Using Career Pathways to Assimilate High School Students into the Engineering Profession

Dr. S. Jimmy Gandhi, California State University - Northridge

Dr. S. Jimmy Gandhi is an assistant professor at California State University, Northridge. His research interests and the courses he teaches includes Quality Management, Lean Manufacturing, Innovation & Entrepreneurship,Sustainability as well as research in the field of Engineering Education. He has over 30 conference and journal publications and has brought in over $500K in research grants to The California State University, Northridge.

Dr. Vidya K Nandikolla, California State University - Northridge

Dr. Nandikolla has backgrounds in Mechanical, Electrical and Control Engineering and has developed courses in electro-mechanical areas to improve engineering curriculum. She has experience developing and teaching engineering core courses with hands-on experimentation and industry collaboration within classroom encouraging creativity and teamwork.

Dr. George Youssef, San Diego State University

Dr. George Youssef received his Ph.D. in Mechanical Engineering from University of California Los Angeles in 2010 and joined the faculty at San Diego State University after four years appointment at California State University Northridge. His research interest is in the general area of solid mechanics with focus on nontraditional materials such as polymers, composites, and smart materials. His research contribution in dynamic properties of shock-loaded materials, interfacial strength of direct bond wafers, environmental degradation of polymers, and biomechanics of walking. Dr. Youssef has several publications in archival peer-reviewed journals. His research has been supported by National Science Foundation, Department of Defense, and private industries. Dr. Youssef was recognized in 2014 by San Fernando Engineers Council as Distinguished Engineering Educator and is one of the 2016 Society of Automotive Engineers (SAE) Ralph R. Teetor Award winners.

Dr. Peter L. Bishay, California State University - Northridge

Dr. Peter L. Bishay received his PhD in Mechanical and Aerospace Engineering from University of California, Irvine in 2014. He joined California State University, Northridge in 2015 as a Mechanical Engineering Assistant Professor. His research interests are in the fields of computational solid mechanics and smart materials & structures.

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Abstract

Career Pathways is a Workforce Development (WFD) program that is supported by State government to instill specific skillsets in K-12 students. Career pathways generally consist of partnerships between K-12 school districts, community colleges, four-year universities and community-based workforce investment boards. The overall goal is to bridge the gap between industry-needed skills and those obtained through formal education. The expected outcome is the transition of students into industry after high school, transfer into a community college, or seek a four-year college degree. Regardless of the career pathway outcome, the WFD program inculcates hands-on, practical skills in participants. These skills were included based on industry feedback about the gap between current graduates' skills and those expected in the field of practice. The skills were also echoed in the 'Engineer of 2020' report by the National Academy of Engineering. As a result, the career pathways include programs and services that addresses aforementioned skill gap and increases the employability of students; particularly in the high-tech industry. The overall emphasis of this effort is on the engineering profession, in which the responsibilities and expectations from an employee in the 21st century are significantly different from those required decades ago.

At California State University Northridge, the authors have collaborated with a local community college, two local school districts and a local workforce development investment center to create two separate pathways focused on Technical Innovation and Entrepreneurship as well as Digital Manufacturing. The first pathway, i.e. Innovation and Entrepreneurship, ingrains an entrepreneurial mindset and up-to-date tools used by industry in all the participants (i.e., future workforce). Through this pathway, students are enabled to keep up with the changing demands of industry in the 21st century.

On the other hand, the Digital Manufacturing pathway introduces K-12 students to basic design skills by means of The Engineering Design Process through 3D additive manufacturing. Specifically, participants learn Computer-Aided Design in SolidWorks while gaining hands-on and practical skills in realizing their design using the 3D printing rapid prototyping machines. In addition, students work in groups to gain teamwork skills, collaborate on interdisciplinary projects such assistive technology, and communicate their ideas in visual (e.g., modeling and drawings), oral (e.g., presentations and interactive discussion), and written (e.g. reports) formats. The Engineering Design Process and 3D printing are used as the core pedagogies in this pathway because they have proliferated the biomedical, robotics, and aerospace industries. Thus, the high school students trained in these pathways are gaining and sharpening their technical and interpersonal skills to prepare for successful long-term employment in the engineering practice. In this paper, the authors discuss the development of these pathways and how they are being currently implemented with a focus on continuous improvement. Preliminary results based on pre- and post-experience survey indicate significant increase in students' skills in both career pathways.

