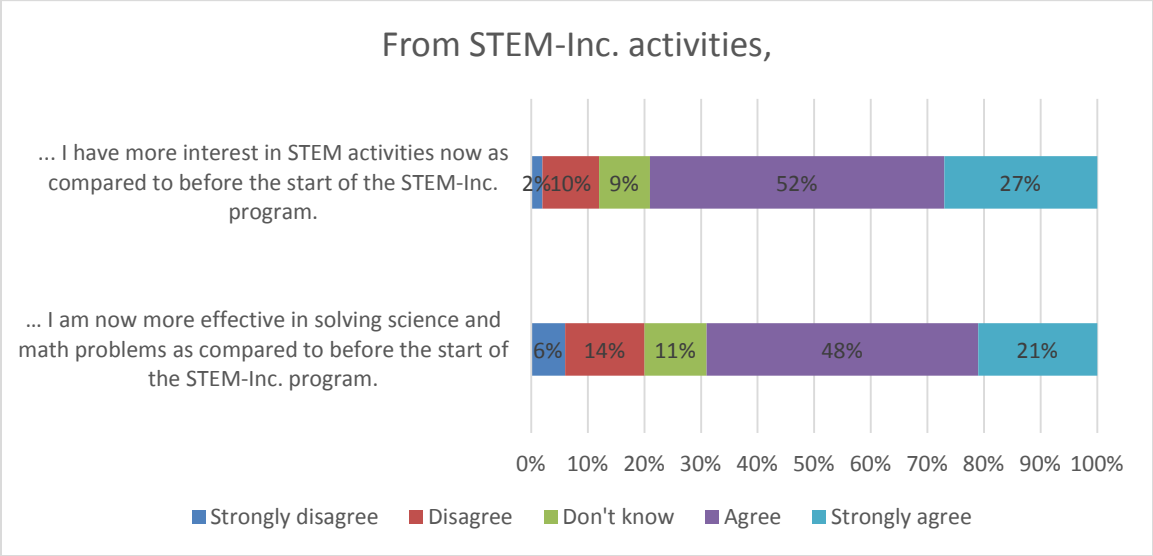

Figure 5. Student self-report of change in STEM interest and science/math problem solving as a result of STEM-Inc activities.

Similarly, student self-efficacy (1<2=low, 2<3=medium, 3<4=medium-high, 4<5-high) in math and science, as well as confidence with Engineering, Computer Science skills was high at program entrance, and did not significantly change between fall and spring (Table 2). For the Lean Startup group, however, there was a consistent increase in student self-efficacy for all categories.

Table 2. Student Self-Efficacy in Math & Science, Confidence with ECS and Entrepreneurial Skills, Fall to Spring, 2015-2016

	Total 2016		**Traditional 2016**		**Lean 2016**	
	Mean (Pre)	Change (Post)	Mean (Pre)	Change (Post)	Mean (Pre)	Change (Post)
Math self-efficacy (construct)	3.68	-0.04	3.97	-0.16	3.48	0.04
Science self-efficacy (construct)	3.77	0.04	3.92	-0.08	3.66	0.12
Confidence in conducting engineering tasks/skills (construct)	4.29	0.22	4.23	0.19	4.44	0.24
Confidence in conducting computer skills (construct)	3.88	-0.03	3.79	-0.1	3.95	0.03

Confidence in conducting entrepreneurial skills (construct)	3.67	0.36	3.38	0.58	3.89	0.2

The STEM-Inc staff also asked students to complete an 8-item self-assessment at the end of the program year regarding their degree of agreement to learning business/entrepreneurship skills from STEM-Inc. activities. On a scale from 1="Strongly Disagree" to 5="Strongly Agree," students agreed to have learned most business/entrepreneurial skills (Means ranged from 3.7 to 4.1; Figure 6).

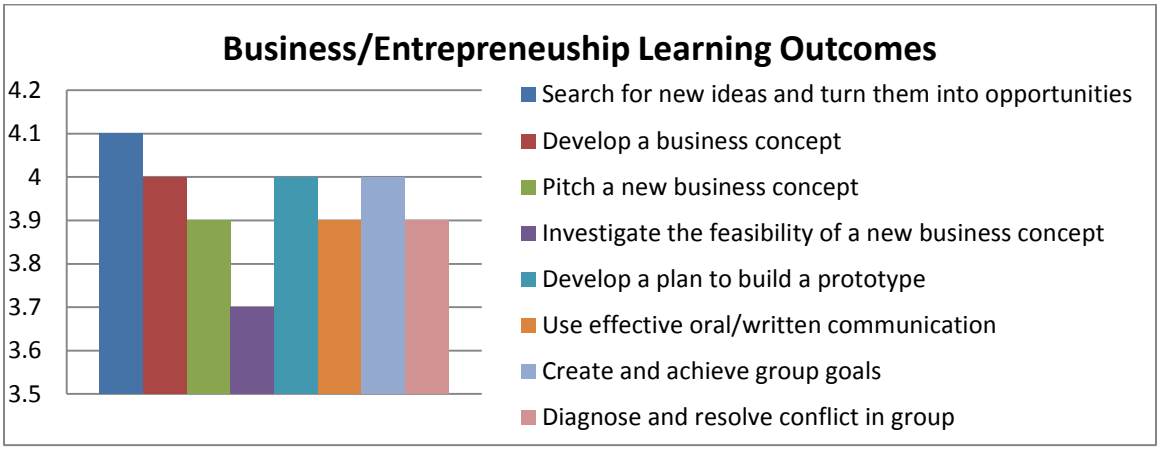

Figure 6. student reported scores on business/entrepreneurial learning outcomes, spring 2016.

In addition, two out of three participants (66%) said STEM-Inc helped them refine their products. Through Lean Startup methods, students were able to "interview prospective customers about their potential needs," which helped them "create better product specifications."

Conclusions

STEM-Inc is an NSF ITEST project that is designed to research the effectiveness of using business venture creation principles, for example, the lean startup approach, to integrate Engineering education with Entrepreneurship practices. Results from two years of STEM-Inc project implementation indicated that such intervention is effective and has generated positive learning outcomes for students not only in STEM subjects but also in developing Entrepreneurship skills that are often needed in many STEM jobs.

Specifically, STEM-Inc is increasingly recruiting students from historically underrepresented groups in STEM careers. Forty-eight percent of STEM-Inc. student participants identified as Black or Latino in Year 2, compared to 30% in Year 1. Forty-nine percent also identified as female in Year 2, compared to 32% of student participants in Year 1.

STEM-Inc has attracted students with high interest in STEM fields and careers; some students increased that interest from fall to spring. Field interest in ECS and entrepreneurship, as well as STEM career interest were high during program entrance and did not significantly change from fall to spring across all students. Similarly, student self-efficacy in Math & Science, confidence with ECS and entrepreneurial skills, was high during program entrance and did not significantly change from fall to spring across all students, although the Lean Startup group did observe slightly higher self-efficacy.

Nonetheless, STEM-Inc helped students developed a greater interest in STEM activities and improved students' skills in solving science and math problems. Seventy-nine percent of participants agreed or strongly agreed that STEM-Inc. students develop a greater interest in STEM activities over the course of the program; and sixty-nine of students also reported they were now more effective in solving science and math problems than prior to the program.

Furthermore, STEM-Inc is developing ECS career-readiness and Entrepreneurship skills among participating students, per self-report. Participating students reported learning ECS skills like identifying connections between math, science and engineering as a result of STEM-Inc activities. Students also agreed that they have learned multiple business/entrepreneurial skills from STEM-Inc activities.

Acknowledgements

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