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From the Entrepreneurially Minded Learning Framework to Economic Development: Expanding the Three C's with Six I's

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Abstract

KEEN's well-established entrepreneurial mindset model is a crucial catalyst in training engineers to seek innovation and economic development [1]. The Three C's model of following one's Curiosity, making connections between concepts, and Creating value can not only be taught, they form a set of habits that pair with self-directed learning to nudge engineers to more creative and innovative solutions. The expectation is that more creative and innovative solutions will result in economic and socio-economic development. They form the Entrepreneurial Mindset that is the first of the two components of Entrepreneurially Minded Learning. The second component is the Engineering Skillset.

This exploratory paper builds on the Entrepreneurially Minded Learning Framework to clarify additional terms and concepts that can be incorporated into, and in conjunction with, the current framework to expand the overall potential impact of the framework. This expansion is particularly important when the goal is successful development of an innovative product and the subsequent formation of a start-up (new business or a group within a going concern) to support its launch into the marketplace. These additional terms and concepts come from over a decade of field research with, and participation in, applied-learning engineering education programs and economic development and entrepreneurialism support in three different state systems and primarily with Predominantly Undergraduate Institutions (PUIs). This paper is designed to spark a dialogue within the engineering education community leading to further definition and application of the concepts so they may ultimately be translated into various pedagogical methodologies related to entrepreneurialism and economic development.

Background

The United States has been the source of many technological innovations including the first trans-continental railway, the power grid, Apple, Amazon, and Google. One could say that being creative, innovative, and problem-solving are basal characteristics at the heart of American culture. The history of the US is strongly colored by innovators dating back to Benjamin Franklin, Thomas Jefferson, and others continuing through the development and expansion of the US. The drive to succeed is so strong in the culture that it is often named as "the American Dream" and as a whole, it overshadows a more critical point – what are the components of "success" and how are we measuring them? The triple bottom line theory [2] began a very critical and much need change associated with that definition of success: it expanded it beyond just making profit for a corporation, to factoring in some way the effect of the company's actions on the people it encounters (employees, product/service users, society as a whole) as well as the planet (the net effect of the company's actions in "succeeding" on the planet where we live). In the last decade we have seen the definition of success expand to including impacting millions or even billions of people as well as profit levels rising sharply enough so that we no longer have just a national and global "Billionaire's Club" but also a national and global "Trillionaire's Club."

At the heart of these global "successes" are entrepreneurs. The University of Michigan started the first entrepreneurship program in 1927 [3] almost a century ago. Over the century since then, researchers have documented industry cases and built both prescriptive and descriptive models recommending how to train individuals to become entrepreneurs and create successful and innovative products, services, and businesses. Over these years many things have changed in education, entrepreneurship, and economic development. Thus, it is important to check the founding axioms and mutual definitions that form the basis of this body of knowledge. What pieces, assumptions, or nuances may no longer be true, what may have become true based on new information or technology, and what assumed or "conventional" wisdom may have changed substantially [4]. Fundamentally, we are practicing what we teach in the 3C's framework: "Demonstrate constant curiosity about our changing world" and "explore a contrarian view of accepted solutions." The goal of this paper is to explore the trendlines in the decade of field observations and participation to spark a renewed dialogue in the entrepreneurial education community to re-assess and raise questions that can lead to expanded understanding and new pedagogical options to develop the entrepreneurial mindset and key additional skill sets in engineers who will lead economic and socio-economics development for the next several generations.

Part One: The KEEN Entrepreneurially Minded Learning Framework

KEEN's Entrepreneurial Minded Learning Framework (KEEN Framework) is often shorthanded to the 3 C's of Curiosity, Connection, and Creating Value; however this is the tip of the iceberg in terms of its overall value as a model. The 3C's are a component of the full mindset and represent a desired learning outcome for the entrepreneurial thinking curriculum that was created to assist engineering faculty in awakening and engendering an entrepreneurial mindset as part of engineering education. The overall goal is for students to: "DEMONSTRATE constant curiosity about our changing world; EXPLORE a contrarian view of solutions; INTEGRATE information from many sources to gain insight; ASSESS and MANAGE risk; IDENTIFY unexpected opportunities to create extraordinary value; and PERSIST through and learn from failure [1 at page 5]."