Introduction

According to The National Career Pathways Network, a career pathway is defined as, " … *a coherent, articulated sequence of rigorous academic and career/technical courses, commencing in the ninth grade and leading to an associate's degree, baccalaureate degree and beyond, an industry recognized certificate, and/or licensure*."[1] Thus, Career Pathways are developed, implemented, and maintained in partnership among secondary and postsecondary educational institutions in addition to local industries and community-based workforce development centers. The inclusion of industries and their lobbyists is motivated by a skills gap that exists between new graduates and the practice of a profession, which was highlighted in recent study by the American Society of Mechanical Engineers that surveyed employers, new college graduates, and academic professors [2]. Hence, the purpose of career pathways is to offer the students an opportunity to be involved in curriculum that promotes hands-on and experiential learning while preparing them to be workforce-ready contributors. This will reduce the skills gap by allowing students to [1]:

- Understand and consider career options;
- Discover workplaces and their relationship to curricula;
- Make choices about future education and training (i.e., continuous professional development);
- Understand the expectations for achieving career goals;
- Maintain portfolios of progress and achievement; and
- Become flexible but focused employees.

In July 2014, the California Legislature passed and the Governor signed into law the California *Education Code,* sections 53010 through 53016, and the Budget Act of 2014, Statutes 2014, creating the California Career Pathways Trust (CCPT). Funds in the amount of $250 million were made available to school districts, county school superintendents, direct-funded charter schools, regional occupational centers or programs operated by a joint powers authority, and community college districts in the form of one-time competitive grants [1]. The CCPT program was established to:

- Fund specialists in work-based learning to convene, connect, measure, or broker efforts to establish or enhance a locally defined career pathways program;
- Establish regional collaborative relationships and partnerships with business entities, community organizations, and local institutions of postsecondary education;
- Develop and integrate standards-based academics with a career-relevant, sequenced curriculum following industry-themed pathways that are aligned to high-need, high-growth, or emerging regional economic sectors; and
- Provide articulated pathways to postsecondary education aligned with regional economies.

As a result, the state government expects to address the graduates/industry skills gap and to train people into well-paying jobs (i.e., high-need and high-growth). In turn, this will maintain California's global economic competitiveness. The appropriated funds were distributed to 39 consortia across the state of California.

The authors of this paper are part of one of the consortia located in Southern California, which received funding in the amount of $6 million. The funding was received by the Glendale school district and the consortium comprises of two local school districts, a local community college, a regional four-year degree granting university and 25 industry partners. Additionally, a community-based workforce investment board, which acts a liaison between educational and industrial partners, is also part of this consortium. Here, it is important to note that the quadruplet partnership between K-12, a higher education institution, industry and a community center is not only consistent with the funding agency requirements, but also streamlines the transition of students into high-tech jobs. The specific focus of this consortium is to create pathways for high school students to make strides in areas of high- growth jobs based on predictions published by the State of California, Employment Development Department [3]; namely *(i)* Innovation and Entrepreneurship, *(ii)* Digital Manufacturing, *(iii)* Animation, and *(iv)* Web Design. In this paper, STEM-based career pathways, i.e. innovation and entrepreneurship and digital manufacturing, are discussed in detail, since the academic appointments of all the authors are within the College of Engineering.

Benefits to High School Students

The number of students pursuing engineering careers is not enough to be able to keep up with the industry demand for engineering graduates. Due to this gap between the supply and demand of engineering graduates, it is essential that we develop outreach activities with high school educational institutions to make students aware of the engineering profession [4,5]. Today, there exist a variety of outreach programs in high schools to educate the students about the STEM related careers. By having this opportunity available, it gives the high school students a sneak peek of engineering classes at no cost and is beyond just providing information. The interaction with the students during the outreach activities indicated to the authors that hands-on experience gained is a better learning tool than just passing on the information via presentations and lectures. The students are exposed to all aforementioned pathways before making their choice through targeted outreach activities. The outreach has two outcomes as it relates to the pathways. First, it increased the awareness of high school students about engineering education and careers, which is vital to first generation students. Second, the outreach efforts served as an introduction to the pathways and it was used as the main program recruitment utility. Recruitment was done in two stages. Students were first invited to visit the California State University, Northridge (CSUN) campus, as part of a CSUN college day for major and career exploration. This was then followed by the engineering faculty making outreach visits to the high school campuses.

