Effectively Transforming Students through First Year Engineering Student Experiences

Noe Vargas Hernandez
Mechanical Engineering Department
University of Texas Rio Grande Valley
Edinburg, TX USA
noe.vargas@utrgv.edu

Arturo Fuentes
Mechanical Engineering Department
University of Texas Rio Grande Valley
Edinburg, TX USA
arturo.fuentes@utrgv.edu

Stephen Crown
Mechanical Engineering Department
University of Texas Rio Grande Valley
Edinburg, TX USA
stepehn.crown@utrgv.edu

***Abstract*— The premise of this Research to Practice Work in Progress Paper is that 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 many 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, soft). 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. For this reason, the focus of this paper is on non-technical skills for student academic success. The objectives of this paper are (1) identify the potential skills necessary to thrive in an engineering program; this includes a literature review on skills, (2) define educational experiences as interventions to develop these skills in the students, and (3); explore the metrics associated with the selected skills; this is necessary to measure improvements. 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. These successful students will continue their transformation into professional innovators to tackle critical needs in their respective regions. Educational experiences on innovation will help in the development of specific skills to initiate a transformation in the student that can allow them to thrive in an engineering program. 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.**

Keywords—self-innovation, self-entrepreneurship, skills

I. INTRODUCTION

The University of Texas Rio Grande Valley (UTRGV) is a new Hispanic Serving Institution serving students in the Rio Grande Valley (RGV) region created in 2015 through the merging of two legacy institutions, University of A and University of B, and the creation of the School of Medicine. UTRGV has an enrollment of approximately 30,000 mostly underrepresent minority students (88.8% Hispanics). The RGV region faces multiple challenges; a third of the population falls under the national poverty level [1] and has very low educational attainment levels. An opportunity for the RGV region is its very young population; more than 30% of the residents are below the age of 18. This young population represents a valuable asset and a critical challenge. Most of the students attending UTRGV are the first in their family to attend College, and they bring with them their potential as well as their socio-economic challenges. The objectives of this paper are (1) identify the potential skills necessary to thrive in an engineering program; this includes a literature review on skills (e.g. for innovation, creativity, design, etc.), (2) define educational experiences as interventions to develop these skills, and (3) explore the metrics associated with the selected skills; this is necessary to measure improvements; this includes summarizing previous and ongoing efforts to transform at-risk non-traditional high school and college freshman students through educational experiences to develop specific skills.

II. STUDENT SELF-TRANSFORMATION

Students at UTRGV face multiple socio-economic challenges. While the faculty in the Mechanical Engineering Department make an extraordinary effort to efficiently teach technical content and develop the student's technical skills, some students continue to have problems and are unsuccessful in their academic work. What may be obvious knowledge and skills to students at other institutions may be foreign to some of our students. For example, the ability to identify the problem one is facing (e.g. selecting courses for next semester, failing the course midsemester). When encountering a personal problem related to their education, the student may know that something is wrong but is unable to think critically and summarize the situation as a starting point to pursue a solution. Students at other institutions with stronger socio-economic (although not the only factor) backgrounds may have more developed skillset and resources to effectively think critically and identify these problems. Possibly these students have better access to helpful advice, role models, family support, or other critical experiences that our students may lack. Most of the students attending UTRGV are the first in their family to attend college; this means that they continuously face unfamiliar personal challenges and few resources to help them navigate their academic path. Students are required to be innovative if they are to effectively address these new challenges on their own. The connection with innovation is illustrated with a fundamental definition for innovation: "Innovation is often also viewed as the application of better solutions that meet new requirements, unarticulated needs, or existing market needs" (as explained in Wikipedia). Like many other institutions,

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engineering colleges and departments, technical innovation is taught and instilled in our students as they mature and learn throughout their academic careers. However, if students do not develop basic college survival skills and the innovation to effectively address new personal challenges they may drop out or be suspended before they have had a significant opportunity to learn and apply (technical) innovation skills in college, let alone in their professional life A literature survey in engineering education on the topic of "innovation skills" [2-8] quickly yields a healthy amount of research work on how to develop technical innovation skills in students for their professional life, not necessarily personal innovation for their academic life survival. Hence, the authors propose the development of innovation skills in students not only for professional technical innovation but also for personal self-transformation while they are early in their academic studies. This means that students facing challenges that pose "new requirements" and "unarticulated needs" can use their innovation skills to come up with "better solutions", in essence using innovation for self-transformation, not just for technical product innovation.

