Innovation Skills for the Self-Transformation of Underrepresented Engineering Students

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Abstract

Underrepresented engineering students typically face multiple challenges, for example, the lack of role models and familiar guidance during their studies. Successful students have specific characteristics (i.e. skills) that allow them to thrive. In this paper the authors explore the necessary skills that may allow students to self-transform and innovate into successful engineering students.

1. Introduction

The U.S. Census Bureau reports that Latinos accounted for only 6.5% of the STEM workforce in 2011, even though they comprised 17% of the population. Hispanics are not only the largest minority group in the U.S., followed by Blacks, but are the fastest-growing minority group [1]. Thus, it is not surprising that one of the largest increases in college enrollment is expected to come from the Hispanic population. The University of Texas Rio Grande Valley (UTRGV) is a new Hispanic Serving Institution (HSI) created in 2015 through the merging of two legacy institutions, UT Brownsville and UT Pan-American, and the creation of the School of Medicine. UTRGV serves approximately 30,000 students from the RGV region (mostly underrepresented minority students - 88.8% Hispanics). Most of the students attending UTRGV are the first in their family to attend College. This region has been one of the faster growing areas in the Nation according to the U.S. Census Bureau [1]. The RGV region has a very young population; more than 30% of the region's residents are below the age of 18. The region has low education attainment; only two out of three people age 25 and older have a high school or higher degree. Furthermore, a third of the RGV region population falls under the national poverty level [1]. This socioeconomic background is key to understand some of the challenges that engineering students face, and the potential approaches to overcome some of these limitations.

2. Skill Deficiencies

Promoting STEM student attraction, transfer, retention, and academic success is critical for the future workforce and the economy of our Nation especially for the underrepresented populations in the STEM workforce. At various higher education institutions, including minority serving institutions, there is a need to address primary skill deficiencies in engineering students. These deficiencies in skills can be technical and non-technical (i.e. personal or soft skills). Most of the current efforts from faculty and existing educational programs focus on developing technical skills, where the faculty makes an extraordinary effort to help students learn and understand the courses' contents. This focus on technical skills is fundamental in an engineering program, but the lack of non-technical skills limits the success of the student. Hence, promoting these non-technical skills becomes crucial to enhance the success of underrepresented students.

3. Self-Innovation Skills

3.1 The Case for Innovation

The RGV region presents multiple challenges that must translate into opportunities in order to improve the socio-economic future. As defined in Wikipedia [2] "Innovation is often also viewed as the application of better solutions that meet new requirements, unarticulated needs, or existing market needs." We need innovations in our region, and these will come from innovators capable of introducing new methods, ideas or products. It is important to clarify that innovation in this case refers to an impact at the personal level (i.e. innovation thinking), and at the regional and national levels with the innovative engineering solutions (i.e. economic impact). UTRGV Engineering students are called to become those innovators that can act as true agents of change [3]. Those socio-economic regional challenges are ever present in all aspects of the lives of the population. UTRGV engineering students are directly and indirectly affected by these challenges as manifested by deficiencies in technical and non-technical

skills. For this reason, the path to becoming a professional engineering innovator starts as a student learns and applies innovation principles to transform themselves into better, more efficient students. An RGV student with deficiencies must train to think differently; the resources, inspiration, advice and role models in many cases are minimum or nonexistent. The perspective of our UTRGV Engineering students is challenged with "new requirements and unarticulated needs" that require innovative responses, hence the need for self-innovation.

3.2 Development of Non-Technical Skills

Innovation helps in identifying value and opportunity, and as engineers can learn how to innovate with their technical solutions, the premise is that students should start by innovating themselves, then create communities of learning and thrive in the engineering program. What are the necessary non-technical skills for student success? This is initially addressed in the next subsection. Once these skills are identified, educational experiences can be designed to develop the specific skills in each student. The primary objective will be to provide students with experiences to develop these basic non-technical skills. These skills will enable the self-transformation of students to be more effective and successful. It is expected that a critical mass of these students will promote and nourish communities of learners. This will create a self-innovation community or ecosystem, which has to be nourished by the institution. These successful students will continue their transformation into professional innovators to tackle critical needs in their respective regions. This transformation of self, community (as a student), and region (as a professional) can become a model that can be transferred to other institutions interested in preparing resilient learners.

3.3 Skills in Engineering Education

The literature in engineering education has proposed a variety of skills sets (sometimes also referred as competencies and inventories of skills) from multiple perspectives and for various purposes:

- Sets of skills for a given technical topic, for example engineering design [4].
- Sets of skills for a particular task or activity, for example problem solving [5]
- Sets of skills for professional skills [6]
- Sets of skills for methods (also known as batteries) for measuring skills [7]
- Sets of skills for measurements of skills based on demonstration as well as self-perception of the students [8]
- Sets of skills for studies of differences between males and females [9]
- Sets of skills promoted by ABET [10]