The second part of the KEEN Framework contains three parts: DESIGN, OPPORTUNITY, and IMPACT. Design is where we see the application of the mindset in the form of being able to spot new opportunities – for new products, new potential customers, new advances in technology or services. Impact is significance multiplied by scale. This is where we hope to see the effect of the KEEN Framework as new engineering solutions result in economic development, "validating market interest, identifying supply chain distributions, and communicating engineering solutions in terms of societal benefits [1 at page 3]."

The KEEN Framework has many layers to it and it is in the application of the entire KEEN Framework where the need for additional critical components could be useful, as when the KEEN Framework is connected to economic development, the over-arching goal is to create Innovation that is more than just invention. A simple search of Google Scholar yields over five million research documents using or purporting to define "innovation," many in very specific contexts or with certain connotations [5]. While there are some papers using innovation and invention interchangeably, there is a significant trend to include bringing the idea to practice, or implementation, as necessary for innovation.

In order to emphasize the consequences (positive or negative) of innovation and link it directly to economic development, we expand the definition to:

Innovation = Idea + Implementation + Impact.

This is the first set of three "I"s – those used in defining innovation succinctly. The purpose of this expansion is to add clarification as to the components that are necessary to achieve Innovation and represents a transition or launching point from the 3 C's to the first "I" of "Idea." These three "I"s are defined as:

IDEA: The idea is the heart of the innovation. It is the concept that comes from following one's curiosity, identifying a pain point, or making a connection and inventing something new. It can be new to the world, new to an industry or market, or used in a new way. This is the part of "innovation" that can be used interchangeably with the term "invention," though it is not necessary for the innovator to also be the inventor.

IMPLEMENTATION: if one never does anything with the idea – publish it, commercialize it, freely share it, or something else, then the idea goes nowhere and does not rise to the level of an innovation. This "I" is therefore critical both as a litmus test for inclusion AND exclusion in the definition of Innovation. It also sets the course for further entrepreneurial endeavors. It is the transformation from IDEA to IMPLEMENTAION that allows for the reduction to practice that results in a value that can be used in the marketplace or for a social good and creates a linkage to economic development.

IMPACT: this concept is already included in the overall KEEN Framework, and is defined as significance multiplied by scale [1 at page 3]. Scale is how many people are affected by the innovation and is expressed as a number or range of individuals. Significance is how important the innovation is to however many people it impacts. The purpose of explicitly using this "I" as one of the three "I"s in the definition of Innovation is to expand and clarify the Idea and Implementation need to lead to Impact by clarifying the definitions of Scale and Significance to something that is easier for people using the model to spot and therefore determine whether it is worth it for their goals and resources to transition it to the public realm in the form of an entrepreneurial enterprise.

Significance may be seen as happening at four levels with corresponding multipliers: micro, meso, macro, and epic. Micro is the smallest level of significance. At the micro level, an innovation makes a small difference in the lives of those included in its scale, even if it is transparent to their day-to-day lives. For example, if someone writes a script to automate a small task they do occasionally, it has micro significance at a small scale (one person). If they upload that script to GitHub and others start to use it as well, it still has micro significance, but its impact has increased because it now reaches a larger scale. This same calculation works at the increasing significant meso, macro, and epic levels. Meso significance is a medium difference in the life of each individual the innovation touches, macro significance is a large difference, and epic significance fundamentally changes some portion of each individual's life. An innovation at a large enough scale to include a critical mass of an industry, market, or segment of society that is also of epic significance has the highest potential to disrupt that industry, market, or segment of society. While we hope innovations are all making the world a better place, significance is a combination of both positive and negative results.

If you meet the first two parts of the definition of innovation it will have an impact. Unlike idea and implementation which are litmus tests, impact is a key part to the definition to make it intentional and by design. This connects to the ABET outcomes around societal, economic, environmental, and other impacts; to risk management; and to embedding justice in engineering work by thinking about unintentional impacts on groups – both positive and negative – that may result in a significant harm or benefit to them.

This model, as seen in Table 1, can be used to plot multiple inventions and determine their relative significance and scale in a broader view to aid in determining which of the various inventions may be the right one under the current resource and time constraints to become the center of a new entrepreneurial venture. We have filled in a column and a row to demonstrate the process.