Pathway Implementation

The pedagogical objective of each pathway is being delivered to students in three consecutive modules. The duration of each module was set to eight weeks to balance between the academic and professional commitments of students and facilitators, respectively. The duration was also selected based on grouping of specific and relevant skills into one coherent module. The high school students came to California State University Northridge campus for the pathway training on Saturday mornings from 9:00a.m. until 12:00p.m. The decision of day and time was done in consultation with school administrators, parents, and participants, since students nowadays are involved in multiple extra-curricular activities.

The admission of students into a pathway was done based on an application process, which was disseminated to students in partner high schools. A related point to consider is the recruitment of applicants, which commenced well before the application process. Substantial recruitment effort was needed since the program is new and there are other programs that compete for the same student body. As discussed in the previous section, recruitment was integrated as part of outreach. The application consists of three sections, which are academic experience (class level, overall GPA, career goals, etc.), demographics (gender, ethnicity, parents and siblings education background, etc.), and communication skills. For the latter, students provided a short statement justifying their interest in a particular pathway program as well as their expected learning outcomes. Finally, each student was required to get a recommendation letter from a teacher at his or her high school. The teacher was asked to evaluate the student on his/her ability to solve problems, dedication and sense of responsibility, mathematics and science background, level of creativity, level of participation in class discussions, motivation as well as leadership skills. Each application was evaluated by responsible faculty member and based on their recommendation students were admitted to the pathway.

Innovation and Entrepreneurship Pathway

Historically, entrepreneurship and innovation have been the principal sources of economic growth, technological progress, productivity, and rising standards of living. Entrepreneurship plays an important role in net new job creation [6]. Recent research indicates that "high-growth (incumbent) businesses contribute about 50 percent of job creation and startups account for about 20 percent of job creation."[6] Most of those high-growth companies, however, also are entrepreneurial firms under six years old. The current "state" of entrepreneurship in the United States is uneven across industrial sectors, across geographies, and in economic effects [7]. The very aim through this Innovation and Entrepreneurship pathway is to "accelerate" startups through a combination of hands-on learning and the creation of an entrepreneurial mindset in tomorrow's workforce.

As one of the practical levels of innovation and entrepreneurship in education, the school becomes a place for experimenting, a place to develop and participate in project-based learning environments, a place where entrepreneurship is part of the organizational and educational culture, and where the teacher and the director are themselves immersed in the entrepreneurial mindset. Therefore, the underlying teaching philosophy in the innovation and entrepreneurship pathway is the students' learning outcomes, which are achieved through hands-on and experimental studies rather than traditional textbook and lecture based learning only. In response, the authors aim to create real life project scenarios for students, which include creating business canvas as well as business plans, selling and proving their idea/product, negotiating and convincing the venture capitalists to invest in their product/service, etc. To inculcate students with this knowledge, curriculum was developed and has been discussed in detail in this section of the paper. The Innovation and Entrepreneurship pathway consists of three highly interactive and hands-on modules. This way, students are better prepared to join the workforce with skills such as continuous improvement, creative thinking, understanding the need of the customer and meeting the needs of the customer while simultaneously providing overall value. The experiences that the students will obtain through this pathway will help them to develop these much-needed skills which could translate to an entrepreneurial mindset [8].

In line with the other pathways in the consortium, the innovation and entrepreneurship pathway was also developed with three eight-week modules, the details of which are discussed below.

1. The A-Z of an Entrepreneurial Venture

This module is focused on the creation of an entrepreneurial mindset then on the entire lifecycle of a start-up, which include different types of ventures and business model development. The latter includes creative thinking, lateral thinking, and critical thinking discussions that help align the mindset of student towards the first stepping-stone of Entrepreneurship. This course also focuses on educating students on developing a mindset on how to ask the right questions so as to not be satisfied with the current status quo and thus create a culture of continuous improvement. The end deliverable for this module is a business canvas that students of the pathway create and present.

2. Innovation in The Global Supply Chain

The second module gives the student an understanding of the global supply chain, exposes them to how innovative thinking can be applied to the supply chain and how it can provide a significant competitive advantage to their own firm or to the organization they are part of. This understanding of their position in the value chain and how to leverage that position is extremely beneficial to the student, who is striving to be an entrepreneur by developing an entrepreneurial mindset and differentiating oneself from the competition. Additionally, erratic macroeconomic cycles along with disruptions caused by natural disasters have made supply chain management both more difficult and important to business success [9]. To adapt to this dynamic environment, businesses are actively managing their supply chains utilizing strategic and operational levers at their disposal to transform vulnerabilities into competitive advantage. Thus, this module includes incorporation of concepts from quality and risk management such as The Voice of Customer. This will greatly benefit the students, as there is a strong growth for jobs in the supply chain domain [10].