There aren't many studies focusing on the necessary skills for innovation [11,12], instead, the focus is on specific skills such as entrepreneurship [13,14], leadership [15], and creativity [16,17] among others. The universe of identified skills and their corresponding assessments is ample, and this presents a challenge and an opportunity. It is the task of the proposed approach to review and select the most appropriate skills for our given purpose. This characterization of the student, as explained earlier, will focus on non-technical (i.e. professional, soft skills) necessary for thriving in environments with limited resources and having backgrounds with recurrent socio-economic challenges. This is a preliminary list of skills, or skill precursors, to provide an idea of what is sought:

- Assertiveness
- Motivation
- How to ask for help in a timely manner
- How to take informed decisions
- How to deal with failure and bounce back
- How to continuously adapt to unexpected changes
- Prioritizing tasks and scheduling time
- How to take notes

3.4 Mapping Innovation and Entrepreneurship Skills to Students' Education

As explained in the previous subsection, when talking about innovation skill in engineering education, the reviewed literature focuses on the skill needed to prepare students as innovators and entrepreneurs for their professional life; in other words, for success after their graduation [18]. Understandably, this should be sufficient for the case where students from institutions don't suffer from major skill deficiencies and other challenges typical of underrepresented serving institutions. Because of the complexity and dimension of this challenge, it would be too difficult to effectively develop every missing skill in every student in need at these institutions. Instead, the suggested approach is to (1) change the mindset of selected students and teach them meta-skills (i.e. fundamental behaviors) for continuous self-transformation. And (2), these selected students will make a critical mass of trained students would lead communities of learning and propagate their motivation.

Innovation and entrepreneurship are effective approaches to solve technical and commercial issues, and the premise of the presented approach is that these approaches (or at least the most relevant) can be transferred by analogy to engineering students for self-transformation. The reasoning is as follows; our engineering students face a plethora of challenges such as: missing skills, support gaps, socioeconomic challenges, lack of immediate role models,

limited mentoring and resources in general, among others. Students with these self-transformation meta-skills (i.e. skills that can generate further skills) will be able to find "new ways and better solutions" (Wikipedia definition for Innovation) to the "new" challenges they face daily in their educational process. While innovation skills may help students be resourceful and allow them to generate potential solutions, knowledge about entrepreneurship would help them implement these innovative solutions in real life.

Continuing with the analogy, for the self-transforming engineering student, the innovative product is their educational process, and their entrepreneurial business is themselves as student, as a brand. Similarly to successful innovators and entrepreneurs, students will engage in continuous self-transformation to promote their innovative products and business startups.

The focus of this paper is to identify the innovation and entrepreneurship skills and initiate and analogical comparison for a set of student self-transforming skills. Future work will focus on how to develop each of the selected self-transformation skills. Preliminarily, the strategy may be to provide students with simple design, innovation and entrepreneurship educational experiences to learn about the technical aspects of the product development process, and adding one layer of reflection to help students abstract and learn practical lessons for self-transformation. For example, Controlled failure is a must for any innovator and entrepreneur, as long as you are able to learn from it and quickly bounce back (i.e. resilience). Through a practical exercise, while designing a simple product or business model (e.g. business model canvas), the students can derive a self-transforming skill: Failure is an opportunity to learn and quickly bounce back.

4. Survey of Innovation and Entrepreneurship Skills

The first step is to identify the innovation and Entrepreneurship skills, that later will be mapped by analogy to the context of self-innovation student skills. In an initial survey of innovation and entrepreneurship skills the first thing one can notice is that most of these skills are "soft" skills (also known as personal or general skills). This precisely matches the category of skills needed for student self-transformation. This doesn't mean that the technical skills aren't important, especially in the case of engineering students, but these are addressed daily by teachers in the classroom. What are left out are the non-technical skills (i.e. cognitive, behavioral and functional skills). Another characteristic to notice from the innovation and entrepreneurship skills is that these are practical in nature. Some of these skills may have a fundamental theory that substantiates them, but it is common to find these skills based on experience and practice. This gives an early indication that future work on how to develop the selected self-transformation skills in students; one should look at how innovation and entrepreneurship is taught. Typically, its teaching includes some fundamental theory lessons that quickly moves to practice, cases, and exercises where learners are strongly encouraged to get out of the building (e.g. NSF I – Corps Lean Launch Pad approach).

The Table 1 is a preliminary collection of innovation and entrepreneurship skills. These are presented and organized based on their affinity. It is important to clarify that there is a clear difference between innovation and entrepreneurship. While innovation applies creativity to solve problems in new ways, entrepreneurship applies these innovative solutions to cash in on the innovation [19]. For the purposes of this paper, both sets of skills are of interest, and although innovation and entrepreneurship have clearly different goals, some of the required skills are shared.

