Integrating an Innovation Concentration into the Engineering Curriculum

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Abstract

A recent survey of global innovation-based competitiveness ranked the US 6th overall across 40 countries in innovation-based competitiveness. In fact, the US is falling behind, ranking last in year-to-year improvement in innovation and competitiveness [1]. To improve on this, the US must produce more STEM graduates capable of driving innovation. Many mid-sized universities in rural and low-technology states lack a culture or ecosystem that fosters innovation. To grow into thriving centers of technological innovation, these states must change their culture. STEM students – particularly engineering students – need a background in innovation processes, as well as real-world connections and experiences, to help develop their innovation instincts.

The College of Engineering (CoE) in collaboration with the Walton College of Business (WCOB) at the University of Arkansas is addressing these needs by developing a scalable, repeatable, applied innovation curriculum through a multi-discipline, multi-college academic innovation track. Starting as freshmen, engineering students will be partnered with business students to focus on innovation principles and processes, while incorporating classroom content with hands-on experiences and internships to focus on new product development. Students from both colleges learn why innovation matters, how to work together to create innovation, and how to solve problems that have market demand. To expand this change to an innovation climate, the University will partner with regional engineering and technology industries in a manner that can serve as a model for other institutions. The CoE will use a combination of qualitative and quantitative data to evaluate and iteratively improve the program with the overall objective of attracting, retaining, and graduating students who are capable of innovating. These students will enter the workforce better prepared to improve the economic health and competitiveness of the US [2].

This paper focuses on the strategy, design and development of this program, lessons learned, and plans for the future.

Introduction

A topic of significant discussion and debate by the University of Arkansas College of Engineering Dean's Advisory Council over the past five years has been a concern that engineering graduates have programmatically been taught to use their methods and "toolkits" in a way that has (unintentionally) resulted in a reduction in or elimination of innovativeness by its formulaic approach. As a result of these discussions and encouragement by the Advisory Council, the Dean of the College of Engineering (CoE) and the Dean of the Walton College of Business (WCOB) decided that one way to address this would be to recruit a team to integrate *innovation* into the CoE and WCOB curriculum and to include opportunities for the students of both colleges to do so together.

One of the benefits of spending many years in industry – over 50 years of combined experience – in new product development, is the experience of leading and managing teams who are constantly innovating. This includes creating and inventing ways to build new products and processes and ways to significantly improve or replace existing products and processes and leading and managing teams of various professions and skills types (engineering, finance, marketing (product and outbound), manufacturing, service and support, etc.), from new hires, to seasoned, to end-of-career professionals. From that experience, we have realized that (1) the formulaic approach to engineering (and business) education has pushed innovation to the wayside, and (2) lack of experience in working with other-than-their-own professions and skills types result in culture shock when new graduates enter the workforce.

The second realization, lack of experience working with other-than-their-own professions, is an "a-ha" moment in understanding why it is that groups who need to work closely together in companies (engineering and marketing, finance and sales, service and support and engineering, to name a few) seem to be unable to communicate and, to the extreme, even harbor ill feelings and ill will to those who should be their "partner." An excellent way to solve a problem is to find the root cause and to eliminate that root cause so the problem actually does not exist. Creating a curriculum that includes opportunities for those who need to be able to work together to allow them to understand each other and their roles in successful *innovation* better prepares them for personal and professional success post-graduation.

Literature Review

Two key elements in integrating innovation into the engineering curriculum are creating an environment and culture that encourages and *expects* innovation and the means to attract students who have a desire to create and innovate. When creative and innovative people are in a culture where innovation is not encouraged they experience the tension of efficiency and standardization over creativity and innovation [3].

For 2017, the United States was ranked 4th overall in the Global Innovation Index behind Switzerland, Sweden, and Netherlands [4] maintaining the ranking it had for 2016.

And, notably, in the same index ranking it lost 8 positions in Infrastructure (21st), three positions in Knowledge and Technology Outputs (10th) and was ranked 41st in Education [4].

