Expanding and Evolving an Innovation Concentration

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Abstract

Recent reports published by the Walton Family Foundation [1] [2] highlight the importance of innovation to the US economy and the critical relationship between innovation, university research and education for workforce development and economic prosperity. To develop an innovation-based ecosystem, the US must produce more STEM graduates capable of driving innovation.

> "At the heart of an innovative local ecosystem is its capacity to absorb new knowledge for industrial use. Industrial innovation is defined by the capability and propensity to engage, translate, absorb and exploit new knowledge and the active participation of a university, including facilities, faculty, staff and students who can aid this process." [2]

In 2018, the US declined from fourth to sixth in the Global Innovation Index with the United Kingdom (fourth) and Singapore (fifth) advancing. [3] The 19 States comprising the "American Heartland" have a State Technology and Science Index (STSI) significantly below the mean for the US. And, five states in the southern Heartland are in the bottom ten for the country. [4] Research Universities can be (and are) major sources of innovation through the commercialization of their research.

However, research does not need to be the only source of innovation from research universities. Innovation can also come through students by way of purposely developed or enhanced courses, pedagogy, and experiences designed to create a spark or foster an existing spark, fan the flames, and fuel them to help them grow. It is unfortunate to create the spark in first-year students and then ignore it until it is time for the senior design / capstone project; the innovators need to continue to learn, experience, and grow throughout their academic career. To be a meaningful real-world experience, an innovation concentration needs to incorporate learning and experiences within disciplines students will encounter once they have begun their professional career including: engineering (of many types); business, marketing, finance, accounting, manufacturing, supply chain, sales, and management; industrial design, architecture, science, service and support; and, an understanding of business customers and users – from first-year through to capstone.

Translating this into pedagogy and curriculum means innovation-based or innovation-infused courses, problem-based and active learning-based, real-world experiences in partnership with the innovation ecosystem and a progression based on gaining knowledge, skills, and experience. And, to match the real-world, these courses need to be interdisciplinary, multi-disciplinary, trans-disciplinary, and multi-college / multi-school (engineering, business, arts & sciences, architecture, etc.). Innovation is at the Venn diagram intersection of engineering, creativity and business, at the core of what is commercialized and provides the basis for entrepreneurship. Innovation is not a solution looking for a problem; it is a solution for a need. [5]

Expanding and Evolving an Innovation Concentration describes our initiative to develop the concept, pedagogy, faculty, curriculum, outcomes, experience, and the students to create

graduates who can engage, translate, absorb, apply critical thinking, and exploit this new knowledge of innovation, and who can innovate and experience this continuously through their academic career.

Introduction

Three years ago, the University of Arkansas College of Engineering (CoE) began by offering a pilot program, now collaboratively developed with the Sam M. Walton College of Business (WCOB). The origin of the program stems from the CoE Engineering Dean's Advisory Council observing, over time, that recently graduated engineers, newly hired by their companies, seemingly struggled with developing new ideas, new ways to approach problems, or being able to solve problems they had not seen before. It was almost as if the creativity, innovation, enthusiasm and "out of the box" thinking they brought with them into engineering programs was being (unintentionally) trained out of them by the prescribed approach focused on formulaic methods and "toolkits."

A second significant observation was that students were also very short on team-based project experience with others outside their discipline. The initial – and, oftentimes, lasting – effect of this deficiency being an inability to work with and communicate with others – including engineers, those with differing skills, and everyone else involved in product or services development thereby creating quite a culture shock for new graduates. The workplace for engineers is not only engineers – it includes business professionals (e.g., marketing, sales, finance, accounting), customer support, and customers. To be successful, engineering and business students need to be able to survive and thrive as *partners*, not adversaries. And, experience shows that this is an issue that does not go away with time; it actually gets worse without direct management coaching and intervention.