3. Entrepreneurial Capstone Experience

The final module is focused on giving the students a culminating experience in setting up their own new venture as well as being able to fill out the paperwork to start a new business. In essence, the first two courses are prerequisites for this module. In this module, the tools and concepts from the specialization courses are integrated to develop a comprehensive venture pitch and plan to present to experts and investors. Finally through this module, students will learn how to pitch the venture through a written analysis of the business model canvas and a video for potential funders, what are the 'dos' and don'ts' of the pitch, getting funded and steps in the funding process.

At the end of all three modules, the students will have developed the skills discussed earlier to start a new venture as well as create a competitive advantage for themselves when they go out into the workforce.

Digital Manufacturing Pathway

The recent economic shifts highlighted the need for more technical jobs, which also are higher-paying jobs. These jobs are not only important for the benefit of workers and their communities, but also important for the economic and technological competitiveness of the United States. To induce more students into technical jobs, the effort must start in K-12 education systems, which was the impetus of the Digital Manufacturing Pathway for K-12 students. At the onset of developing the pathway, the authors realized the skill gap created by the lack of technical training in K-12, which is basically out of scope of the precollege educational system. Thus, the Engineering Design Process was selected to be the first pedagogical basis of the pathway. The design process guides engineers in development of products from conception, i.e., creative ideas to meet a need or solve a problem, to realization, i.e., manufacturing of actual products on the market. The redefined engineering design process (aka design cycle) as seen in Figure 1, was integrated in mechanical design courses at the undergraduate level at the college of engineering, which reported significant improvements in the technical, design skills of students as they moved to higher-level courses and into the job market [11]. The importance of the design cycle is the unification of the thinking process about systems design; thus, enabling students to approach any problem with systematic methodology seeking the most economically and technically feasible solutions.

Manufacturing, the latter part of design, is one of the main drivers of economic activities. This is the second pedagogical basis on the pathway development. In order for the U.S. to gain and maintain advantage in global competitiveness, manufacturing necessitates speed to market. To reduce time-to-market, 'digital thread' can be used to integrate and drive design, manufacturing, and product support. One consideration of 'digital thread' is intelligent 3D solid model that include the design intent, which can also be used to create the machine movement during manufacturing.

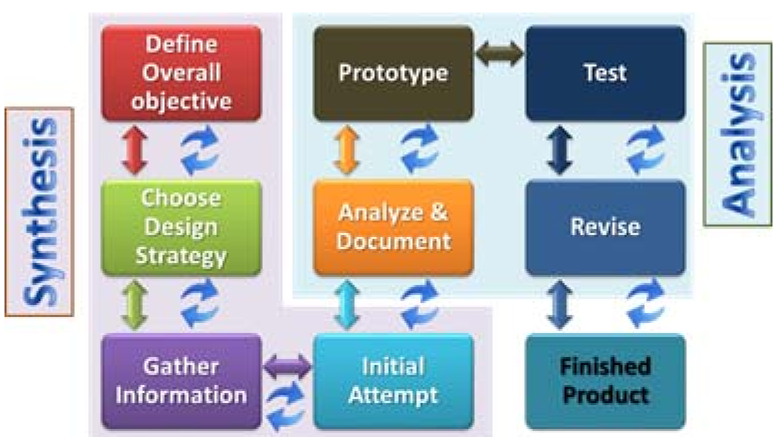

Figure 1: Modified Engineering Design Cycle [11].

This workforce development program is designed to equip interested students with necessary introductory skills to thrive in the area of digital and advanced manufacturing. This Digital Manufacturing Training is also divided into three training modules: Introduction to Computer-Aided Design with SolidWorks, Introduction to Additive Manufacturing using 3D printing, and Capstone Design Project. The description of each module is as follows:

1. **Introduction to Computer-Aided Design with SolidWorks**

This is a cornerstone module in the Digital Manufacturing workforce development training, where students learn the main concepts of engineering and mechanical design. The topics of this module include: engineering design process and its symbiotic steps, forced-innovation design mindset, fundamentals of orthographic projections, fundamentals of 3D solid modeling, feature-based modeling, constraints-based modeling, associated modeling, and intelligent modeling. The module includes lecture presentations, class discussions, hands-on experiences, and team projects.