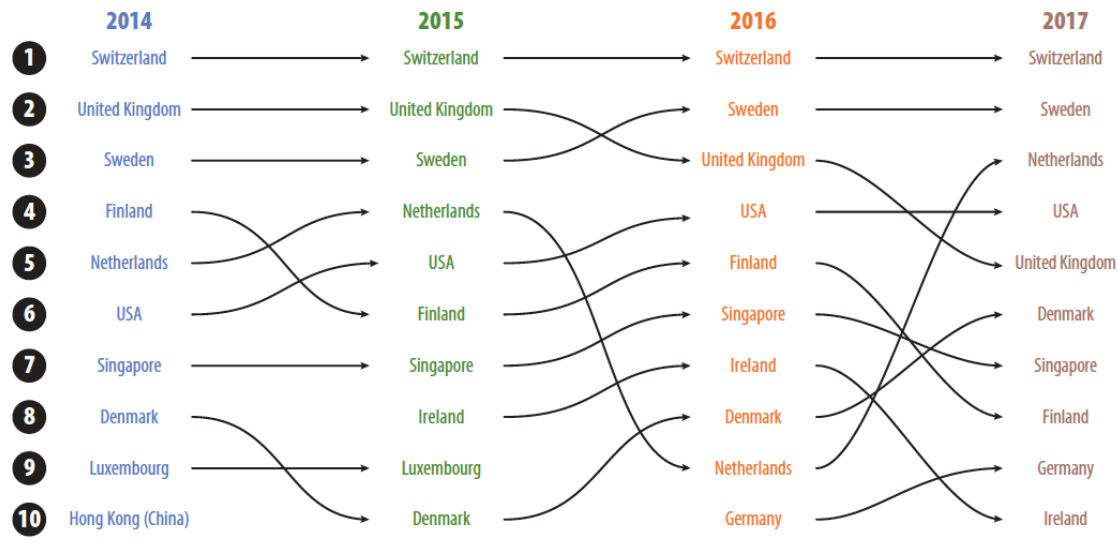

Figure 1. Movement of the top 10 of the Global Innovation Index 2014-2017 [4]

Within the United States, many mid-sized universities in rural and low-technology states lack a culture, environment or ecosystem that fosters innovation. The Consumer Technology Association™ recently identified nine states in their lowest tier on their Innovation Scorecard (defined as: "Modest Innovators"): Alaska, Arkansas, Hawaii, Kentucky, Louisiana, Mississippi, New Mexico, Tennessee and West Virginia. These "Modest Innovators" are characterized as:

> "…[those with] room to improve across most of the [Innovation Scorecard] categories, with slower internet connections, small tech workforces, low numbers of STEM graduates and slow or declining entrepreneurial activity [5]."

Innovation is the intersection between engineering, business (including entrepreneurship) and creativity (including areas beyond the traditional engineering and sciences such as art). In engineering, the focus is oftentimes simply finding a solution to a problem. However, when focused on *innovative* products and services as solutions to problems the role of entrepreneurship is to commercialize those innovations. That *innovation* is the core of what is commercialized – what it is that makes an advancement unique, interesting and different. And, education plays a key role:

> "As was stated in the landmark report Rising Above the Gathering Storm (NRC, 2007), the vitality of the U.S. economy is 'derived in large part from the productivity of well-trained people and the steady stream of scientific and technical innovations they produce. Without high-quality, knowledge-intensive jobs and the innovative enterprises that lead to discovery and new technology, the U.S. economy will suffer and our people will face a lower standard of living.' Indeed, according to a recent National Science Board (NSB) report, some 16.5 million individuals in

> 2010, including many in non-STEM jobs such as sales, marketing, and management, reported that their job required at least a bachelor's degree level of science and engineering expertise (National Science Board, 2015). According to Kelvin Droegemeier, NSB vice chairman, the key message of the NSB report is that STEM knowledge and skills enable both individual opportunity and national competitiveness, and that the nation needs to develop ways of ensuring access to high-quality education and training experiences for all students at all levels and for all workers at all career stages [6]."