The Deans of the CoE and the WCOB chose to address these needs by recruiting a team to integrate innovation for engineering and business students, partnered, into pedagogy, curriculum, and real-world experiences with other-than-your-own professions. Creating a program that includes opportunities for those who need to be able to work together to allow them to do so and to understand each other and their roles in successful *innovation* better prepares them for personal and professional success post-graduation. [5]

Literature Review

In a recent survey of the needs for aligning education systems for 21st century skills [16], three key skills were frequently identified by national education systems: collaboration, critical thinking, and problem solving. These are *transferrable skills* in contrast to the *content and knowledge-based* approach taken in most classes where the emphasis is on facts, memorization, and rote problem-solving that reward correct (and singular) answers. The need for 21st century skills has evolved to focus on "learning progressions (that) reflect typical trajectories of specified learning domains that describe how skills or concepts might be demonstrated, both in their early forms and in increasingly advanced forms." [16, p. 19] Important in this approach is a combination of “scaffolding” – providing a means to deal with knowledge or skills not yet available to the students – and guided learning transition from “unknown” to “known” or “inexperience” to “experienced.” What is then rewarded is the application of knowledge through transferrable skills in learning progressions to open-ended questions of increasing difficulty. The challenge for the education system is to align the three elements of pedagogy, curriculum, and assessment.

Integrating a new approach into the education system at the program level can be quite challenging. At the course-level, instructors have significant freedom whereas at the program-level, the process is collective where “compromise dominates and satisfactory conclusions may or may not be reached.” [17] While this is a challenge, the very nature of higher education academic institutions provides the opportunities for individuals to foster change. Effective ways to do so include passion, storytelling, networking, improvisation, bricolage, network bricolage, hustle, bootstrapping and resource seeking. [17] In other words, it parallels many of the same skills and approaches required to start a truly new program in an existing, established company.

A review of the literature over the past ten years for the topic of this paper – integrating a multi-college interdisciplinary innovation concentration into curricula – yielded an interesting set of trends:

1. Most articles fell into one of the following categories: Engineering-only, Capstone- or Large Project-only, or general concepts and considerations – mostly engineering-only.

2. The terms “multidisciplinary”, “interdisciplinary”, “cross-disciplinary”, and “trans-disciplinary” were used nearly synonymously and mostly directed within their (singular) college (higher level discipline).

3. When “entrepreneurship” and “innovation” were used together, most of the focus was on “entrepreneurship.”

4. There is no clear preferred means to assess students’ progress along the innovation and/or creativity spectrum.

For integrating innovation into “Engineering-only” focused literature [18 – 80], topics and coverage includes: relationships of research to commercialization, the disruptiveness of adding active learning to engineering education, adding the Arts (for STEAM), application of science and technology history, design thinking, project- and experience-based learning, integrating entrepreneurship education, integrating creativity, the Conceive – Design – Implement – Operate (CDIO) model, continuous improvement integration, closing the gap between research and practice in engineering education, industry collaboration, global sourcing, “Engineering Education 4.0”, deep vs. broad knowledge in interdisciplinary education, 24-hour entrepreneurship competitions, entrepreneurship training for engineering students, appreciation and understanding of non-disciplinary perspectives, and inventive problem solving.

For integrating innovation into “Capstone- or Large Project-only” focused literature [81 – 108], topics and coverage includes: project-based learning comparing team-based vs. individually assigned projects; integrating business skills; CDIO; integrating design, manufacturing and business realities; integrating business concepts and entrepreneurship using case studies; multi-scale approaches and innovation into various engineering discipline’s projects; creative problem solving; reviews of learning models; developing a culture of experimentation; social innovation networks; designing for an unknown future; improved teaching-learning process; collaborative teaching; developing an entrepreneurial mind-set; business engineering programs; and, vertically-integrated teams.

For integrating innovation into “Academic / University / Industry Partnership” focused literature [109 – 121], topics and coverage includes: Europe vs. other geographies; integrating a technology ventures program; makerspaces; research and commercialization collaboration; tech startup learning activities; integrating innovation and entrepreneurship competencies into companies; an industry-academia model for research; technology transfer and licensing; intellectual property; open data usage; and, engineering leadership.

And, for the general topic of integrating innovation focused literature [122 – 154], topics and coverage includes: transdisciplinary learning; merging disciplines; innovation in the classroom; integrating innovation through collaboration of business and engineering; changes in the teaching and learning process in a complex education system; role of transdisciplinary studies; engineering education reform; introducing students to entrepreneurship; increasing student engagement; sources of innovation and creativity; teaching engineering ethics; developing decision-making competencies; impact of problem-based learning on women in STEM; faculty workshops; cultures of innovation; and, educating creatives.

The fact that there is very little published on the design, pedagogy, implementation, and iterative improvement of multi-college interdisciplinary innovation-based concentration / track for engineering and business students together does not confirm they do not exist. There were two programs identified:

1. University of Nebraska [155]: focused on computer science, computer engineering and management, only.

2. The Ohio State University [156]: an integrated business and engineering honors program taking existing classes together as a cohort focused on entrepreneurship and a cornerstone and capstone project together.