III. SELF-TRANSFORMATION SKILLS

How is one to develop the fundamental skills in these students, enabling them to thrive in an academic environment with limited resources and challenging backgrounds with recurrent socio-economic challenges? This situation is not unique to students at UTRGV, it can be generalized at different levels to any student that faces a challenge and has limited resources. As previously mentioned, these challenges may seem simple and obvious, but for some students it is truly a challenge that requires them to be innovative. This is a preliminary list of challenges that students face:

- Applying critical thinking, for example to learn from failure (i.e. resilience)
- Being assertive in the face of new challenges
- Find motivation in adverse situations
- How to ask for help in a timely manner
- How to make informed decisions
- How to continuously adapt to unexpected changes
- Prioritizing tasks and scheduling time

In previous research the authors surveyed innovation and entrepreneurial skills, as shown in Table 1. Based on this previous work, the authors concluded that innovation and entrepreneurship are excellent approaches to solving technical and commercial issues that engineers face in their professional life. These approaches (or at least the most relevant) can be transferred by analogy to engineering students to develop self-transformation skills. The reasoning for this is as follows. Innovators and entrepreneurs face complex challenges with limited resources such as: missing skills, support gaps, socioeconomic challenges, lack of immediate role models, limited mentoring and resources in general, among others. These challenges are similar to the ones our students face in their academic life. Following the analogy, students need to identify the innovative product and the entrepreneurial business, in this case the innovative product is their educational process, and their entrepreneurial business is themselves as a student brand.

TABLE I. 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

* [9-19]

IV. Desegragated Learning Framework

The promotion of self-transformation skills is part of a wider effort to improve the educational experiences of our students. In previous research [20], the authors developed an innovative framework for programs of study for the Mechanical Engineering Department at UTRGV. This framework, Desegregated Learning, identified multiple integrative challenges in undergraduate education, namely: Segregation of Course Content (e.g. single semester classes), Segregation of Educational Programs, Segregation of Educational Setting (e.g. focus mainly on the hours students spend in the classroom and laboratories), Segregated Student Involvement (e.g. students grouped and taught by classification), Segregated Faculty Involvement, and Segregation of Student and Faculty Demographics (e.g. need for promotion among segregated groups in the educational process). For each one of these challenges the authors presented solution approaches. Since then, the department has embarked on a gradual program reform aiming for the attainment of a more integrated educational experience. The efforts presented in this paper contribute directly to this Desegregated Learning Framework, particularly tackling the Segregated Student Involvement and the Segregation of Student and Faculty Demographics.

V. Initial Skill

As previously explained, this paper introduces the concept of self-transformation of students using innovation and entrepreneurship approaches to develop skills for students to thrive in their academic path. This in the context of an ongoing departmental reform that aims to have a more integrated learning experience (i.e. desegregated learning). Where to start? What self-transformation skill should be the first one to develop? As described in previous sections, the authors identified a variety of innovation and entrepreneurship skills. Based on past experience and daily interaction with students, one specific situation was identified as critical. Some students have a difficulty identifying when they are in trouble, it is only when they talk to a faculty or mentor when they realize that they have a problem. The student may suspect that something is wrong but are not able to effectively identify what it is. Other students may have the ability to quickly identify the problem as a first step to solve it, while others cannot identify it. These students are unable to efficiently analyze their situation and think critically, assessing the situation and asking the pertinent questions. For this reason the authors decided to start with this fundamental skill that any innovator, entrepreneur, and self-transforming student must possess: Critical Thinking (e.g. learning from failure). How to effectively develop an educational experience for students to learn critical thinking?

VI. Learning Through Challenges

One way to teach critical thinking skill is through challenges. As described in Bransford et al. seminal work "How people learn: Brain, mind, experience and school" [21] the design of effective learning environments requires the "rethinking of what is taught, how it is taught, and how it is assessed." An important contribution from this report is the notion of learning through projects, cases, problems, and challenges. There are various benefits of using challenges to teach students; one of them is that the educational experience will be closer to real life and more engaging for the student. This challenge-based educational experience must be carefully planned to avoid confusion in the student. Schwartz et al. [22] applied a design thinking approach to develop a framework to transform a teaching lesson into an effectively structured educational challenge. This framework is the STAR Legacy Cycle, shown slightly modified in Figure 1, which is a specific implementation of Challenge Based Instruction. The stages of this cycle closely resemble the steps in the engineering design process" Problem Identification, Problem Formulation, Conceptual Design, Embodiment Design, and Detail Design.

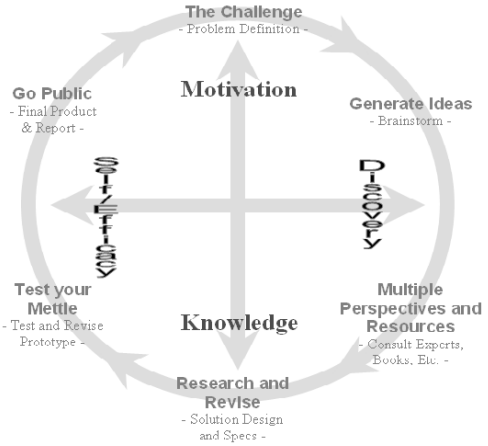

Fig. 1. Relationship between the stages of the STAR Legacy Learning Cycle and student Motivation, Discovery, Knowledge, and Self-Efficacy [23]

The authors have previously developed educational challenges [23] with great success, and believe that the selected skills can be developed through educational experiences designed following the STAR Legacy Learning Cycle form of Challenge Based Instruction.