Yet, there are significant barriers to successfully educating and developing an educated STEM workforce. For the 2011 freshman cohort at the University of Arkansas CoE, the graduation rate from the College was 48% (an increase of 2% abs. year-over-year) and for the WCOB was 45% (a decrease of more than 3% abs. year-over-year) [7]. One of the most effective means of improving retention is to provide *authentic STEM experiences* involving

> "…hypothesis-driven, hands-on experimentation in which the outcome is unknown, peer-to-peer support, faculty-student interactions, and academic support…. Classroom-based strategies that engage students in authentic STEM experiences are in line with evidence-based instructional strategies that require moving away from lectures and recipe-based laboratory exercises toward more open-ended and student-driven STEM experiences…. Undergraduate research programs and internships may be particularly important for students from underrepresented groups since they may facilitate students' identities as scientists and engineers…. Authentic experiences may also involve opportunities to work on industry related projects [8]."

Using these approaches with an *innovation* focus are the guiding principles of our strategy and approach.

Overall Strategy for Solving the Problem and Filling the Need

For an *innovation* STEM experience to be *authentic*, it necessarily requires exposure and experience with the other critical element and partnership: the business aspects of marketing, perceived user value, product management, manufacturing, cost and profitability, and service and support. We have developed a three-pronged approach to bringing this key aspect of the *authentic STEM experience* to the Engineering Curriculum: The development of the Freshman Engineering Program Honors *Innovation* classes, the creation of the McMillon Innovation Studio, and the inclusion of business majors from the WCOB into the 2018-2019 academic year FEP Honors Innovation (FEP HI) Fall and Spring Semester classes.

For 10 years, the CoE has had a Freshmen Engineering Program (FEP) Honors *Research* class that provided research opportunities for teams of Honors students matched with a faculty with active research as mentor. We chose to use this model, at a high-level, because it is familiar to the faculty as an approach, though basing a project and team on *innovation* rather than research is definitely a new approach resulting in a different method of recruiting faculty for mentoring the teams.

In order to "quick start" the integration of *innovation* into the engineering curriculum, we created an overall strategy of starting with piloting a Freshman class, then piloting a Senior Design/Capstone class, then providing pathways from the Freshman class (two semester class) to the Senior Design/Capstone class. The concept was to introduce the key elements of *innovation* in the first year, including results and recommendations from [6] and [8] and the experiences from an existing Freshman *research* class, expand on key aspects from the Freshman *innovation class* in existing sophomore- and junior-level major-specific classes (again using the results and recommendations from [6] and [8]), and then bring it all back together with an *innovation-based* Senior Design/Capstone class and project.

The McMillon Innovation Studio at the University of Arkansas, which grand opened in October 2017, is an interactive learning environment for students of all backgrounds to work with corporate partners to analyze, design, develop and perform in market tests on future looking retail technology. The purpose of the Studio is to produce students who think from an innovative perspective and become catalysts of change in their chosen industries. The students actively involved with the Studio are primarily from the CoE and the WCOB.

The CoE FEP HI program and the McMillon Innovation Studio program are further described in detail in the following sections.

Implementations to Realize the Overall Strategy

The development of the Freshman Engineering Program Honors *Innovation* classes is the basis for two prongs of the three-pronged approach we have taken to provide an *authentic STEM experience* to the Engineering Curriculum.

<u>CoE Freshman Engineering Program Honors Innovation Classes</u>

The Freshman Engineering Program (FEP) was established by the College of Engineering at the University of Arkansas during the fall of 2007 for the purpose of increasing student retention from the first year to the second year. FEP provides proactive support to FEP students through orientation, academic advising, peer mentoring, and professional development workshops. All incoming freshman students that plan to major in one of nine CoE programs complete a common curriculum during their first year. As a Freshman Engineering Program, one of our primary concerns is our students' progression through introductory courses including calculus, chemistry, physics, and introduction to engineering. The course sequence is offered as two, one-credit hour courses each semester of the first year. Course content focuses on engineering problem solving, hands-on projects and information about the CoE departments so they can make an informed decision about which major they want to pursue during the fall semester of sophomore year. The goals of these projects are to reinforce engineering skills taught in the course, develop teamwork skills, incorporate engineering design and maintain or increase interest in engineering.