There are aspects of innovation in many programs and there is even stronger interest in integrating innovation, experiential learning, open-based problems, and true multi-college, interdisciplinary curricula, pedagogy, and experiences. However, it is quite challenging to do in reality, which may explain why there are few actual examples of these programs.

Objectives

What is the process for developing a multi-college, interdisciplinary curriculum that emphasizes innovative and creative thinking, the ability to work on interdisciplinary teams and solve open-ended challenges, especially ones students' have not previously seen?

"Entrepreneurship and innovation" are popular topics in academia, the literature, and the media. Yet, once past the title and initial discussion, the focus invariably is on *entrepreneurship* – not *innovation.* This focus on entrepreneurship is fueled by the excitement of "the start-up experience," the aura of its founders as *entrepreneurs*, and the community for economic development. "Entrepreneurship leverages innovation to create value" [10] and "entrepreneurs need to search purposely for the sources of innovation" [11] to be successful. Whereas "[i]nnovation – or practical creativity – is mainly about *making* new ideas useful [and] an innovator…solve[s] old problems with new ideas…or solve[s] new problems with old ideas used in radically different ways." [12] Innovation is possible without entrepreneurship whereas entrepreneurship is most often based on innovation.

Recent studies on future workforce needs identify the need for "refreshing curricula to include skills required in the future workforce – both digital as well as 'human' skills such as communication, problem-solving, creativity, collaboration and critical thinking." [13] And, while it might be natural to infer that proficiency in new technologies would be at the top of the skills list, it is "only one part of the 2022 skills equation…as 'human' skills such as creativity, originality and initiative, critical thinking, persuasion, and negotiation… attention to detail, resilience, flexibility and complex problem solving [will] see outsized increase in demand relative to their current prominence." [14] At the same time, "[m]any corporate HR [human resource] executives…stated that the curricula of educational institutions – starting with the earliest educational stages – are insufficiently aligned with the current needs of their industry, and even less with the future needs of the [Fourth Industrial Revolution]." [15] In addition, a concern expressed by the CoE and the WCOB Deans' Advisory Councils is that the current focus on formulaic approaches to problem presentation and solutions for students has actually taught these needed skills *out* of the students.

It is these needs and shortcomings that we are focused on addressing. Our focus for this concentration is on *innovation* as we believe that it is applicable to most – if not all – of our students in some form whether they enter the workforce through employment in an existing company (most) or through creating their own company.

Interestingly, when we first began designing the innovation program, with combined engineering and business students (and faculty), we found a challenge with terminology. We began by describing the needs and approaches: open-ended, problem-based, active learning, student-driven and student-focused, innovation-focused, and *interdisciplinary*. The challenge we found with *interdisciplinary* is that within a particular college (e.g., engineering), the view of faculty was that students and departments already worked together and were, therefore, *interdisciplinary* by definition. We then added "multi-college" to make it clearer: multi-college, interdisciplinary innovation program and team.

Once we were aware, we noticed a number of terms being used in the literature: multi-disciplinary, interdisciplinary, cross-disciplinary, transdisciplinary, to name a few. [6]

- Multidisciplinary: Combining or involving several academic disciplines or professional specializations in an approach to a topic or problem. *In this approach, multidisciplinary teams deliver medical, psychosocial, and rehabilitative care.*

- Interdisciplinary: Relating to more than one branch of knowledge. *An interdisciplinary research programme.*

- Cross-disciplinary: Relating to or representing more than one branch of knowledge; interdisciplinary. *A cross-disciplinary panel of scholars.*

- Transdisciplinary: Relating to more than one branch of knowledge; interdisciplinary. *Our transdisciplinary approach to research and education*.

However, most examples were *within* a college (e.g., engineering vs. business) or within a discipline (e.g., computer science and computer engineering vs. industrial engineering and a specialty within industrial engineering). We have chosen to stay with *multi-college interdisciplinary* as it captures the essence and, at least in the academic environment, is clearly understood by students, faculty and staff. And, this made it easier to recruit faculty, staff and students.