Table 1. Survey of Innovation and Entrepreneurial Skills*

Personal Characteristics
Optimism, Enthusiasm, Confidence, Positive Attitude, Enjoyment
Vision, Focus, See the Big Picture
Initiative, Self-Starter, Proactivity
Risk Tolerance, Trend Setting, Risk Management, Deal with Uncertainty, Ambiguity
Decision Making, Tradeoffs
Resilience, Learn from Failure, Bounce Back, Exit Preparedness
Motivation (self), Compulsion to Succeed, Drive, Success Driven, Hunger to Achieve, Passion, Dreamer, Ambition, Purpose
Deal with Stress
Understand What You Don't Know
Branding (Personal)
Persistence, Stamina, Determination
Authenticity
Flexibility, Adaptability, Open Mind, Agility
Courage, Bravery
Assertiveness, Competitiveness
Personal Image, Positive Image
Knowledge of Social Media
Work Independently
Self-Discipline
Efficient, Goal Oriented
Personal Fulfillment
Value Contribution to Society

Interpersonal Skills
Leadership, Motivator, Inspiring
Communication
Listening
Emotional Intelligence, Non-verbal Communication
Negotiation
Ethics, Integrity
Rigor, Quality, Strong Work Ethic
Empathy, Understand Motivation and Perspectives of Others
Delegate
Close the Sale, Aware of What One Has to Offer
Persuasion, Self-Value
Team Building, Collaboration
Networking
Able to Ask for Help, Resourcefulness, Mentoring
Give back to Community, Help Others, Build Community

Critical and Creative Thinking Skills
Creative Thinking, Thinking Outside of the Box, Curiosity, Relentless Questioning
Problem Solving, Deal with Ambiguity, Comfort with Confusion,
Recognizing Opportunities, Identify Trends, Strengths and Weaknesses
Critical Thinking, Logical Thinking
Self-Criticism, Strengths and Weaknesses, Know Oneself, Reflection
Problem Framing and Decomposition, Systems Thinking

Practical Skills
Set Goals
Planning, Organizing
Management Resources (Time, Money, etc.), Prioritization
Life-Long Learning

Innovation Specific Skills
Divergent Thinking, Think Outside of The Box, Counterfactual Thinking, Creative Thinking, Ideation, Aleatory Techniques, Aleatory Genetic Algorithms, Lateral Thinking, Imagination
Conceptual Blending, Multidisciplinarity, Remote Associations, Analogies
Intuition, Improvisation, Gut Decision
Knowledge Acquisition, Research, Technical Knowledge, Specific Knowledge, Being a Knowledge Sponge
Modeling Concepts, Thought Experiment, Prototyping
Incubation
Perspective Shift
Hypothesis Testing
Exploring Universe of Solutions, Morphological Analysis

* [20-30]

5. Mapping Process

How to relate the innovation and entrepreneurship skills ti the student self-innovation context? The following sections provide selected examples of how this could be achieved. These examples selection was based on the observed occurrence during the survey.

5.1 Resilience

It is well known in innovation and entrepreneurship that failure is necessary as part of the learning process. This, preferably, under controlled circumstances whenever possible; as a well-known CEO suggested, failure is necessary, you can put a dent in the company's car, just total it. Innovation requires expanding the boundaries of what is known, it is expected to explore uncharted territory, and it isn't always clear where the boundary is for what does and doesn't work. For the case of students, and in particular in engineering, the culture is such that the concept of failure is typically frowned upon. The general belief is that everything an engineer produces shouldn't fail. Of course this is true for safety and reliability reasons, but the learning process is a process of self-innovation, and the students are subject to failure in the form of failed exams, rejected applications, denied scholarships, etc. It is crucial for a student to be able to assimilate the situation, draw pertinent lessons, and quickly bounce back, all this as part of a natural process of daring to innovate one-self.

5.2 Branding

Being a student should be equivalent to launching a small business. Much of the small business dynamics can be paralleled to being a successful student. For example: setting goals, being efficient with resources, recognizing the proposed value, defining stakeholders, cultivating a positive image, and reinventing the brand to respond to the changing market, among others.

5.3 Leadership

Students should be able to take ownership and control of their education as much as possible, and even serve as an example for others to follow. This may seem obvious, but if a student does not have role models or a context from where to learn this, it may be difficult to understand creating a passivity and dependency on what the professors require for a course. In future work, students will be trained to develop leadership skills to take control of their educational process and to lead communities of learning for the courses they are taking. The hope is that other students will benefit greatly from these immediate role models.

5.4 Mentoring

In innovation and entrepreneurship it is widely accepted that mentoring plays an important role in the success of a product or a business. It may seem obvious, but some students completely avoid contact with faculty outside class time, not attending office hours and just keeping to themselves. Something as simple as asking for help can make a great difference in the academic life of a student.

6. Summary

There is plenty of engineering education literature on innovation and entrepreneurship skills for students, but these invariably refer to skills to be developed for the purpose of using them during their professional life (i.e. after graduation). The premise of the approach presented here is that engineering students from underrepresented serving institutions can benefit from innovation and entrepreneurial skills, where they manage their education similarly to launching a small business where they are the innovative product. This premise and approach need to be further detailed and tested, but it is interesting to see the similarities between a student and an entrepreneur; both need an innovative product, face continuous challenges, and have limited resources at their disposal. The preliminary list of non-technical skills may seem simple and obvious, but for underrepresented students, these can mark a difference. Once the inventory of skills is identified, and the corresponding educational experiences are designed, the important questions will be how to implement these experiences and how to measure each skill.

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