Engineering Virtual Studio: KEEN Modules to Foster Entrepreneurial Mindset in an Integrative, First/Second Year Online Course

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1. Abstract

Engineering is a field that interacts with its surroundings by applying science to practical problems. In developing future engineers, teaching the technical fundamentals is only part of the task; engineering programs must also develop engineers that are able to apply those skills into the real world. Example problems are sometimes shown in classes, but lack the interactivity necessary to instill the skill in students. Introducing students to entrepreneurship directly promotes creativity and marketplace connection while indirectly instilling connection to real world problems and promoting scholarly and pre-professional identity within engineering.
Here we introduce foundations to an entrepreneurial mindset to freshmen and sophomores via online modules, which we developed and piloted this academic year. We have previously built a one-credit, online, pass/fail course, Engineering Virtual Studio (EVS), that builds understanding across foundational coursework and into real-world relevance through discussions with peers and upperclassman mentors. Our new Entrepreneurial KEEN Modules integrate into EVS investigations into market and society driven problems, to which students explore solutions in consultation with campus and local experts, all in an integrative context. This instills a mindset of problem establishment and problem solving as cornerstones to foster real-world relevance, motivation, and goals for students beginning as early as possible in their undergraduate study.

This entrepreneurial foundation helps provide context and relevance to foundational material, and fosters independence and personally relevant vantage points on coursework and the whole of the major. Here we report on our work-in-progress and initial formative assessment of performance and motivation of students in the entrepreneurial modules.

2. Introduction and Justification

Our nation needs engineers that will drive innovation and leadership. Colleges and universities have outstanding undergraduate programs to train these rising engineers. Students receive critical elements of integration, real-world connection, leadership, and communication, however, only late in their undergraduate education. All engineering programs necessarily begin with foundational study, in mathematics, basic sciences, and underlying engineering principles. Explicit integration over this material, engagement with real-world products and research, and presentation of ideas usually happens only in upper-level courses (e.g. Garcia and Sinfeld 2011). This structure of curricula is sensible given the goal of proper foundation preceding higher difficulty challenges.

The big ideas and real-world challenges, however, are the elements that attract many students to engineering in the first place. Departments of engineering should meet this interest directly, as early in undergraduate education as possible. As programs meet this goal, students become engaged in larger ideas more quickly and become facile in connecting between materials and thinking broadly. With early engagement in big ideas, our students will be more adept at tackling our nation's problems and leading scientific progress in the 21st century.

One of the best ways to combine creativity and engineering is through the introduction of entrepreneurialism and an entrepreneurial mindset. All initiatives involve a combination of

content and environment. Current initiatives to introduce entrepreneurialism range from creating entrepreneur living communities where students reside in an exclusive Program residence hall and take one specialty class per semester for their first 2 years (Green 2011) to introducing entrepreneurial case studies into specialized higher level classes (Garcia, Sinfield 2012) or developing case study modules that could be integrated into core curricular classes (Weaver 2011). Our intervention shares the aspirations of the Weaver work in that repeated, modular exposure to entrepreneurial mindset can motivate students, but the Weaver work requires that faculty in core classes adopt the generated modules. Our work is unique in that we built and delivered modules in the context of an intervention that persists throughout the first four semesters in an online workspace concurrent with traditional courses, requiring no alteration of core coursework or housing, and focusing on integration, real-world connection, and personal identity formation. Our work promotes consistent integration across courses and early and frequent connection to entrepreneurial vantage points; provides examples to motivate underclassmen and opportunities to engage with experts and real people outside the academy; and challenges students to develop their skills in teamwork, communication, and creativity.

In this work we developed and piloted modules to expose freshmen and sophomores to the foundations of an entrepreneurial mindset within an online community. Engineering Virtual Studio (EVS) is a one-credit, on-line, pass/fail course to build community and explicit connections across foundational coursework and into real-world relevance. EVS is different from other endeavors because it utilizes information from technical foundational classes, but is not specifically tied to any which one, and also does not involve the alteration of core course's semester schedule. The content was facilitated by the Kern Entrepreneurship Education Network (KEEN), a program of the Kern Family Foundation to foster entrepreneurial mindset in undergraduate engineering students.