The program was conceived as:

- scalable:
  - not to be dependent on any one faculty member
  - able to evolve from a pilot class to multiple classes and sections

- repeatable:
  - post-pilot class, the course designs/syllabi, pedagogy and experiences could be reusable regardless of the actual specifics of examples, topics, or instructor

- multi-college:
  - colleges of engineering (first two years) and business (third year onwards)

- interdisciplinary:
  - first two years' pilot with CoE First-Year students (all disciplines) only
  - third year's pilot with CoE and WCOB combined First-Year students (all disciplines)

- academic:
  - books, literature articles, subject matter expert lectures
  - in-class activities and out-of-class assignments reinforcing lectures and readings

- open-ended problem-based [7]:
  - designed to drive motivation and learning

    - problem identification (i.e., need(s)) required
    - needs or problems may have more than one solution
    - there may be more than one way to reach solution
    - realistic to real-world experiences and expectations

- active-learning based [8]:
    - develop and practice collaboration, paired and group activities
    - reinforcement of topics, approaches, and skills
    - direct in-class feedback to students and teams
    - provide a direct relationship of the topics to the students and teams

- experiential learning-based [9]:
    - provide exposure to real-world complex problems
    - reinforcement of understanding needs before solutions
    - introduce and reinforce the ambiguity of real-life situations

- four-year multi-college interdisciplinary track / concentration progression
    - first-year introduce the overall concepts
    - middle years introduce innovation-based concepts into existing classes
    - final-year innovation-based multi-college interdisciplinary senior design/capstone
    - nurture, develop and expand innovation and creativity
    - positive reinforcement through the entire academic career
    - demonstrate skills in continuous and interconnected curricula
    - reinforce real-world needs and situations with continued exposure

This paper focuses on the strategy, pedagogy, design, development and most recent evolution of this program, lessons learned, and thoughts on future evolution and expansion.

Methods

> [S]ignificant improvements in pedagogy and student engagement must shift the emphasis to "formative assessment" in the classroom itself, and away from graded, exam-based "summative assessment". This is required, in particular, for higher level learning outcomes such as deep conceptual understanding and problem solving strategies, but is also a key to encouraging learners to take control of and "regulate" their own learning. It can also allow the curriculum and teaching to develop around the learners' own interests, as is the aim of "science in society", "real problem solving in mathematics", and "projects" in technology and across STEM. [161, p. 2]

A systems-level approach to pedagogy is necessary, rather than a faculty-focused or individual-focused approach. Working with individuals, departments, colleges, industry, and local government has been used in the design, development, and implementation of the program and curriculum across the entire system for a holistic pedagogical approach. [162, pp. 142, 148]

The "Pilot Approach". The thought of taking a "pilot approach" comes from the chemical engineering approach of designing and building chemical plants on a small scale to work out the problems and then "scaling-up" to a full-sized plant. However, scaling-up from a pilot process to a full-sized product plant is not a linear scaling as many processes, transformations, flow, chemical reactions and heat transfer are not together linearly scalable. That is: scale-up is (usually) possible but requires careful planning and "watching the dials and turning the knobs" on the first series of runs. Our first class sequence is a bench design, our second class sequence is a small pilot and third year will be a full pilot plant with subsequent years scaling to full production. Even then, we will have start-up issues and fine tuning to deal with as we continue to iteratively improve – watching the dials and turning the knobs as necessary.

By using the "pilot approach," and managing the specific changes made to iteratively improve and expand, year-to-year, we have been able to focus on retaining what worked, addressing what did not work, and adding a new variable each time that can then be iteratively improved upon the next time followed by expansion, if desired and needed.

Assessing Progress for the Pilot Programs. The CoE and WCOB are currently using qualitative data analyses through entry, mid-way, and exit surveys. Our intention is to research and apply appropriate quantitative data analyses to further evaluate and iteratively improve the program with the overall objective of attracting, retaining, and graduating students who are capable of innovating in a realistic, commercializing environment and to better prepare them for entering the workforce and to contribute to the economic health and competitiveness of the US.

Results and Discussion

First-Year Innovation Experience. The Honors Innovation Experience was first piloted in 2016 with 19 first-year engineering students. The fall semester was designed as two, eight-week courses. The first eight weeks (colloquium) consisted of guest lectures from industry professionals or academics that covered topics related to innovation including 1) Where Good Ideas Come From, 2) Lean Start-up, 3) Project management, 4) Patents, and 5) Manufacturing and Scaling. During the second eight weeks, students formed five teams and selected a CoE faculty member to serve as their innovation mentor. Most mentors gave the students an innovation-based project to work on, but one group developed their project idea with guidance from their mentor: the mentor identified his areas of interest and agreed to mentor them as long as their needs-based idea was within his areas of interest and expertise (this turned-out to be an *extremely* important iterative improvement for the second year's pilot). The students worked on their projects during the rest of the fall semester and most of the spring semester conducting background research into competitive products or services and developing a proof of concept (PoC) for their project. Because written and oral communication is imperative to be successful, not only in a student's college career but also in the workforce [157], students were required to read *The Craft of Scientific Presentations* [158]. In April, the student teams pitched their product or service at the CoE Honors Engineering Symposium. Students were also required to write a full paper, as well as develop a project poster (for the poster session and evaluation at the Symposium) and a pitch deck (for presentation and evaluation at the Symposium) for their design.