VII. Self-Transformation Educational Experience

Critical thinking is the initial self-innovation skill selected for further development. How does one create an effective education experience to develop said skill? As previously explained, the authors will follow the STAR Legacy Cycle [23]

for Challenge Based Instruction. This provides a step by step inductive learning approach based on cognitive principles reported in "How People Learn" [22]. Added to this, the educational experience will involve an innovative challenge for students to learn about innovation and develop skills useful in their future professional life, and simultaneously draw a lesson from reflection and self-efficacy to identify by analogy how that critical thinking skill can be used in their academic life as a student. These are the steps in the STAR Legacy Cycle as it applies to developing the critical thinking skill:

A. *The Challenge*

A real life and open ended question with the purpose of engaging the student and positioning them in a place of inquiry about specific course content. An example of a challenge would be the design of simple product to tackle the regional epidemic of malnutrition, obesity and diabetes. Specifically, the design of exercise equipment that is affordable, simple and effective that can be used at home. Such a challenge is accessible to students because they likely have some familiarity with the problem, yet it is not a trivial problem for the student and will require assistance, research, learning, innovation, and persistence.

B. *Generate Ideas*

Students need to think critically about the product and make a list of issues relevant to the challenge. This step is learner and community centered, where they need to collaborate with other students and engage in a critical discussion. The problem is especially pertinent as it is a common problem in the region that has not been fully addressed with an innovative idea from a large pool of workable solutions.

C. *Multiple Perspectives*

Students are asked to consult with "experts" about ideas and approaches to solve the challenge. This step is community and knowledge centered. Students must talk to actual users, professors, researchers, among others to elicit these ideas.

D. *Research and Revise*

This step focuses on knowledge and the learner. Relevant material is introduced in the form of papers, reports, patents, etc. for the student to compare their generated ideas. This step may be revisited iteratively.

E. *Test Your Mettle*

Students perform summative assessment to review their ideas, and if necessary iterate to Research and Revise.

F. *Go Public*

The student then presents the results and findings. This serves as a motivation for the student to do well. Professors, experts and the general public will provide their feedback and assessment to the student.

G. *Reflection Exercise*

Up to this point in the process, the student is able to design an innovative device for exercising purposes. In this process the student has develop innovation skills useful for their professional development. What is needed now is to help the student realize that this design thinking challenge based process is similar to other challenges in their academic life. The student will be guided through a reflection exercise to identify an actual challenge in their life, for example complying with the department graduation requirements. Students are then asked to go through the cycle generating ideas, consulting experts, researching, revising, testing and presenting their solutions. At every step, they will be asked to identify the critical questions.

In summary, the students will go through a technical innovation learning challenge and then reflect on how this process can be adapted to a personal academic challenge. The hope is that this type of educational experiences (i.e. challenges and reflections) for selected skills will contribute to self-transformation.

VIII. METRICS

How to assess the success of the self-transformation educational experience? This is challenging since it can take semesters or years to see the effects in terms of persistence, excellence, among other potential metrics. There is more than one way to develop a specific skill such as critical thinking, and it has multiple dimensions and levels of achievement. One approach is to embrace experiential learning and desegregate the educational setting by allowing each student to explain how the skill was achieved. This is similar to the concept of micro (or nano) certificates that are awarded when a specific goal is achieved, or badges assigned when a task is completed. What the authors propose is a portfolio of skills where each student will explain through a brief reflection how the skill was developed and to what level. The portfolio will indicate each skill's definition and examples of how to achieve the different levels of learning (e.g. novice, expert, etc.). Mentors will read and certify each entry; when a student completes the portfolio, she or he will receive a title of mentor and funding similar to a teaching assistant. It is expected that a critical mass of this mentors will also have a positive effect in their class cohorts by leading communities of learning, serving a peer role models, and increasing the expectations and motivation among other students.

It may be difficult to prove that the completion of a well-planned portfolio could ensure complete and consistent expertise in a student, but it can be argued that this is what happens in real life with innovators and entrepreneurships. The experiences innovators and entrepreneurs go through keep shaping their perception of the world, and mentoring is critical in achieving success. A skills portfolio hence is not intended to be an absolute assurance for academic success, but it will definitely make the student aware of what is needed for self-transformation.

IX. Conclusion

Critical thinking is the initial self-innovation skill selected for further development. How to create an effective education experience to develop said skill? As previously explained, the authors will follow the STAR Legacy Cycle [20] for Challenge Based Instruction. This provides a step by step inductive learning approach based on cognitive principles reported in "How People Learn" [21]. Added to this, the educational experience will involve an innovative challenge for students to learn about innovation and develop skills useful in their future professional life, and simultaneously draw a lesson from reflection and self-efficacy to identify by analogy how that critical thinking skill can be used in their academic life as a student. A study on this will be conducted in the fall 2018 semester through a funded project to promote innovation called "The League of Extraordinary Innovators". This is a desegregated educational experience where students from any engineering department and level can work on their technical innovation ideas as an extracurricular activity.

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