Table 1. Examples of Scale & Significance

SCALE (# of Individuals Affected)

PLANET	shift to paper straws	Trade Tariffs	Industry Impact of AI	invest in research that cures disease
NATION				launch of economic development centers in each state
REGION				creation of a new charity
COMMUNITY				scholarship at local University
INDIVIDUAL				person wins powerball
	MICRO	MESO	MACRO	EPIC

SIGNIFICANCE
(Importance to the class of Indviduals)

Some organizations assign numerical values to their significance factors, particularly for making resource allocation decisions. It is important to note that bigger is not always better for innovation impact. Rather, organizations are most likely to thrive when they assign the highest value to the level of significance that is best aligned with their innovation risk tolerance. In other words, organizations that assign the highest value to epic significance in their resource allocation processes are in alignment with their innovation risk tolerance when they also accept that a high percentage of ideas will fail and they reward individuals who fail big as long as they learn from the experience and incorporate that learning in the next iteration. This is sometimes described as failing faster to achieve bigger success. On the other hand, an organization that has a lower innovation risk tolerance, and thus rewards steady, incremental improvements, is best aligned with a micro or meso significance factor. This also opens the space to apply the entrepreneurial mindset to career development and other professionalism topics in engineering education.

Part Two: Entrepreneurial functions/roles

Up to this point the discussion has centered on using the KEEN Framework broadly in engineering education to spur engineers toward implementing ideas of any variety and recognizing the impact of their innovation. In the next section we zoom in to those innovations that are "commercializable." While we are using the language of commercial enterprises, the concepts hold true for social and socio-economic innovations as well as those that contribute to revenue growth for a company. We are deliberately broadening our entrepreneurial definition from the traditional "ability to start new businesses, especially when this involves seeing new opportunities to make money" [6]. For profit or not-for-profit, any industry or cause, if an organization or a new strategic arm or unit of an organization is created around one or more innovations, the engineer needs to understand both the entrepreneurial mindset and entrepreneurial functions or roles described in this section.

While the overall goal of the KEEN Framework is to create an entrepreneurial mindset in every engineer that becomes a habit or pattern of behaviors used across the length of breadth of their professional work [1 at page 5], see also [7], [8], [9], [10], [11], [12], & [13], the entrepreneurial functions are critical to a subset of engineering career paths though not to all paths. One of the purposes of the entrepreneurial functions model is to provide a set of mechanisms to make economic and socio-economic development teachable in the same way the KEEN Framework has made the entrepreneurial mindset teachable. To do this, we need to start with a shared understanding of the necessary knowledge, skills, and abilities to move an idea through the full innovation process while also creating an organization around that idea; we will call that new organization a startup. Whether the startup is a new, stand-alone organization or a sub-organization within a larger structure, there are several essential steps needed in its forming, including:

- The identification of a problem that when solved, can create a value to others
- The identification of what population has the problem
- The identification of the seriousness of the problem
- The conversion of the solution to the problem (opportunity) into a product
- The ability to explain how the product is the solution for the problem
- The analysis of what it takes to create the product
- The creation of a minimum viable version of the product that others can see and understand
- Iterative refinement of the product to maximize value and eliminate waste from its production
- Development of the processes, materials, and delivery mechanism for the creation and distribution of the product
- The ability to recruit others into becoming members of the team supporting all of this, contributing time, effort, and/or financial support
- The ability to lead and manage the team
- The ability to create systems within the team for communication, data management, financial accounting, market analysis, manufacturing/production processes, sales, etc.
- Creation of legal protections and an organization/organizational infrastructure

It is extraordinarily rare to find a single individual who both excels in doing and/or managing all of these tasks and also has the bandwidth to complete them simultaneously. Therefore, almost all start-ups include more than one person and are therefore a team. We have grouped the essential knowledge, skills, and abilities (KSAs) to create three archetypal functions: ideator, interpreter, and implementor. While each function has a distinct purpose in the organization, there are areas of overlap between each pairing of functions as well as across all three functions simultaneously. These areas of overlap are important for keeping any tasks from falling through the cracks as well as supporting communication between the functions.