2. **Introduction to Additive Manufacturing and 3D Printing**
This is the second module in the Digital Manufacturing workforce development training, where students learn the steps of realizing their design through 3D printing. In this module, a historic background about 3D printers is first introduced, and then the impact of 3D printers on third industrial revolution is discussed. Students will be able to immediately hold, evaluate, test and use their designs as well as share it with each other and the world.

3. **Capstone Design Project**
The main goal of the third module is to design an assistive technology mechanical object to help people with special needs. Each group of students deliver well-defined 3D solid models, fully functional assistive technology device, formal design report, and formal design presentation.

Survey Findings & Analysis

This paper was written at the conclusion of the first module from each pathway. The pathways at California State University Northridge recruited 14 students in the innovation and entrepreneurship pathway and 7 students in the digital manufacturing pathway. For reporting purposes to the funding agency and to assess and evaluate the impact, a self-perception pre- and post-module survey was designed and administered to students. The survey was developed jointly by the faculty administering the pathways in consultation with faculty who are experts in survey design. The initial survey that was developed was piloted among a few faculty members at California State University, Northridge, before being distributed to the students.

Innovation & Entrepreneurship Pathway

Module 1 started on September 26, 2015 and concluded on November 14, 2015. As part of the continuous improvement philosophy of the grant, surveys were administered by the faculty teaching this pathway. The student feedback will be used when making changes to the program for next cohort of students.

Fourteen students started the pathway, but one student stopped attending after Week 6 due to which only 13 completed the post surveys. The group of students was a diverse from several different ethnicities as well as grade levels in high school. Approximately 69% of participants were male and the remaining 31% were female. The percentage of women in the program represent significant increase over the current enrollment in the College of Engineering as well as the national average of women in engineering [12]. While gender diversity was evident in the participants, ethnic diversity was not well represented such that 85% of students identified themselves as White. This lack of ethnic diversity is attributed to the students' demographics in the feeder schools, which are part of the grant consortium.

The overall results of survey responses are shown in Table 1. The self-perception survey consisted of six questions to evaluate the students' knowledge for topics ranging from innovation to business plans, where 1 = no knowledge, 2 = heard the term but do not know much beyond that, 3 = heard the term and understand something about it, 4 = aware about it and understand quite a bit about what it means, and 5 = very aware of it and understand details including how it works.

Table 1: Summary of data collected from Innovation & Entrepreneurship pathway

Topic	**Pre-survey (n=14)**			**Post-survey (n=13)**		
	Mode	Ave.	SD	Mode	Ave.	SD
Innovation	2	3.14	1.23	5	4.85	0.38
Entrepreneurship	4	3.71	0.91	5	4.85	0.38
Target Marketing	4	2.86	1.29	5	4.62	0.65
Creative Thinking & its Application	3	3.64	1.08	5	4.54	0.52
Venture Capital Financing	1	1.86	0.86	4	3.85	0.69
Business Plans	3	2.71	1.14	5	4.77	0.44

From reviewing the average, the post survey results show that the students in this pathway understood topics related to the basics of innovation and entrepreneurship but were not as fluent when it came to the understanding of the topic of venture capital financing. Creative Thinking also scored relatively low. This could have been possible because of a lack of time spent on venture capital financing, which will be focused on in the third module.

In addition to the summative evaluation, students were also asked formative questions about level of satisfaction with the module as well as areas of improvement. Interactive discussions and collaborative learning were greatly enjoyed by students. In the collaborative learning aspect of the module, students discussed a topic, then formulated and articulated their opinion. This was highly valued as the students were able to hear varying perspectives about a topic. Conversely, according to the students, improvements can be made by including a lot more hands-on work and increasing the amount of group discussions that were held in the class to address real world problems.

Digital Manufacturing Pathway

Ten students initially enrolled in Digital Manufacturing pathway, but only seven were able to finish the first module. The demographics of the participants are 71% Whites and 29% Hispanics. The same percentages were reported for male and female as well as 11th and 12th grade, respectively.

The pre- and post- surveys asked the students to rate their skills and knowledge about four topics: (1) Engineering Design Process, (2) Engineering Design Tools, (3) Computer-Aided Design, and (4) Parametric Solid Modeling. The five-point scale system remains the same as the one used in Innovation and Entrepreneurship pathway survey. Table 2 shows a summary of the survey, which lists significant increase in the skills and knowledge of the students.

