The Engineering Virtual Enterprise: A Framework for Soft and Entrepreneurial Skills Education

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ABSTRACT

This work seeks to tackle common workplace deficiencies present in associates-level, Pre-Engineering students, as well as cultivate entrepreneurial spirit and ability. These deficiencies cause attrition in the number of Engineering graduates, and have been identified by employers as being important to the modern engineering workforce [9]. Our proposed platform, the STEM-based Virtual Enterprise (VE), is a business simulation program in which students start and run a virtual firm within their classroom. The program is currently being successfully used in other STEM areas, notably BioTechnology and Information Technology[1].

The STEM-VE program, a combination of in-class pedagogy, software tools, and an international network of participants, is designed to develop entrepreneurial competencies, interpersonal skills (e.g., teamwork, effective communication in working with those in different roles and positions), critical and analytic thinking and problem solving. Each student assumes a position within the firm and carries out the responsibilities of his or her department.

This paper specifically lays out the framework for two Engineering Virtual Enterprise (***ve^{eng}***) engagements that campuses could adopt to provide an encapsulating experience for Pre-Engineering majors.

[1] The previous work described is based on funding from the National Science Foundation (under DUE-0501711 [14] and DUE-0802365 [13]). Any opinions, findings and conclusions or recomendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation (NSF).

1. BACKGROUND

The American Recovery and Reinvestment Act of 2009 supports innovative solutions to pressing national problems in science, health, the environment, education, public safety, and other critical areas, as a way of stimulating much-needed economic recovery and jobs creation. The Act, which provides tax breaks and increases funding for research and science, is based on the belief that entrepreneurs can innovate America's way back to prosperity [1]. Last December, the President proposed another round of economic stimulus measures that target job creation and support small businesses by providing loans, tax credits, among other measures [3].

In the engineering fields, the importance of entrepreneurial innovation is recognized: "Engineering is a key component of innovation and our technological society. Changes on a global scale are rapidly occurring for engineering, and Federal leadership is needed to respond quickly and informatively" [11]. "Engineering lies at the interface between science on the one hand and society on the other" [6]. Engineers apply scientific and mathematical principles towards designing practical solutions. While engineering education has traditionally favored STEM competencies, "the constraints on engineering problem-solving today are increasingly not technical, but rather lie on the societal and human side of engineering practices" [6]. In a Special Issue of *Journal of Engineering Education*, Sheppard, Pellegrino, and Olds [15] write, "[i]t would be naive to treat technical and non-technical challenges and opportunities as separable". The boundaries are "increasingly blurred" and engineers are being called on to design solutions for our increasingly complex world; preparing them to meet these challenges and opportunities will require designing and delivering re-tooled engineering courses and programs. Active learning strategies

like Virtual Enterprise teach and encourage students, to be creative, experimental, and entrepreneurial preparing them to overcome these constraints.

There is wide recognition of the need to challenge "traditional" ways of teaching engineering and related STEM fields. Researchers have found that the creation and perpetuation of "impersonal" and hierarchical classroom environments discouraged collaborative learning. Using a strategy/intervention that "alters traditional patterns of interaction," encourages communication and teamwork "without compromising the quality of learning" [2]. VE would fall within this category of interventions. Going further, Turner [17] concludes that non-technical, or soft skills are not developed in isolation from technical skills. Rather, the development of hard and soft skills interacts in significant ways, with each process strengthened and informed by the other.

The rationale for the Engineering Virtual Enterprise program draws upon studies of project-based learning and curricula that infuse entrepreneurship into engineering and technician education courses, supporting and strengthening the development of soft skills, as well as improving student recruitment and retention: Tubaishat [16] demonstrated that including topics such as project management and product development in a Computer Science course helped students deal with non-technical aspects of project development, strengthening their communication and other soft skills. Problem-based learning, much like that of VE, was successfully integrated into an engineering program where students worked in teams to design a product that met pre-determined criteria. Students developed familiarity with the design process, and with the importance of working within a strict time frame as they would in a real-world setting [5]. Integrating entrepreneurship and related project management skills into engineering curricula enhances student profiles as integral participants in the knowledge-based economy [12]. The University of Edinburgh developed a series of interdisciplinary courses to improve students' ability to work across disciplines and "improve their preparation for industry [7]. By focusing efforts on a single project, student teams were able to see the connections between "engineering design and economic viability". Students' interest in pursuing careers related to this engineering project was also enhanced. Dabbagh and Menascé [4] examined students' overall perception of the engineering profession in a first year course that introduced entrepreneurial concepts using a project-based model. In the course, student teams formed IT companies that competed to develop business support software in a simulated market environment. Compared to students in a "traditional" course, students in the projects-based course had "significantly improved" perceptions of engineering professions and of entrepreneurial opportunities in engineering. Researchers suggest that infusing engineering curricula with entrepreneurship and projects-based learning can increase student recruitment and retention [4].