We are able to deliver entrepreneurial content through EVS in units we call EVS KEEN Modules. There are a total of four EVS KEEN Modules, one per semester of the first and second years, to introduce four key elements of entrepreneurial mindset (Kriewall and Mekemson 2010). The EVS KEEN Modules integrate initial investigations into market- and society-driven problems, to which students will develop solutions in consultation with campus and local experts. Within we instill entrepreneurial problem-establishment and problem-solving as a cornerstone to foster real-world relevance, motivation, and goals for students beginning as early as possible in their undergraduate study. These lightweight, but substantive and interactive, early interventions will seed interest in entrepreneurism, innovation, invention, and marketplace as students begin investment into themselves, their driving interests, and their academic and professional goals.

3. Work

3.1 Methods

EVS Structure

Each EVS semester is a one credit, pass/fail, online course to provide a platform for growth of the BME Community through small group discussions. The online small group discussions (6 students per virtual table) help students develop their communication skills through posting electronically on discussion boards. EVS is built to be a lightweight intervention atop the demanding traditional course load. We have found a balance between substance and accessibility through introducing 6 modules each semester, which permits 2 weeks consideration

and discussion for each module topic. The last two weeks are left for self-reflection as students write a personal reflection essay and compile portfolios, both of which develop the students' scholarly and pre-professional identity and integrate across their formal coursework and outside experiences.

EVS Module Structures

Each of the EVS modules follows the same presentation and discussion model. Each EVS module links a core concept within the underclassman foundational course load to a real-world, current topic in engineering. Each module has up to four initial elements: introduction paragraphs that connect the core concept and real-world engineering products and problems; a review paper or multimedia that illustrates that connection; when appropriate, a computational model simulating that connection; and a set of preliminary, starting questions to initiate online, integrative discussion. Students participate in discussions within their teams of six and dissect the published material; explore the computational model; and examine the discussion questions. Each freshmen team is visited by an online mentor, upperclassmen who serve as part-time TAs, to help foster a local community of scholars, both pushed and supported to complement their deep foundational study with broader, integrative consideration. The fall sophomore semester has more student freedom in which they pursue a larger, self-guided project. Each module ends with the team "leader" (a rotating position) of a particular module posting the highlights of team discussion to a course-wide board.

EVS KEEN Modules

EVS KEEN Modules (4 in total) follow the basic EVS module structure, but add interaction with an expert to help introduce the relevant topic. Inclusion of experts within student discussions builds real-world relevance and expertise in students' individual understanding and group work, fostering deeper idea development and personal connection to entrepreneurial mindset. After team discussion of introductory material each team generates questions that they would like to ask the experts. These questions are filtered by an EVS administrator and then forwarded on to the experts. The expert's responses are then given back to the students to serve as bases for summative discussion. We deliver four modules around the four cornerstones of KEEN entrepreneurial mindset: Technical Fundamentals, Business Acumen, Societal Values and Customer Awareness.

EVS KEEN I Module – Technical Fundamentals: In this module EVS introduces awareness of basic fundamental knowledge to the students through specific examples—for example, motor control in health and in rehabilitation. The expert is a biomedical engineering professor who neural control of movement in health and in different disorders. This module will help students develop thought processes to help identify opportunities, begin evaluation of technical feasibility, engage in ideation towards solutions, and begin to collaborate within their group to bring scientific and engineering principles into practical solutions.

EVS KEEN II Module – Business Acumen: In this module EVS students interact with an expert with entrepreneurial experience and an engineering background. For the neurorehabilitation topic we collaborate with a biomedical engineer who works in the university's Skandalaris Center for Entrepreneurship. The students develop awareness in business, how to present engineering solutions in economic terms, how to build an effective and

mission-oriented team, and how to anticipate future technical, societal and economic change. This module helps students learn the importance of investigating the market and validating market interest, begin to ideate preliminary notions of a business plan, evaluate economic viability, and continue to develop collaborative methods to constrain possible product ideas with market-driven wisdom.