First year engineering students at the University of Arkansas come from a variety of K-12 backgrounds and begin their course of study in math from pre-calculus (a semester behind) up to differential equations (three semesters ahead). Approximately 20% of incoming first year students have earned credit for calculus I either through Advanced Placement (AP) exams or dual enrollment with their high school and community college. These students often have other credits for core course and sciences and are well ahead of the engineering eight semester degree plans. During the first year of FEP (i.e., 2007), the director recognized a need to challenge the more advanced students while not letting the other students fall behind. Therefore, in 2008 a new series of courses called Honors Research Colloquium (first 8 weeks fall semester), Honors Research Experience I (second 8 weeks fall semester) and Honors Research Experience II (spring semester) were created. During the Honors Research Colloquium students attend weekly research seminars delivered by the University of Arkansas faculty about his or her research program and learn to utilize library resources to conduct background research on engineering topics. During the second 8 weeks, students form teams and are matched with a CoE faculty mentor. For the remainder of the fall semester and during the spring semester students conduct research guided by their mentor. The Honors Research Experience culminates with the Honors Engineering Symposium where students can showcase their work to other students, faculty and the public.

As a direct result of the Dean of Engineering's Advisory Council recommendation to incorporate innovation into the engineering curriculum beginning with the freshman year, FEP piloted a series of courses called the Honors Innovation Experience to parallel the Honors Research Experience. These piloted courses were limited to nineteen honors students who were enrolled in calculus II or higher during fall 2017 and were looking to use their creativity to begin engineering design at the freshman level. During the Honors Innovation Colloquium (first 8 weeks fall semester) students explore topics in innovation and entrepreneurship including intellectual property, venture capital, market need, product costs and marketing channels via seminars presented by industry professionals. Beginning in the second 8 weeks, and continuing into the spring semester, for the Honors Innovation Experience (HIE) students form teams and work on an innovation design project under the guidance of a faculty mentor. Students practice concepts such a market interviews and perceived user value to establish a need for their product or service and develop a prototype (working or theoretical). These students then pitch their product or service at the Honors Engineering Symposium.

During the piloted courses, the instructor for the HIE solicited faculty with innovative design experience (either through academic research or industry experience) to mentor the student innovative design projects. The Innovation projects for the first year's pilot are summarized below:

- **H2.0: Facilitating Clean Water Solutions:** This team researched and developed a product that focuses on the use of recycled agricultural waste to create activated carbon to be impregnated with solver nanoparticles as a means of water filtration that is longer lasting, easier to use, and cheaper to produce than other commercially available water filters.

- **Modular Engine Design:** This team researched and compared existing engines to determine the best fit for a low cost, recreational aircraft. Because of the engine's versatility, they concluded that the engine could be successful in other markets.

- **Development of Commercial Software for Autonomous Heavy Vehicle Maneuvering:** This team built and programmed a digital signal processor (DSP) for use in electric vehicles. The DSP converted the power from the car into a form for the motor to use. The revolution speed of the wheel was controlled by the DSP which altered the current flowing through a balanced three phase load. The motor could also resist the motion of the axle which converted the kinetic energy from the car back into electrical potential energy.

- **An Alternative Method for Collecting Solar Energy and Employing it to Dry Grain:** This team questioned if it was possible to harness solar energy without using expensive solar panels. Their project explored an alternative device that harnessed solar energy to heat and pump air. They explored using this device to dry grain in developing nations.

- **Mobile Manufacturing and 3D Printing Using Robotics and Electrified Flooring:** This team's project focused on a subset of a greater project which was to develop a mobile 3D printing robot. This group worked to design and develop an electrified floor to power the mobile robot.

Four of the five project teams achieved results related to their original plan whereas the fifth project team had the real-life experience in innovation of needing to pivot – which they successfully did. And, one of the five teams came to the conclusion that their approach would not be viable and therefore recommended that it no longer be pursued. Another real-life experience in innovation.

Retention from first to second semester for all of the FEP cohort is approximately 70%, and most students who leave FEP return to the University of Arkansas in the spring semester as a student enrolled in a different college (e.g., business or science and arts). During the fall semester, three of the students enrolled in HIE changed their major to a college outside of CoE at the University of Arkansas, and therefore left the HIE program. However, 84% of the students completed the HIE and participated in the Honors Engineering Symposium.

The students enrolled in the piloted courses were encouraged to participate in a voluntary survey during Spring 2017. Students were asked to rate aspects of the course by answering Strongly Agree (SA), Agree (A), Undecided (U), Disagree (D) or Strongly Disagree (SD) to a set of provided statements. Seven of 16 students participated in the survey, and the results are presented in Table 1, below.