2. PLATFORM: VIRTUAL ENTERPRISE

Virtual Enterprise (VE) contextualizes disciplinary content by having students develop realistic, commercially viable projects in the classroom. The lines between disciplines are blurred as students take a holistic view of their firm and its tasks; soft skills are integral. The authors, principals of the Institute for Virtual Enterprise (IVE) at the City University of New York (CUNY) have nine years of experience in the design and administration of such programs – both academic and non-credit – that help students develop the soft and entrepreneurial skills essential to success in the workplace. CUNY-IVE operates programs that reach CUNY's twenty-three campuses, which serve about 450,000 students.

VE has teams of students act entrepreneurially as they design and operate simulated firms in the classroom. The simulation is a combination of **in-class, active-learning pedagogy**, a virtual economy (the **IVE MarketMaker**) with additional software tools, and an international community of simulated student-run firms (the **IVE Partner Network**). Through VE, students acquire soft and entrepreneurial skills while making concrete use of the content of their academic majors. Soft skills are the interpersonal skills (such as teamwork, effective communication in working with those in different roles and positions), critical and analytic thinking skills, and problem solving skills that are part of the League for Innovation's 21st Century Learning Outcomes [18]. Each student takes on a position within the firm and carries out the responsibilities of her or his department (such as, Research and

Development: establishing timelines and ethics protocol; Purchasing: setting up inventory procedures). Students have a blended learning experience in which they participate in face-to-face activities both within the simulation (such as, taking part in virtual firm staff meetings, writing up business plans, developing surveys for potential customers) and outside the simulation (such as, discussing articles about industry issues, exploring various organizational models).

The STEM-VE experience, which customizes the simulation for students in STEM majors, has proven to be a powerful method for instilling a passion for the underlying STEM discipline and a sense of entrepreneurial efficacy. Results from NSF funding by the Advanced Technological Education Program [13,14] where the STEM-VE curriculum was infused with IT content, produced a high level of student interest and engagement. Especially interesting is one such study performed with students from populations typically underrepresented in IT. This study found these entry-level students reporting a great shift in attitude toward the discipline, and aspiring to study and work in the field [8].

3. THE VIRTUAL ENTERPRISES FOR ENGINEERING *(VE^{ENG} CAREERS* AND *VE^{ENG} PROJECTS)*

This framework proposes two engagements as "bookends" on an associates-level, pre-engineering major as follows:

***ve^{eng}* Careers**

A non-credit, pre-semester institute designed to help students entering the pre-engineering major understand the breadth of engineering careers, the many fields and types of organizations in which engineers work, and the variety of technically and socially important problems they help to solve. This approach mirrors recommendations made by the National Academy of Engineering: "students who are introduced to engineering design, engineering problem solving, and the concept of engineering as a servant of society early in their undergraduate education are more likely to pursue their engineering programs to completion. The same approach is also more appealing to women and underrepresented minority students" [9,11]. Students explore the match between engineering careers and their own strengths, interests, and values. The engagement will have small groups of students staff and simulate several types of engineering firms, identifying and providing rudimentary solutions to relevant industry problems. The aim is to strengthen students' interest in engineering and motivate them to persist in engineering degree programs and ultimately in engineering careers.

***ve^{eng}* Projects**

A three-credit course in which pre-engineering majors near the end of their associates degree operate a simulated, student-run engineering firm. This course gives students opportunities to apply and practice their engineering and applied math knowledge while participating in activities that promote the development of entrepreneurship and workplace competencies. Student participants will act as entrepreneurs taking the firm from its business plan to engineering project conceptualization through planning for deployment. This experience is expected to enhance participants' (1) understanding of the types of problems that engineers help to solve, (2) understanding of the process of starting an engineering venture, and (3) entrepreneurial and soft skills.

Focal Projects

The National Academy of Engineering has organized the state of engineering problems into fourteen categories as part of EngineeringChallenges.org [10]. Of these categories, seven have both sufficient ongoing examples within the Engineering community, sufficient literature, and are a level that is accessible for community college pre-engineering students. These categories will form the topical foci of the two ***ve^{eng}*** engagements ***(ve^{eng} Careers*** and ***ve^{eng} Projects)***:

1. Provide access to clean water.
2. Restore and improve urban infrastructure.
3. Advance health informatics.
4. Engineer better medicines.
5. Prevent nuclear terror.
6. Secure cyberspace.
7. Advance personalized learning.

Both the ***ve^{eng} Careers*** and the ***ve^{eng} Projects*** will draw their choices of engineering sub-disciplines and projects from this list. The engineering

instructors responsible for teaching the courses will elaborate on facts about the careers involved in these areas by giving students access to a series of online resources (e.g. links, career websites, and transfer institutions).

Expected Results
The authors hypothesize that the net result of these engagements will be:

1. student participants in the ***ve^{eng} Careers*** Institute will be better aware of the breadth of engineering projects and careers, and will plan choices of future study and careers accordingly.
2. the ***ve^{eng} Careers*** Institute will improve retention and recruitment in the pre-engineering major, as demonstrated by a significant change in attitude towards the engineering disciplines.
3. project-based learning experiences, as offered in ***ve^{eng} Projects***, will instill demonstrable improvement in problem solving skills, soft skills and entrepreneurship self-efficacy.