While conducting the piloted courses in the first year, we realized (for iterative improvement) that the content presented by the faculty and industry professionals in the first eight weeks of the course should be expanded upon and reorganized into a more logical series of presentations. We also observed that the student team that came up with their own project idea (noted above as an *extremely* important iterative improvement needed), as opposed to being given a project by their mentor, was much more engaged and invested in their project.

During fall of 2017, we expanded the Honors Innovation Experience to include 40 first-year engineering students. The colloquium presentations were re-ordered based on our first-year retrospective, 1) Where Good Ideas Come From, 2) Business Strategy, 3) Student Experiences from Last Year, 4) Venture and Investment Capital, 5) Pitch Decks, 6) Supply Chain/Manufacturing, 7) Product Life Cycle Analysis, 8) Intellectual Property Management. We expanded the topic list based on "holes" we observed in the curriculum during the piloted first year, and moved project management to the spring semester when the teams really began to manage their own project deliverables. We also transitioned to student-defined needs-based innovation projects *only,* which continued into the spring semester and culminated, again, with the Honors Engineering Symposium in April. The improvement in course content was recognized by the students with one stating: "This course was easily the most valuable academic experience I've had in College thus far. I am greatly encouraged by everything we've done…".

Our major insight into improving the course for the third iteration was to keep student-led project ideas, but to make sure that what they selected was something of value to a customer (truly needs-based) and not just a "solution looking for a problem." To do this, the students needed to understand the existing product market, as well as, a method to identify the value of a product to the consumer. We felt that students needed to be exposed to additional topics in the colloquium, including "Market Research and Perceived User Value", in addition, students were also required to read *Talking to Humans* [159]. But the biggest change we made to the course was the addition of twenty honors students from the WCOB. We decided to conduct a multi-college, interdisciplinary experience for the students to better simulate the real-world process of new product development, and to (hopefully) eliminate any bias the students had toward another major and/or college's students. The class began with 30 engineering and 20 business students who sat together through the colloquium portion of the class. We, as instructors, made an effort to not identify who was from which college to naturally observe how the students interacted with one another. At the conclusion of the first eight weeks, students were asked to form teams of five (three engineering and two business students), and to select an innovative project idea. Students were then matched with a faculty mentor with appropriate interests and expertise and began background research on their project and conducted market interviews. It is worth noting that the faculty mentors recruited, are volunteers (though nominally compensated), and are asked to only provide *mentoring* and to help keep their mentees from going "off the rails."

Unfortunately, only three of the twenty business students chose to continue with the spring portion of the Honors Innovation Experience. Some students had scheduling conflicts and could not fit the class into their schedule, while others were not interested in continuing with the product development portion of the course. Feedback from these students included:

> …that the course was "very engineering heavy", and

> "While I know it is the first-year for this course to partner with the WCOB College, I feel as though it is still mostly focused towards engineers rather than business students. In addition, I feel as though the purpose of business students in this course is unclear. While this course taught me how business skills are needed in the actual field, the need for business students in this course specifically seems unclear."

Not *all* business students felt this way, though, as one commented:

> "Great course, the ability to hear from important people from around the world was really awesome. Learned a lot, got to work with engineers who are always interesting, and improved general knowledge."

While we believe we are on the right track, there are clearly iterative improvements we can make to improve the balance of engineering and business and to better explain the importance and purpose of having business students in the class.

WCOB students in the program learned the right lessons from their experiences. They expressed an understanding of the innovation process, learned the importance of experimentation and gained an appreciation for the lessons associated with failure, but failing fast. Students indicated they enjoyed their interactions with engineering students and gained new perspectives as a result of these associations. The Honors program advisors enthusiastically support the program and look forward to recruiting students for class next fall.