Table 1: Student perceptions of the HIE experience during the piloted year (Fall 2016 and Spring 2017).

	SA	A	U	D	SD
The climate of the class is conducive to learning.	42.9%	57.1%	0%	0%	0%
The course emphasizes problem solving.	85.7%	14.3%	0%	0%	0%
Course activities/assignments helped me learn course material.	57.1%	28.6%	14.3%	0%	0%

My problem-solving abilities improved because of this course.	71.4%	28.6%	0%	0%	0%
This course improves my understanding of concepts and principles in the field.	71.4%	28.6%	0%	0%	0%
Course Projects increase my understanding of concepts and principles.	57.1%	28.6%	0%	14.3%	0%
My ability to work with others was enhanced in this course.	71.4%	28.6%	0%	0%	0%
I am likely to use content from this course to be more successful in my college career.	100%	0%	0%	0%	0%
Giving an oral presentation enhanced my ability to present findings efficiently and effectively.	85.7%	14.3%	0%	0%	0%

Because of the success of the first year's set of piloted innovation courses, the courses were expanded to 40 students with the same eligibility requirements in fall 2017 and spring 2018 with implemented improvements learned from the first piloted courses. The two major improvements were restructuring of colloquium topics and requiring students to create their own innovative project idea.

Because we relied on industry experts to lead the colloquium presentations during the beginning of the fall semester, we were limited by speaker availability during the piloted courses. During the second year of HIE, we were able to reorganize the topic order of the presentations to create a better flow of the innovative process and to incorporate homework assignments to reinforce skills learned during the colloquium. These exercises benefit the students when they are actually developing their product or service in the spring semester.

In four out of the five groups that participated in the first year's set of piloted courses, the faculty mentor provided an innovative design idea that the students then modified and developed during the course. In the fifth group, the mentor explained his areas of expertise and the students expressed their areas of interest. Together they defined a project for the students to develop. The members of the student-defined project appeared much more invested and engaged in the work. Student ownership over an innovative idea *they defined themselves* appears to be a key aspect of success for groups involved in HIE. Therefore, in the second year of HIE, students were required to develop their own innovative idea, and were then matched with a professor with experience in the needed area of design. The professor then worked with the student teams to develop a reasonable scope of work for the spring semester. The professor then mentors the student teams as needed providing guidance and feedback throughout the semester.

The development of the – Innovation Studio is the basis for the third prong of the three-pronged approach we have taken to providing an *authentic STEM experience* to the Engineering Curriculum.

<u>The McMillon Innovation Studio at the University of Arkansas</u>

The CEO of Walmart Inc., who is also a graduate of the WCOB, realized a critical deficiency in the labor force: specifically, the ability to bring creativity and innovation to new opportunities.

Through a generous personal financial gift by this CEO, we were able to create The McMillon Innovation Studio with the objective of producing students who are able to think from an innovative perspective and can be catalysts of innovation in their respective industries.

The mission of the team charged with creating the McMillon Innovation Studio, visited similar programs at many other Universities and found that most programs seemed to focus specifically on the output of the program being a "startup company." The student engagement in most of these programs seemed to be secondary to the "startup process." We decided to stay focused on the primary product of the University – students – and to put them at the center of the learning process and on October 14th, 2016, we had the grand opening. Now, student teams could work alongside innovative companies looking to solve difficult industry challenges and whether they succeeded or failed they would learn through the process. We chose to form these teams with students from different backgrounds, majors and interests to ensure cross-training and co-development of skills. The McMillon Innovation Studio focuses deeply on learning through doing with small injections of instruction through the process. The degree of instruction and the depth of action depends primarily on the model the student is involved in and we decided to test three models: 1) Internship Model, 2) Design Contest Model, and 3) Class Room Model.

<u>The Internship Model:</u> The primary vehicle and the physical embodiment of the McMillon Innovation Studio was a physical space located near the WCOB, the Computer Science and Engineering and Mechanical Engineering buildings, and co-located with a parking garage for ease of access. This model would create a deep collaboration between an industry partner with *preferably* pre-market technology needs, and a team of students who would be hired specifically to work with that company. Over the course of a semester, students would evaluate the needs of the company, the needs of the market, and the intended customer and work with that company to build, test, and locally pilot that technology or need. These needs would range from final mile delivery robots, to developing ecommerce business models for sustainably sourced potting soil, to new models of delivery service leveraging delivery lockers.