4. VE^{ENG} CAREERS

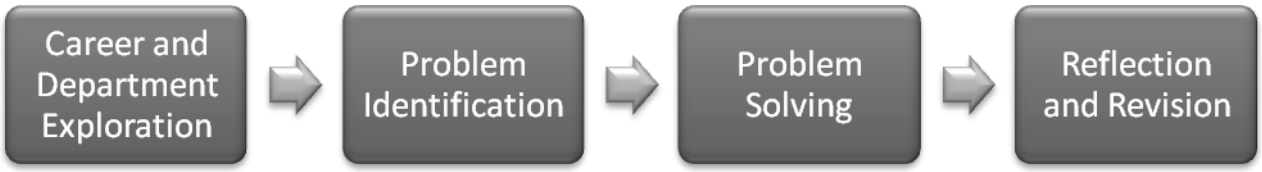

Figure 1: The flow of the VE-eng Careers engagement.

The ***ve^{eng} Careers*** (*non-credit, pre-semester institute*) will help students entering Pre-Engineering majors understand the breadth of engineering careers, the many fields and types of organizations in which engineers work, and the variety of technically and socially important problems they help to solve. The engagement will initially follow this general plan (also see Figure 1):

Phase I: Career and Department Exploration
During this phase the organizational structure for an engineering firm is established. Students research the staff positions. The instructor can facilitate this process by using a sample organizational chart from a partner or fictitious firm and by directing students to career research websites. This process allows the students to explore the breadth of careers in the industry, identify particular career tracks, and make informed decisions about their choices within the field.

Phase II: Problem Identification
During Phase 2, the firm's clients will identify potential problems/issues/needs and supporting information (such as existing solutions and users' ancedotal demands) will be gathered for the problem solving process in Phase 3. The demands of management and the needs and capabilities of the eventual users should be uncovered during this phase. As part of this process, students will familiarize themselves with the breadth of products and services that are already provided by other firms. Students will conduct a needs assessment for the company and agree on a priority project in conjunction with the company's management.

Phase III: Problem Solving
The firm devises a possible solution to the problem identified in the previous phase and presents it to the management. This solution will likely be simplistic and may involve bringing together several existing solutions from other firms. Members of the management may be simulated by faculty colleagues, corporate partners, or other members of the international VE network. Students will prepare and deliver technical whitepapers on their solutions plus presentations geared towards a non-technical audience.

Phase IV: Reflection and Revision
Based on feedback provided in the Problem Solving phase, students will revise their product descriptions. Rudimentary SWOT (strengths, weaknesses, opportunities, and threats) reports will be prepared about the firm and its proposed solution(s).

5. VE^{ENG} PROJECTS

The ***ve^{eng} Projects*** (*3-credit, 45 contact hours*) course will have students act as entrepreneurs in the classroom in a simulated engineering firm from

business plan development, to engineering project conceptualization, and through planning for deployment. Students will leave the course understanding how entrepreneurs operate and how "***intra***preneurs" start novel ventures within a larger enterprise. Much of the development work will involve the project team developing numerous projects within the focal areas. The operation of the course will follow this general pattern:

1. Review a sampling of the breadth of engineering companies and products.
2. Select a niche within engineering; create a corporate identity.
3. Research and design the firm's management structure including departments and officers. (Typical departments for the simulation include: marketing, finance, human resources, and R&D.)
4. Staff positions within the hierarchy (organizational chart).
5. Design a flagship product or service; produce a demonstration product.
6. Conduct market research (on VE students or corporate partners); or in the case of responding to an outside firm's need, present the limited version of the product for feedback.
7. Solicit funding by developing the enterprise's business plan, including identifying target consumers and marketing strategy.
8. Implement product, starting with implementation plans and Gantt charts, and ending with proper technical documentation.
9. Develop promotional materials, including analysis specifying quantities such as TCO and ROI, if applicable; develop website and presentation for non-technical audiences.
10. Presentation of product(s) to prospective consumers and/or integrators.

6. CONCLUSIONS

The framework described here extends the highly effective STEM-based VE program, which evaluation research [8,13,14] has shown to be extremely successful in being adapted to the Information Technology (IT) and BioTechnology disciplines.

This engagement adds to the possible modalities for engineering entrepreneurship education at American institutions. This would meet a national priority for redeveloping the workforce both with 21st Century communication skills and entrepreneurial spirit, as outlined in the American Recovery and Reinvestment Act (ARRA) and other educational initiatives of President Barack Obama.

While the described scope of this work is focused on offerings at Community Colleges, the potential for broader impact on the national discussion about engineering curriculum reform is great. If offered both at the Community and Senior College levels, it could serve as an articulation bridge between these institutions. Further, the ***ve^{eng}-Careers*** construct can be used to help students at Community Colleges explore the career potentials opened by transferring to baccalaureate programs at local senior colleges.

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