IDEATOR: the person or persons in this role generally thinks at the big-picture level, is able to see connections between disparate knowledge domains and is able to spot an opportunity by twisting an idea like a kaleidoscope. They need to be able to have strong communication skills as they will need to describe the opportunity to the Interpreter(s), potential investors, and recruits. They are a creator of the vision of the future that includes the wonders and benefits generated by the opportunity.

Key Ideator KSAs:

- **K -** Enough domain-specific knowledge from multiple domains
- **S -** Skills in: communication, understanding people and motivation, integration, leading others
- **A -** Ability to: think strategically (e.g., at the big picture level); originate new concepts, intuitively or logically; to see and solve problems; create a vision of the future around the opportunity

INTREPRETER: the person or persons in this role shares the ability to think at the big picture level but is able to translate that vision into a series of tasks, outcomes, and systems that can be broken into manageable parts and are able to execute these items themselves or delegate the completion of them to IMPLEMENTERS or IDEATORS.

Key Interpreter KSAs:

- **K -** Enough domain-specific knowledge and skills to successfully to identify organizational needs and problems; knowledge in a shared domain with the Ideator and Implementer to be able to communicate concepts to both of those roles; knowledge of systems design and management; knowledge of enterprise systems; knowledge of the overall economic development process
- **S -** Skills in: communication, understanding people and motivation; organizations (building, and managing); managing projects; identify others strengths and weaknesses to best place them within the organization; mediation;
- **A -** Ability to: think strategically (e.g. at the big picture level) and also procedurally/sequentially; organize; identify, create and manage systems, people, and critical pathways;

IMPLEMENTERS: the person or persons in this role designs or creates items and services needed within the startup within their domain of expertise. These include engineers, technicians, programmers, marketing staff; human resources; legal services; etc.

Key Implementer KSAs:

- **K -** Deep domain knowledge in their specific functional area (engineering, finance, programming, etc.)
- **S -** Technical skills; Logical, analytical, creative thinking based on the needs of their domain;
- **A -** Ability to: problem solve in their domain; create and maintain the deliverables associated with their domain;

While some of these KSAs are taught or honed as part of standard courses in business development or in a lean business canvas model, many of them may not be identified as necessary by the team going through the process until it is too late, or the individuals assigned to the roles may not be the best fit for the particular duties associated with the role. It should also be noted that multiple people may be sitting in the same role, and KSAs may not be distributed exactly the same way, but all of the KSAs will be necessary at some point in the transformation from an idea to an organization built around one or more innovations. As mentioned above, it is possible for one person to sit in all three of these roles but is extremely rare, not sustainable, and generally results in the failure of the endeavor if the team is not expanded because the chance of burnout for this individual is extremely high.

In another scenario, the Ideator and Implementor may be the same person (someone who came up with an idea for new software who also has the skills to code it into being) and the second person in the team is Interpreter and Implementer when they translate the product concept to the right kind of organizational structure and also has the skills to establish the organization and build its stems infrastructure. The key is that they are each implementing different things: one is implementing the product and the other is implementing the structures needed to launch the business housing the product.

There are numerous KSAs that overlap between roles; the whole brain thinking model developed by Hermann [14] is another source of KSAs/Traits and includes the Hermann Brain Dominance Instrument (HBDI) [15] which is a survey that was developed using functional MRI's to create a map of the path of least resistance that the individual uses in solving problems and has been used by the researchers to document the impact of pedagogy on students' approaches to problem solving by administering the HBDI at the beginning and close of a student's tenure in the program [16]. Part of the theory is that everyone can use all of the parts of their brain, and we all have a path of least resistance when we solve problems. However, when we move through the pathway from those to which we have the strongest connections to those where we have weaker connections, we spend more energy achieving results because working in that part of the pathway is not as well exercised for us and thus requires more energy. The best teams make sure that all four quadrants are used as all are significant in solving problems.

