
AC 2012-4817: TEACHING STUDENTS TO BE TECHNOLOGY INNOVATORS: EXAMINING APPROACHES AND IDENTIFYING COMPETENCIES

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Teaching Students to be Technology Innovators: Examining Approaches and Identifying Competencies

Abstract

To prepare students for a more competitive global economy, universities are increasingly promoting programs and courses that focus on innovation. Given their early stages of development, limited information about best practices, target competencies or desired outcomes is readily available. This exploratory study examines the nature of educational programs that offer an educational credential focused on innovation. The purpose is to understand their structure, content, and value they propose to students by examining program descriptions and required courses. It explores what teaching innovation means at a program-level and identifies where programs are situated within the spectrum of topics that characterize innovation education. The results can be useful in the development of core competencies related to innovation and understanding approaches to teaching it.

Introduction

The United States led the world's economies in the 20th century because we led the world in innovation. Today, the competition is keener; the challenge is tougher; and that is why innovation is more important than ever. It is the key to good, new jobs for the 21st century. That's how we will ensure a high quality of life for this generation and future generations. With these investments, we're planting the seeds of progress for our country, and good-paying, private-sector jobs for the American people. (President of the United States, Barack Obama, 2009)

In a stagnating and increasingly competitive and global economy, awareness of the role of innovation in economic development and organizational performance takes on more prominence. The President of the United States has stated, “To win the future, America needs to out-educate, out-innovate, and out-build the rest of the world” and points to the country’s accomplishments in the 20th century to make his point. The national agenda outlined to accomplish this involves investing in research and development; investing in the human, physical, and technological capital needed to perform research and transform education; creating an environment ripe for entrepreneurship and risk taking that allows U.S. companies to grow and be competitive globally; and investing in industry sectors of national importance.¹

The topic of innovation is frequently referred to within the context of organizations that “need to innovate in response to changing customer demands and lifestyles and in order to capitalize on opportunities offered by technology, changing marketplaces, structures, and dynamics” (p. 1323).² Innovation is often associated with driving growth in established companies as it is at the origin of new products, features, processes, methods, efficiencies, and markets that generate revenue and employment. It is also the foundation for the launch of entrepreneurial ventures,

which have historically been among the most powerful generators of economic growth.³ As reflected in statements from political leaders, the ability of a country to innovate is key to the creation of jobs, profit, and standard of living and therefore, is an important strategic and policy issue for governments at the local, regional and national levels. Increasingly, it is also considered essential to the success and sustainability of social and non-profit ventures.

Given the role universities play in developing human capital, there is growing interest in investing in educational programs that emphasize innovation so that graduates are more inclined to generate value for organizations or establish new ventures of their own. Given the higher costs of public education, academic programs offered at state-funded institutions are increasingly being scrutinized in terms of whether investments are paying off in terms of job creation and economic development and judgments are being made about those that provide the best returns. For example, in laying out his agenda for higher education reform, the governor of Florida recently suggested that state funding should be directed at degree programs likely to produce more jobs in fields like science, technology, engineering, and math (STEM), which he suggested would produce more qualified employees than would programs in the humanities.⁴

Defining Innovation

The definition of innovation is layered and multifaceted. Dictionary definitions are relatively straightforward: *the introduction of something new or a new idea, method, or device.*⁵ The economist and political scientist, Joseph Schumpeter, defined innovation as the *commercial or industrial application of something new – a new product, process or method of production; a new market or sources of supply; a new form of commercial business or financial organization.*⁶ The author Kimberly defined innovation as having three aspects: *innovation as a process; innovation as a discrete item including products, programs or services; and innovation as an attribute of organizations* (p. 108).⁷ The National Science Foundation defined the process of innovation as *the introduction of new or significantly improved products (goods or services), processes, organizational methods, and marketing methods in internal business practices or the marketplace* and described it as complex and conceptualized in different ways.⁸

Authors Baregheh, Rowley, & Sambrook found there was overlap in definitions of innovation across disciplines, and set out to create a common one that would provide a better understanding of the notion of innovation for diverse fields.² To do so, they analyzed 60 definitions and used content analysis to identify terms used most commonly in them. These included: *new* (42 occurrences), *product* (33), *idea* (21), *service* (21), *process* (21), *organization*, (15) *development* (12), and *technology* (11). They identified six attributes of innovation to represent the flow of innovation which is reflected in their definition: *innovation is the multi-stage process whereby organizations transform ideas into new/improved products, services, or processes, in order to advance, compete and differentiate themselves successfully in their marketplace* (p. 1334).