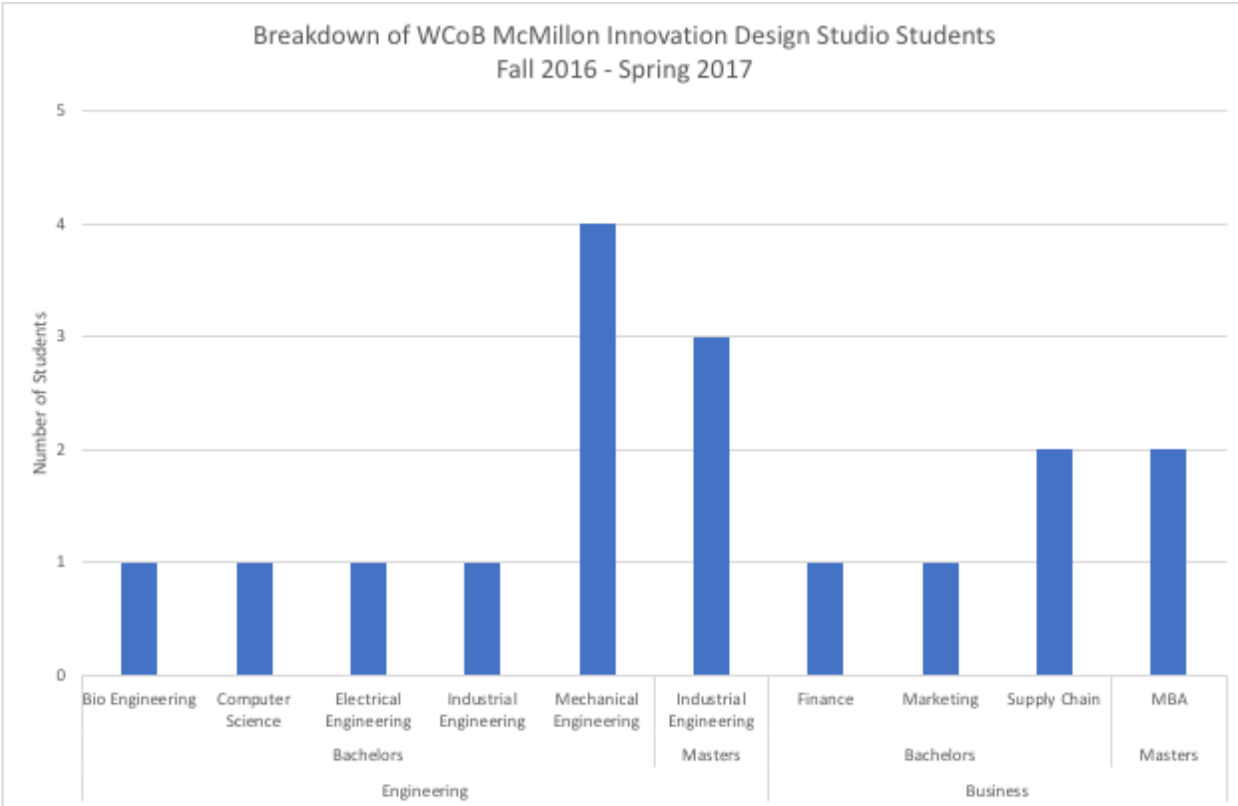

Figure 2. Breakdown of WCOB McMillon Innovation Design Studio Students

Cross-functional teams of students shared skills across majors so much so that business students would learn robotics and problem solving from engineering students and engineering students would learn why price and profitability are so important. This type of cross-pollination also gives students a better feel for what teams will look like in their careers.

> "As a result of working with business students, I've decided to take some business classes and have learned that I really like these classes to engineering classes because there's not always a right answer and I have to think through the implications," said Canon Reeves, CEO of Lovelace Technologies.

This was a quote from a Freshman computer science major and shows how valuable the cross-functional teams are to the process. Additionally, we have students tell us that this is the only place for these different majors to associate with each other. As a result of this class we have seen accounting majors take mid-level management positions in software strategy roles at hiring companies simply because they have gotten great at thinking out of the box and speak the language of business *and* engineering.