Part Three: Commonly Missed Start-up Crisis Points

How, then, do we teach the KSAs for the entrepreneurial functions? Unlike the US Secret Service, which trains agents to spot counterfeit currency by studying real currency until even the smallest difference triggers their consciousness, we have found that giving engineers scenarios where the organization is not performing its best – or possibly even failing – provides the best learning opportunity. The scenario provides a canvas for students to understand which KSAs are most important for different situations and why having assigned roles (even if they rotate) is important for depth and continuity for the organization. We build these scenarios around known "Valleys of Death" for startups and provide five examples below. The "Valley of Death" describes a period in the startup process where a lack of funding and other circumstances can prevent the nascent company from achieving a break-even or profitability point and force it into failure [17]. These circumstances also include team dynamics, lack of administrative systems and more [17 at 1]. We have observed numerous other crisis points that arise early in the economic development process that may also crop up anytime during a design process in an engineering program that will prevent a nascent opportunity from completing its transition to a product and entering the market.

The five examples listed below are particularly useful in teaching entrepreneurship to engineers because they tie to the design phase of the innovation and have implications in both the creation of the original innovation and the creation of the organization needed to move the innovation to market. They are also strongly aligned with the need for a true multi-disciplinary team in the design phase that includes business, engineering management, programming, communication, organizational psychology, art, and other majors that bring subject matter expertise relevant to the innovation.

1. Invention is not equal to ownership. Patents require designation of the percentage of invention related to the product that has been reduced to practice. An issue related to invention and ownership may occur if the team creating the new intellectual property is working for credit in their University. IP policies vary widely from institution to institution with some claiming majority or entire ownership of the product if it was created as part of a student product, to those who claim a right to use the product, to those who claim no ownership over the product. Regardless of the approach, Invention is separate from Ownership so the University must list the student Inventors and their percentage of Invention on any patents pursued for the invention by the institution.

If the invention occurs outside of a university and outside of similar policies in a place of employment, it is common to see a small group equate the percentage of invention with the percentage of ownership. If there are three members of a small group that assisted in the design and implementation process to create the MVP (minimum viable product) for the product, it is common to see the one of the group who had the original vision of the product receive at least the 1% of difference to meet the 100% invention allocation in the patent and for this to flow through to the ownership of the patent. Thus, Inventor receives acknowledgement for 34% of the invention and their partners each hold 33%.

This creates two issues. First, it does not recognize the intended contribution of each of the three partners to the future commercialization efforts of the product. If the Ideator is not contributing any further effort, and the entire commercialization process is going to be managed by the other two partners, then the allocation of ownership should reflect that ongoing contribution. In this scenario ownership of the company may then shift to 10% to the Ideator and 45% to the other two original members of the group.

Second, even if all partners are proceeding equally with continued effort toward commercialization, by allocating 100% of ownership they do not create any reserve of interest to allow for onboarding of future investors or other needed skillsets not present in the current partnership.

Another variation of not planning for expansion occurred in a case study used by one of the authors. It involves a new material being created by an Ideator who served as their own Implementer and a group that bought the patent for the product from this individual, but did not hire this individual to act as their Interpreter in translating the MVP to a scaled-up model to be used in a manufacturing process. Ultimately it led to the death of a promising new product.

2. NDAs, Patents, Trade Secrets. Patents are the go-to for intellectual property especially in universities because they immediately produce something that can be shown to others and can therefore increase the prestige of the university and the inventor(s). However patents have a huge flaw that is becoming more and more significant: as soon as a patent is filed it becomes disclosed/published into the public and some nations have come right out and declared, “Yes, we are going to take those and use them for our own purposes.” There are two alternatives to this – don’t patent anything and hope it never ends up with a foreign company who reverse engineers it and starts to produce it on their own; or treat your intellectual property as a Trade Secret which requires a few changes in your organization and your design process to be actionable for legal enforcement under international law if the secret is stolen. Regardless to your intended approach to legal protection, a non-disclosure agreement between the parties and extending to subsequent participants in the design progress is a legal must-have to prevent an inadvertent public disclosure which could forfeit all right of ownership in the intellectual property.

3. No Books. In startups every penny is precious and one of the most common occurrences is a lack of reimbursement for expenses or time spent by the Founders. Many lenders and grant sources require one to two years of certified account records from the company in order to be eligible to participate in grants, contests, or receive certain kinds of loans. Part of the startup process is to fully establish your corporate entity as an LLC, S-Corp, or some other business within the state where you wish to establish the company’s residency by filing the appropriate paperwork with the Secretary of State’s Office and the paperwork needs to include Articles of Incorporation as well as an Operating Agreement as most banks require an Operating Agreement to start a bank account. In addition, you will need a Federal Employee Identification Number, State Tax ID/Sales Tax Id and employer number. While some engineers may view the books as just documentation and the forms as just paperwork, there are important implications in both product and process that may create problems down the line if appropriate subject matter experts, like attorneys and accountants, are not included at the beginning.