EVS III Module – Customer Awareness: This module features an expert who uses products in the field, who works with customers and can teach the importance of being mindful of client needs. The expert will help students critically analyze solutions for technical feasibility, economic drivers, societal needs and individual benefits. We work with a professor of physical therapy, who introduces how she adjudicates potential technologies to use herself and in her teaching of PT students. This module helps students evaluate customer value, identify distribution methods and supply chains, consider how innovations become meaningfully integrated into regular use, and collaborate to integrate practical within-field history and product use into their group ideas for innovation.

EVS IV Module – Societal Values: This module brings society and real-life situations to the forefront. The 'experts' are a pair: a local community practitioner in the field, and a real-life neurorehabilitation patient. This module places the most responsibility on our students to learn as much as possible about the lives of their potential end users, delving into needs that real people have in their lives, rather than presuming that pre-determined product ideas would automatically appeal to a clientele. This module helps students directly consider and build appreciation for the societal, human-scale needs that drive innovation and progress through entrepreneurial productivity. In the future we are hoping to have more experts provide their own, varying opinions. Hearing and interacting with the different views of professional societal values will increase the students breadth and depth of understanding the term value.

Within each KEEN module, students start with initial readings and discussion. In that first week, unique to KEEN modules, each group needs to generate and submit questions to ask the expert. Except for EVS IV, questions need to include nascent ideas that students believe will be appropriate for technical, business, or practical consideration. (EVS IV instead focuses on the real-life successes and challenges of the potential customer; the student-generated product ideas waits until after the expert interaction.) A EVS administrator vets and consolidates the pre-submitted questions, which makes up an initial set for the expert, who then responds to questions in a moderated chat. Students are able to submit follow-up questions, if they arise, through the moderator. After the expert's response each team considers how their views have matured with the guidance given by the expert.

(In actual implementation, discussions of students have intermingled customer awareness and societal values for both the EVS III and IV modules. In the living of our plan this seems reasonable – yes physical therapists are "customers" of technology and patients personify a "societal" impact, but clearly individual patients are also customers and therapists practice toward goals that impact society. We are also working on how to "define" societal values in an easy to understand and short way.)

3.2 Learning Outcomes

To perform well in EVS, students need to write their impressions of the module topics: their thoughts, difficulties, achievements, individual breakthroughs, and group deliberations. This focus on student consideration provides direct, measurable assays of student outcomes throughout the course. For KEEN Modules in particular, we have student writings upon initial consideration of a question, questions generated by the team, and then writings after expert intervention when the team revisits the question. We therefore have emerging data for individual and team growth during and after every intervention.

As of this draft (March 2014) we have completed our first complete set of the four KEEN modules. Our first goals are to test the viability and base effectiveness of our intervention – do students respond to initial readings to generate appropriate questions? Does the interaction with the expert lead to substantive incorporation of that interaction in module summation writings? Our initial pilot suggests that the formalism indeed works. As illustrations, here are questions submitted by a group of six freshman to the biomedical engineering professor (edited slightly for grammar):

> What research is being done to improve the effectiveness of Deep Brain Stimulation?
> How does different voltages and currents affect the patient during DBS?
> How effective and what is the success rate of DBS?
> How expensive is DBS and what are the risk factors?
> How does bioelectricity of the brain get affected during DBS?
> What are the side-effects of Deep Brain Stimulation?
> How does the cost-benefit analysis of these procedure compare to that of other treatements?
> How does the procedure affect people differently? (Ex. ethnicity, presence of other health conditions, and stage of the respective disease)
> How does deep brain stimulation work on the bioelectric level?