<u>The Design Contest Model.</u> The second model we used was a contest-based model, that's structured similar to an early stage startup accelerator. Students on campus would be invited to form teams to solve a single challenge and have the opportunity to win a cash prize that varied between $10,000 and $16,000 depending on the contest. The cash prize would be intended to

cover the startup costs for the students to form a company based on their idea and approach. Bill Gross, the billionaire, investor, co-founder of IdeaLabs once said,

> "I believe that the startup organization is one of the greatest forums to make the world a better place. If you take a group of people with the right equity incentives and organize them into a startup you can unlock human potential in a way never before possible. You can get them to achieve unbelievable things [9]."

In this model a company presents a specific challenge and students from across the University are invited to form startup teams with at least one CoE student and one WCOB student. The contest will last roughly 12 weeks. Each week of the contest students spend time with a subject matter expert and receive specific mentoring. The subject matter might range from how to use the Lean Canvas [10], to how to start a startup, to time with potential customers, to spending time with Design experts.

This model has proven to be specifically beneficial for helping students connect the innovation process to something a customer would use and inject that design philosophy in their work from the beginning.

> "I've really learned a lot from the Design Contests. This process has really taught me to focus on the usability of my product as well as the end cost. Before this contest I would have focused primarily on the coolness of the technology," said Canon Reeves, CEO of Lovelace Technologies, the winner of the first Design Contest.

<u>The Classroom Model.</u> In this model, we teach the fundamentals of the innovation process and create a funnel for the McMillon Innovation Studio, both in terms of trained students but also in terms of innovative new technology to develop.

This model is one semester long and students sign up to take the course. Companies sponsor project teams and seed the ideas for students to work on. This can range from developing a new organic vegetable brand and securing presells to developing the business case and customer design requirements for a visual based product picking solution that uses AI to control both supplier and retailer supply chains. In this model, instructors teach students Agile project management and bring in mentors to help students develop it from Project Initiation to Implementation. Even though this class is a WCOB class, we partner with both CoE and the Art College to give students full immersion in the process. The end of this model concludes with all of the students from all of the projects presenting to all of the project sponsors.

> "This class is really challenging for me. Most of my other classes, the instructor will tell me the formula and I have to just repeat with different numbers. There's always a known answer. Here, not only is there not a one right answer, but no one knows what this is supposed to look like."

This is a quote from one of the students in our first cohort and is very telling of how different this type of class is from the norm. Another great comment came from a Vice President-level sponsor in a large consumer beverage company during our last cohort.

> “I’ve been in this industry for 30 years and no one has ever thought of something like this. You don’t know anything about this industry and in three months have developed an incredibly innovative solution and given me the numbers behind why it works.”

To date the McMillon Innovation Studio has connected with over 260 students across all three models, and across four colleges on the University of Arkansas campus, since its grand opening just over a year ago. Additionally, the Studio has connected students to over 20 companies in direct engagement relationships and students have created three startup companies as a result of their engagement with the Studio. Two of these companies were the direct result of the design contest and the other new company fulfills a social mission of helping underserved individuals in the community learn to code, find jobs, and earn a greater standard of living for their families. The Studio has helped or is currently helping four non-student startups. While the Studio has accomplished a lot in sixteen months, we have also learned a lot.

College borders are rarely crossed organically: Students from different colleges do not typically take advantage of opportunities to interact. Thus, communicating and marketing to students of different colleges can be difficult. Students of different colleges do not typically follow the same communication vehicles either. This has been a specific challenge for which we have had to develop strategies.

Students prefer smaller, on demand engagements: Recruiting students for 12-week design contests has been challenging for two reasons. First, large sums of money scare students away, and it is difficult for the students to predict what their workload will look like over 12 weeks from the vantage point of the beginning of the semester. However, where there have been short, weekend long, events with small prize amounts or tech related giveaways, students seem to become very engaged across college boundaries.

Experiential learning is a preferred model by Students. In our Classroom Model, we have experienced semester over semester growth that has outstripped our capacity. The Classroom Model started out with 1 section that immediately filled up. The next semester, 2 sections were offered and immediately filled up. The third and fourth offerings had 3 sections that have completely filled up.