Because we are in the pilot phase, we have chosen a very basic progress measurement approach. Students are encouraged, but not required, to participate in a course evaluation for every course they enroll in each semester. Students respond to provided questions with Strongly Agree (5), Agree (4), Undecided (3), Disagree (2), Strongly Disagree (1). Means of responses for each semester are summarized in Table 1 below. We carefully reviewed the evaluations each semester and used the data and comments to iteratively improve the program year-to-year.

Table 1. Summary of means (1- strongly disagree to 5-strongly agree) from course evaluations for fall and spring Honors Innovation Experience from 2016-2018. Students voluntarily and anonymously participated in the evaluations. n/a indicates that the question was not asked during that semester.

	Fall			Spring	
	2016	2017	2018	2017	2018
Number of respondents	10 (53%)	26 (72%)	28 (58%)	7 (44%)	20 (65%)
The climate of this class is conducive to learning *(i.e., open-ended)*	4.50	4.58	4.54	4.43	4.84
This course emphasizes *(open-ended)* problem-solving	3.80	4.50	4.36	4.86	4.80

My problem-solving abilities improved because of this course	3.40	4.08	3.96	4.71	4.80
This course improves my understanding of concepts and principles in the field *(i.e. innovation)*	4.10	4.81	4.50	4.71	4.70
Overall course	4.30	4.58	4.18	4.71	4.90
Course Projects increased my understanding of concepts and principles *(i.e., innovation)*	n/a	4.58	n/a	4.29	4.80
I learned effective oral presentation techniques	n/a	4.54	4.50	4.86	4.95
My ability to work with others was enhanced in this course	n/a	4.54	4.57	4.71	4.60
I am likely to use content from this course to be more successful in my college career	n/a	4.65	n/a	5.00	n/a
The content of this course is relevant to my needs.	n/a	n/a	n/a	n/a	4.55

In addition to the Freshman Engineering/Freshman Business pilot, we are also offering a Senior Design/Capstone Student Program. We are in the second year of this pilot program in which engineering and business students are partnered for a innovation-based real-world senior design / capstone experience, exposing them to a broader innovation climate, with an additional focus on regional humanitarian needs through social innovation. Through this innovation program, students from both colleges learn why innovation matters, how to work together to create innovation, and how to solve problems that have market and humanitarian need and demand.

This year's project is to develop an accessible lawn mower to allow those slightly physically and/or mentally disadvantaged to use (supervised) it as a means to help support themselves. The project includes students from engineering, business, and social innovation and has the additional dimension of having the direct "customer" (may be an agency or non-profit supporting the user) and the direct "user" (may be the person in need but who will not own – only use – the system) not necessarily being the same person or with the same needs. Understanding the needs and requirements, designing solution alternatives, reviewing them with the customers and users, understanding the acquisition and on-going maintenance costs, and what the customers (buyers) can afford are key considerations. And our findings will help determine whether this is an upgrade kit (and who would do the upgrade) or a new from-the-factory model.

Additional challenges in projects such as these include:

1. The students are from different disciplines and on different project calendars for milestones and assignments:
    a. Electrical Engineering, Mechanical Engineering, Business, Social Innovation
    b. The final products (PoC / Prototype, paper, presentation, poster session) dates do not all coincide.

2. Being the senior year, while this is a major focus it is not their only focus.

3. Most, if not all, of the students have never managed a project with their own classmates, let alone a project that involves others outside their discipline.

4. Each student team is organized differently and there is no formal and no regular mechanism for them to communicate and/or collaborate.

5. One student team's final products are for presentation in a "challenge" contest whose dates do not match-up with the other teams' completion dates.

Even though much thought, planning, and definition went into creating this multi-college interdisciplinary program, what was missing was that the students would not naturally, on their own, make more than a passing attempt to talk with the other teams. However, this should not be a *real* surprise for those with real-world experience as it happens regularly in product and services development organizations. It is the origin of the term "the left hand does not know what the right hand is doing (and may not even know why it should care)."

A retrospective at the end of the first semester yielded several issues needing iterative improvement:

1. This overall senior design/capstone project, with its multi-college and interdisciplinary aspects is really a group of *projects* that come together to be a *program*.
    a. Improvement: Have a faculty member act as the Program Manager
    b. Improvement: Have each team select a person to be their Project Manager (communications person)

2. Communications across teams and disciplines does not come naturally (to many)
    a. Improvement: Create a one-page weekly update to be shared by each team
    b. Improvement: All teams meet with the Program Manager weekly, 30 minutes
    c. Improvement: All team members exchange email addresses, etc.