Table 2: Digital manufacturing pathway pre- and post- survey results

Topic	**Pre-survey (n=10)**			**Post-survey (n=7)**		
	Mode	Ave.	SD	Mode	Ave.	SD
Engineering Design Process	1	2	0.94	5	5	0
Engineering Design Tools	1	1.6	0.70	5	4.86	0.38
Computer-Aided Design	2	2.7	1.06	5	4.71	0.76
Parametric Solid Modeling	1	1.4	0.70	5	4.86	0.38

In addition to the summative evaluation, the post-survey asked participating students four formative questions. The first question asked if the students have taken any CAD courses before, and it was found that some of them took no CAD courses while others took CAD drafting or "introduction to engineering" where AutoCAD or Autodesk Inventor was introduced. The second question asked about the most important student learning outcome, and the students mentioned the following: "*how to think like an engineer and take different perspectives*", "*steps for making a new product*", "*learning SolidWorks software and its tools*", "*working together*", and "*introduction to college environment and engineering*." The third question asked what the students enjoyed most in the program, and the students mentioned: "*learning new software in a good pace*", "*meeting new people*", and "*working with a university professor in an interactive and relaxed environment*." Finally, the last question asked about the student's opinion on how this module can be improved. Some students reported satisfaction of the current structure, while others asked for textbooks on the new software, college credits for those who finish the entire pathway.

Furthermore, the students were also asked if they traveled to California State University Northridge for the Pathways classes on Saturdays by riding the bus that was provided by the funding agency or if they made their own transportation arrangements. This detail was asked to judge if it was worthwhile to continue providing bus transportation for the students or if the resources could be used elsewhere. Nonetheless, 71% of students reported using the bus to get to the Pathways Classes on Saturday mornings.

In closing, regardless of the pathway, the benefits highlighted by the students are enormous as noted from the survey results. The authors would like to point out some specific benefits:

- Students connect with the college level classes, through which they not only learn to think outside the box but also develop a mature way of thinking and approaching problems;
- Gives them a chance to bridge the fundamental math and science concepts, and promote collaborative project-based learning at the college level;
- Students get to attend their first college level class while still in high school;
- Students learn the basics of innovation and entrepreneurship with hands-on activities;
- Students learn fundamentals of Computer-Aided Design with SolidWorks, Introduction to Additive Manufacturing using 3D printing, and Capstone Design Project;
- The pathway teaches design-simulate-build activities and thus enables a student to explore a career in engineering; and
- At the end of the training, students earn a certificate that will help them get a part time job in engineering firms as technicians before they start their career in engineering.

Conclusion

The K-12 educational concern in United States relates to the preparation of students for science, technology, engineering and mathematics (STEM) career pathways. As part of our pathways program, it was seen that the students' career interest in STEM areas could be developed and nurtured while at high school or even earlier if they are given proper exposure to such careers and its potential benefits. That is to say, correctly designed career pathways that introduce applicable engineering software and instill an innovation mindset to high schoolers help create early aspirations, which is very important for persistence to STEM careers.

The survey results for both pathways discussed herein show the benefits the high school students gained from their experiences in our pathways. Furthermore, the students had a high level of enthusiasm at the end of the pathways modules, which showed a strong buy-in from the students. This is critical for the success of this program. The continuation rate of the students who continued from module one to module two has also remained high, which is a positive sign. One of the concerns was that due to long duration of the program, students might drop out along the way but this has not happened to date, which again speaks about the success of the program.

It is also worthy to note that the despite the innovation and entrepreneurship pathway being focused towards business, it can be implemented into engineering programs very well since there is a huge push nationwide towards incorporating entrepreneurial skills into engineering students from organizations such as the NSF and Venturewell. This can be applied across various engineering departments and does not have to be restricted to only the more closely related engineering majors to business such as industrial engineering or engineering management.

Lastly, the survey also helps us to implement continuous improvement for the curriculum in module two to make it more beneficial for our student's educational experience. This includes requests from the students to invite industry practitioners to the classroom to share their experiences in relevant fields of digital manufacturing as well as innovation and entrepreneurship. Furthermore, the students were asked questions related to the logistics connected with the pathways and helped the administrators make related decisions such as providing transportation etc. At the conclusion of Module 3 of the pathways program, in the third week of May 2016, there will be additional questions asked to the students about the modes of offering the classes, the duration etc, based on which the administrators and faculty will make decisions on how to modify the offerings in Year 2, which is the 2016 – 2017 academic year.

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