4. Name Choice. In prior to picking a name for your company it is recommended to do a name search on the internet with the Secretary of State’s website as well as a general internet search to make use the name is not being used in the same marketspace as your intended space, or for a business or slang term that you do not wish to be associated with. In addition, an available domain search is also recommended to ensure that you will have a usable website name associated with your company. This may also require some crucial conversations when an Ideator is particularly identifies with a name, or feature than coincides with a name, and doesn’t understand the business or legal reasons for a change.

We have seen teams come up with unfortunate names that included overly long names that formed highly questionable acronyms, ones that turned out to be emerging slang for illicit activities, names where the corresponding domain name would have to be over 50 characters long, as well as names that could not be used in advertising because of alternate meanings in other languages.

5. Ethics. Most people trust their fellow business founders to be acting as responsible professionals and never contemplate one of them hacking the company employee’s emails, stealing intellectual property, or suffering from a disease that can compromise their ability to act rationally and ethically. When requesting to have your operating agreement created by your attorney think about having them add a section where you adopt a simple ethical code. The National Society of Professional Engineer’s Fundamental Canons [18] only requires a few adjustments to fit a corporate setting and is familiar to most engineers. It is also recommended to outline the process by which the code will be enforced in your company and any levels of degree that you adopt as an outcome for the breaking of the Code. These can range from a fine, to complete severance and forced return of interest to the company. This not only connects to ethics discussions in engineering education, it can also be included in teaching design verification and validation where the company is what is being designed.

Conclusion: Questions for further thought

As stated above, part of the contribution of the paper is to spark a discussion around leveraging the entrepreneurial mindset for all engineers to also teach the business development roles to the subset of engineers who will take this pathway. The entrepreneurial functions and crisis point examples are the skeleton of a framework for building this into engineering education as well as identifying which student engineers would benefit most. We close this paper with a starting series of questions for entrepreneurial education in engineering community. Our hope is that a variety of diverse voices will join the conversation around these questions, add to the list of questions, and join us in conducting further research in this area. These questions will also aid any instructor or program that looks to build out the skeleton into courses or modules for their own curriculum.

What could be some of the ethical considerations of differential impacts on diverse groups, and unintended and/or unplanned for results, of launching a product that seems benevolent but when examined in microscopic detail (or after advances in science and technology, is discovered to be the root of a significant societal issue)? Could the impact have been predicted? What obligations do engineers have according to the NSPE Code to try and predict this as part of the economic development process?

What factors should engineering departments consider when deciding where to focus on the entrepreneurial mindset alone and where to use it as a springboard for business or product development? If an engineering department decides to expand the KEEN Framework with a connection into economic development, what might the learning outcomes of the revised curriculum look like?

It is clear that teams play a significant role in both the application of the entrepreneurial mindset and in the subsequent expansion of launching a design product into the economic development pathway. What are best practices for assembling teams in design classes? Do the best practices need to shift if launching a startup is not a considered end goal of the design? What supports are currently in place to support teams in design? Are these adequate as well when viewed in the light of the expansion?

Knowledge, Skills, and Abilities may all be cultivated, acquired, and enhanced with the right support. It may be tempting to place students into roles that align with their current KSAs, as this should enhance the ability of the team to function and increase the likelihood of the launch of a product. Would this practice have the effect of removing a significant opportunity for students to expand their KSAs? Is the success of the product and the team greater than individual opportunities for learning?

If the economic development option for design teams is adopted, what institutional changes need to be made to support this at the Department and the University level? Does the potential benefit to students and society outweigh the attendant costs? Who will bear those costs? The University? The Department? The students in the form of higher tuition or fees? Will the opportunity to do this be universal in the program or will there be a filtering mechanism created? If it is, how will bias be reduced in a down-select process so that all voices and backgrounds have an opportunity to reach this goal?

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