Implementing these changes in the second semester has had an immediate positive effect with the teams coordinating their needs from and assistance to each other (see Figure 1, below). The teams are also looking into using contemporary, agile-focused tools such as Trello for additional communication and cross-scheduling the key intersecting meetings with the customers and users. This parallels the challenges of real-world projects coming together as a program without an overall program manager to ensure interactions happen as needed and that when a team hits a roadblock or when they need help from someone else, that can be made known to the appropriate teams in the presence of the Program Manager – whose goal is to ensure that the program is completed on time, on budget, on committed feature/function/service and on quality. This also provides a means by which the faculty advisors and mentors can have insight into the relevant pieces of the project for their team(s), how their teams work together and with the other teams, and whether there are leadership skills that develop throughout the period.

[Project Name]
[Name 1]
[Name 2]
[Date]
Project Status Update Summary:
[No more than three lines of summary of where you are this week compared to last week. Gantt chart, if available, should also be brought to class for discussion.]
Milestone(s) Achieved [since last Project Status Update Summary]:
1. Xxxxx
2. Xxxxx □ use as many “Milestones” as you need
Next Major Milestone:
1. [Milestone] [and when]
2. [Milestone] [and when] ← if needed, perhaps with another team
***Started* Tasks [since last Project Status Update Summary]:**
1. Xxxxxx
2. Xxxxxx □ use as many “Started” items as you need
***Completed* Tasks [since last Project Status Update Summary]:**
1. Xxxxxx
2. Xxxxxx □ use as many “Completed” items as you need
***Roadblocks* [since last Project Status Update Summary]:**
1. Xxxxxx
2. Xxxxxx □ use as many “Roadblocks” items as you need
***Help Needed from Others and from Whom* [since last Project Status Update Summary]:**
1. Xxxxxx
2. Xxxxxx □ use as many “Help Needed” items as you need

Figure 1. Project Update by Project Team for Program Discussion Weekly

Innovation Experience III & IV – Product Development I & II. This year, a new, additional two course sequence is being "bench scale" tested as technical electives. They are intended to be follow-on courses in the FYE Honors Innovation Experience I & II courses and are open to students from the CoE and WCOB. The course sequence is initially for teams that would like to continue their projects and have a desire to get a deeper understanding of the product development process, further develop their creativity and innovation skills, further develop their team and leadership skills, and improve their interactions with potential customers and users in real-world situations.

In addition to revising, reviewing, and executing their project plan from the first year's course, topics covered in-depth for the first class in this sequence include: 1) The Innovation Process, 2) The Product Development Process, 3) Critical Thinking, 4) Knowing Yourself and Others, 5) Introduction to Situational Leadership, 6) Budgeting and Forecasting for New Product Development, 7) Mid-Semester Retrospective, 8) The Innovator's DNA, and 9) End-of-Semester Progress Report and Future Looking Plans.

For the second class in the sequence, in addition to their project continuation, topics covered in-depth include: 1) What is Innovation?, 2) The Creative Self, 3) Leading Innovators, 4) Creating Innovation, 5) Winning with Innovation, 6) Mid-Semester Retrospective, 7) Innovator's Turning Points, 8) Creating (Smarter) New Ideas, 9) Shaping Better Futures, 10) Sharing Beautiful Ideas, and 9) End-of-Semester Progress Report, Presentation, and Poster Session including Future Looking Plans to be presented at the Symposium. For each class, the topic discussion is student led, covering the concept and readings and applying them to themselves, their team, and the innovation-base project.

Conclusions and Future Plans

One of the strategic initiatives of the CoE and the WCOB is the promotion of entrepreneurship and innovation among our students. Whether students ultimately start a business, participate in a start-up or work in an existing organization, a firm understanding of the innovation process provides students with a competitive advantage in the workplace. Students who possess an innovative mindset are better prepared to succeed in a high-velocity environment where change is constant. By learning models of innovation, students are prepared to work in an innovative culture where principles and practices such as experimentation, collaboration, tolerance for failure, psychological safety and flat hierarchical structures not only enrich the workplace experience, but also lead to better organizational performance. [160]

The CoE/WCOB First-Year Engineering Program Honors Innovation Class is designed to introduce entering first year business and engineering students to the innovation process during their first semester in college. This provides an important perspective for these entering students as they begin their college experience and at a time when they are most impressionable. In addition to the value of learning about the innovation process, we anticipate that students' engaged in this program will adopt an innovative mindset that they will apply to both their coursework and other experiences (internships, study abroad programs, student organizations) throughout their college experience.