Here is a passage from the moderated chat with the physical therapy professor:

> Q: First, what is the general thought process behind making advancements in Bioengineering or the programs that are developed for individuals like those with Parkinson's or that have had a stroke? Personally, we as a team think that the focus of Biomedical Engineering should not necessarily be in the mindset of "fixing people", but more along the lines that we provide the help that the individuals what at the levels that they want: anything from something as invasive as brain surgery to something simple like a rehabilitation program.
> A: I would completely agree with the above statement. The goal of rehabilitation and bioengineering would be to maximize a person's independence with completing a task. The goal should be patient directed and meaningful and should capitalize on any available motion/abilities that they currently have.
>
> Q: Second, what do you think the ultimate goal of these programs and advancements in Biomedical Engineering is. Is it to return people to a function that is considered normal or as close to it? Do you think it is also feasible that we could push the boundary past what was normal and give these people better functioning than what they had before (assuming that is what they want)?
> A: Similar to the previous question/answer the goal is to get people back to doing

activities that are meaningful to them. I wouldn't use "normal" because that is challenging to define. Instead, I would work toward capitalizing on the current abilities and minimizing any barriers or obstacles that the person may have.

Q: Third, having actually had experience with these issues, what do you think the societal view to those that are disabled or handicapped is?
A: Views on disablement are definitely changing. The field of medicine has greatly improved the ability to save lives from acute injuries, but as a result more and more people are living longer with chronic diseases and disabilities. In addition, multiple laws related to accessibility have made it easier for people with disabilities to move around in the community and to work. Together, I hope that society is improving the negative views and stigmas that can often be associated with disablement.

Q: What do you think about human adaptation particularly to new diseases?
A: It depends… if the disease is a one time trauma (stroke-part of the brain tissue may die; spinal cord is sliced) to the system the ability for the body to adapt depends on the severity of the trauma (how much is left over to help out/take over for lost actions). Versus degenerative diseases like Parkinson's disease where disease will continually cause greater and greater damage.

Here is the summarizing paragraph written by a group of six sophomores after the chat with the physical therapy professor:

> We as a team took that a large societal value is typically seen as "fixing things that are broken;" however, this is often just a way of masking a desire to adapt/change in order to overcome a specific adversity (for example, prosthetic limbs in the TED talk). In general, society seems to see what is normal as what is done or possessed by the general public. We believe both from doing this module and from discussing with Maggie [the PT professor] that the general focus of BME should not necessarily be to "fix" people, but to give them the care or rehabilitation to the level at which they are comfortable, be it a program or a invasive surgery to eliminate the problem or suppress it. We think that it is important to have multiple solutions in this way. It may be possible through this to redefine what is normal and as Maggie said, they are definitely already changing with the advances in laws and BME technologies and therapies. We as a team think that there is a human element to BME that must be considered when making advances.

3.3 Deliverables

Our goals for students are to build connection, context, and community during underclassman coursework that would otherwise be dispiriting at best, and contributing to attrition at worst. For the engineering educational community, we aim to build a model of online intervention, with supporting, field-tested material, that will be accessible to all schools with minimal resources or changes to core curriculum and maximal flexibility of implementation. The KEEN Modules will mature into building exactly those deliverables for students and for the academic community.

4. Conclusion and Future Work

To our knowledge EVS is the first online learning environment built to support students throughout the major rather than in an individual class. Our goals parallel those of learning

communities, here with community building used to foster early integrative thought, between foundational material and real-world relevance, and initial scholarly and pre-professional identity formation. In this context, as a one-credit course atop a very challenging traditional curriculum, we seek lightweight intervention elements that provide strong context and meaning with a relatively small time commitment from students. The modules described within have double benefit. For an increasingly innovative world, we aspire to introduce students to flexible, inventive thinking to address and solve problems with an entrepreneurial mindset. Certainly our modules do not form the in-depth exposure students would get in true practica with industry, but we aim to establish early vantage points from which students can address traditional or entrepreneurial challenges with appropriate foundations, and that would help the students determine the appropriateness of subsequent opportunities for deeper interactions with business and/or entrepreneurism. We have additionally found preliminary evidence that the entrepreneurial modules serve well our overall goals for EVS: the connection of core material and underclassman experience to real world relevancies to help students think integratively and about their own motivation, values, and goals beginning in the earliest stages of collegiate study. Our initial pilot has indicated the broad viability of student input and output, through evidence of substantive thought along core ideas and incorporation of ideas, generated by interaction with experts, within summary writings. We next aim to further evaluate our intervention through qualitative study of pre- and post-interaction writings and through focused quantification of motivation, valuation, and integration in our freshman and sophomore engineers.

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