Gender diversity is limited in Engineering. Gender diversity has remained balanced with higher concentrations of business students to engineering students. As the teams shift further toward Computer Science and Engineering the gender diversity in applicants begins to match the demographics of the CoE rather than the WCOB. This is a challenge we discovered in talking to corporate recruiters as well. Several initiatives have started to turn this around. Partnering with organizations like “Girls Can Code” may be one way to increase the long-term applicant pool.

Cross functional teams of students shared skills across degree fields. For example, WCOB student teams working on final mile delivery robots learned from CoE students, how the components of the robot worked together and could repair or re-assemble the robot. The CoE students, working on the same project, learned, from the WCOB students, what the business case was behind the robots and why each type of functionality was important to a consumer need.

Measuring Progress

Changes in creative thinking abilities and in student engagement will be measured by using the Abbreviated Torrance Test for Adults (ATTA) [11] and the National Survey of Student Engagement in Engineering Students (E-NSSE) [12], respectively. The Team Climate Inventory (TCI) [13] will be used to evaluate whether regional technology companies that offer *authentic STEM experience* internships or co-ops experience a significant increase in their climate for innovation in the area(s) in which the interns or co-ops are assigned. This will assist in identifying how innovation instruction develops both innovative skills in engineering students and innovative climate of organizations, while also providing a basis for developing best practices for in low-innovation states.

Future Plans

In the Fall semester of 2018, thirty Honors Engineering and 20 Honors Business Freshman will be recruited to the FEP Honors *Innovation* class. Over the course of the Fall and Spring semesters, the students will form mixed (Engineering and Business majors) teams for as part of the *authentic STEM experience* projects and will be able to contribute from their perspective and also experience working with students of the other perspective – just like they will encounter in "the real world." This actually addresses a major need and issue that has been problematic in the corporate world: the challenge of those working in business-based roles and those in engineering-based roles being able to communicate, understand the value of each other's roles and contributions, and being able to work together to a common goal leveraging those differences. In other words, an objective of this approach is to *avoid* these problems by not having them even develop in the first place.

For the sophomore and junior years, major-specific classes will be identified and *innovation* elements, following the same principles as for the FEP HI classes, will be integrated into the curriculum of those classes. While we believe, at this point, that this is a feasible approach, we may also find it necessary and appropriate to design new classes that are *innovation-centric*. The decision on whether or not to do so will be made as we iteratively evaluate and improve the program as it evolves.

For the Senior Design/Capstone classes and projects, we will look to expand the participation beyond CoE and WCOB students to those in other colleges as naturally occurs by virtue of the projects available.

In parallel, we will be developing relationships with local businesses and corporations to develop multidisciplinary *innovation-based* internships, *innovation-focused* co-op opportunities, and *innovation-based* real-life Senior Design/Capstone projects.

In the next iteration of the McMillon Innovation Design Studio, a more concentrated effort will be made to recruit students to participate in activities by attending classes in other colleges and connecting to student organizations in different colleges. Additionally, in order to scale the knowledge transfer beyond the classroom, the Studio will be testing targeted, "on-demand," vignettes where students can learn specific subjects or skills in a weekend that they can apply elsewhere. The Studio will become more purposeful about how it connects students to industry. Students are interested in making a difference in the world. The Studio will be going deep in a few key subject verticals and leveraging the Design Contest model to scale to a broader group of students. The Studio will be working with departments to scale the very successful Classroom Model so that the capacity of teaching can meet demand from the students. Lastly, due to the interest in students to create their own companies, the Studio will be evaluating the development of a student-based startup accelerator.

Overall, the results and achievements to date have been very promising as we iteratively improve each existing part of the curriculum and develop the next part(s). We expect that completing the curriculum with at least a full iterative improvement of each part will take at least 5 years and will likely be a "living curriculum" since *innovation* is an ever-changing process.

Lessons Learned and Final Thoughts

While there have been many lessons learned, probably the most significant one for all three prongs of our approach is that innovation requires continuous innovation. Now that we have begun the journey of integrating an innovation concentration into the engineering curriculum, it will be necessary for us to continue to iteratively improve and innovate not only *in* the program but also *on* the program to be successful and of lasting value to our students.

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