Another benefit of the CoE/WCOB First-Year Engineering Program Honors Innovation Class is the interaction that occurs between business students and more technically oriented engineering students. While students have opportunities to interact with students from other colleges primarily through their General Education courses, the CoE/WCOB First-Year Engineering Program Honors Innovation Class enables students to interact at the frontier of their disciplines. The class requires students to consciously weigh the challenges of new product development from both a technical and a business perspective. Business students are challenged to evaluate technically innovative product ideas from a business perspective to determine whether these new product ideas will lead to viable consumer markets. This requires business students to work with complex, unstructured problems and make thoughtful decisions based on available data and information. Very few campus experiences will result in this level of thoughtful engagement by business students.

The program also builds students' social networks and communication skills. As noted earlier, students have few opportunities for meaningful academic interactions across different colleges on campus. The CoE/WCOB First-Year Engineering Program Honors Innovation Class enables business students to build their social networks by interacting with engineering students on class projects. The interactions also foster communications skills as students must carefully navigate the divide between the languages of business and engineering. This is excellent preparation for careers in business, as employees in business disciplines are frequently asked to interact with engineers and others with a technical background. Building an understanding of the differences in language and perspectives at an early stage in professional preparation will be valuable to students in future interactions.

For the First-Year Engineering + Business Program Innovation Experience Fall and Spring classes, based on our experiences to date this year, we will develop a stronger recruiting approach for the business students for the next academic school year – especially reinforcing that it is a two-semester sequence and working with the student advisors to help avoid unnecessary conflicts in the Spring semester. We will also use the student feedback to iteratively improve the course – especially the portions that involve the balance of engineering and business.

For the multi-college interdisciplinary innovation-based Senior Design/Capstone project, we will use a retrospective at the end of this semester to identify what to improve for continuation of the project next year – including broadening its applicability. In addition, we plan to develop an additional project for the program that would involve a student-generated, innovation-based, needs-based project.

For the second-year Innovation Experience III & IV – Product Development I & II, based on the experience and feedback from the students, we will actively recruit students from the current First-Year class and also recruit *outside* that pre-requisite class to pilot bringing students into the track who have not taken the first course sequence. This would match the experience of a transfer student or a student who has changed majors, for example. We will also continue discussions with the WCOB McMillon Innovation Studio on partnering to allow student-ideated, student-led, innovation-based projects to further the multi-college interdisciplinary approach. The McMillon Innovation Studio is a recently created physical hub that supports entrepreneurship and creative endeavors on the University of Arkansas campus.

To further expand the number of students reached, we plan to take modules from the First-Year and the Second-Year Innovation Experiences and integrate them into the First-Year non-Honors classes. We will also be evaluating opportunities for integrating similar modules and pedagogy into existing second- and third-year courses where there is an opportunity for both engineering and business students to be in the course. This will allow us to continue to fill-out the innovation concentration.

In addition to the courses described above, the WCOB offers students several additional opportunities to learn more about the innovation process and to put into practice innovative techniques. For example the College offers junior- and senior-level elective classes focused on creativity and innovation. The WCOB curriculum also includes a number of hands-on courses that enable students to apply innovative business practices and the opportunity to participate in a student-run business known as SAKE (Students Acquiring Knowledge through Enterprise) and project-based experiences through the WCOB Innovation Lab where they connect with practitioners while working to solve real-world business problems. While each of these courses helps to engage students in the innovation process, they are all targeted at advanced and/or graduate-level students.

Lastly, we are going to research the most current methods and approaches for assessing evolving, changing and improving (or not) innovativeness and creativeness in order to establish a baseline and then to measure and evaluate our programs and the effects of changes we make to them.

Lessons Learned and Final Thoughts

We have learned many excellent lessons through developing, implementing, and improving this program to this point in time. Probably first, and foremost, remains that an innovation program pedagogy needs retrospectives, iterative improvements, new innovations based on curriculum and course feedback, and an ability and willingness to be flexible. We have also found a student-center pedagory of an open-ended, active learning-based, problem-based approach with student-ideated projects, student-formed teams, and faculty mentors who only mentor is a very good formula for success. While these classes are not for everyone (appropriate students will tell you who they are) there are topics in these classes from which many could benefit. Growing the scale of this program is an objective for the future.

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