Given the recent emphasis on the word innovation, some warn that it risks losing its meaning by becoming a buzz word. The author of *The Myths of Innovation*, Scott Berkun, suggested that the word has been overused and warned people to stop.⁹ His rationale was that Einstein, Ford, da Vinci, Picasso, and Edison rarely said it and people use it as a cop out for clear thinking. He suggested using better words instead, such as: “1) we want new ideas; 2) we want better ideas; 3)

we want big changes; and 4) we need to place big bets on new ideas, phrases which are more powerful and specific than the i-word.” Berkun stated that if you can make “something really good, that solves real problems, works reliably, is affordable, and is built by a happy, motivated, and well rewarded staff, you’ll kick your competitor’s *bleep*.” His view was that if all those are taken care of, innovation will take care of itself.

According to some, innovation has not gotten the scholarly cross-discipline attention it deserves given its importance.^{10, 11} Much of the literature on innovation has been published in the social sciences within the fields of economics and management, where it has focused largely on its relevance as well as research about processes, methods, and routines that help firms and teams to innovate better and faster. As the author Osorio states, “Paradoxically, while it is very relevant to understand how to manage innovations and their effects, practitioners in the private and public sector are increasingly asking to know about the latter: how to create them” (p. 2).¹¹

The Value of Innovation-Related Education

In this competitive, global economy, it is widely believed that contemporary college graduates need a broader range of skills to obtain jobs and create value for their employers. Organizations require workers who can develop innovative processes and products, create conditions that foster innovation and innovative behaviors, and lead and manage teams. Further, it is projected that fewer future graduates are likely to obtain full-time employment due to a shift in the labor force in favor of contract work. This means that graduates, regardless of their field, will have to be innovative and able to differentiate themselves in order to compete and thrive in the professional world “as companies want a workforce they can switch on and off as needed.”¹²

Innovation-related pedagogy is receiving increased attention within the academic fields of engineering, science and technology given its role in product and process design and development. This movement has been driven by changing economic and workforce trends and a need to meet revised accreditation standards.¹³⁻¹⁵ This is particularly interesting in light of research indicating that current pedagogy may not necessarily foster innovative thinking. One study of first year engineering students found that they were more innovative in their design solutions than were seniors. This suggests that educational methods currently being used may hinder rather than foster creativity and curricular changes may be necessary to enhance innovative behaviors over the course of a four year education.¹⁶

In academic environments, innovation education is often closely connected with entrepreneurship education either in name and/or practice. The degree to which the topics of innovation and entrepreneurship are distinguished, distinctly addressed, or overlap within and across programs is difficult to assess given the variety educational models that exist. For the purposes of this paper, entrepreneurship will be associated with the process of establishing a new business venture.

There is evidence, however, that exposure to such education has a positive impact and better prepares students for the contemporary workplace. A study of senior-level engineering students found that those who had taken one or more entrepreneurship courses had significantly higher entrepreneurial self-efficacy than those who did not and were also more likely to get hands-on

skills related to market analysis, technology commercialization, business communication, or internships within start-up companies.¹⁵ Another study found that participating in an engineering entrepreneurship program had a positive impact on retention, GPAs, and entrepreneurial activity. Data collected from alumni found that, relative to a control group, graduates of the program were 73% more likely to have started a new company, 23% more likely to have created new products or services, and 59% more likely to have high confidence in leading a start-up.¹⁷

Approaches to Teaching Innovation

Research related to developing curriculum for and assessing innovation education mirrors that of entrepreneurship, which has been characterized as relatively new and fragmented.¹⁸ Conceptual frameworks are helpful to understand the emphases, desired learning outcomes and competencies associated with innovation education programs.

Innovation has been described as both a process and a result, whereby creativity and innovation are considered the product development process, and entrepreneurship (or intrapreneurship) represents the process of commercialization and dissemination or diffusion of the innovation.¹¹ To ground the teaching of the *innovative process*, Osorio created a design thinking-based innovation model (Figure 1).¹¹ The model represents a process that starts with a problem, idea or opportunity referred to as an innovation challenge and, “goes iteratively from exploration and discovery to alternative generation, then to solution development, and finally to launch and exploitation” (p. 4). This process characterizes innovation as a search for information based on an iterative process of analysis and synthesis. This is characterized by experimentation, interdisciplinary collaboration, learning fast from outsiders, and where risk and ambiguity must be managed.

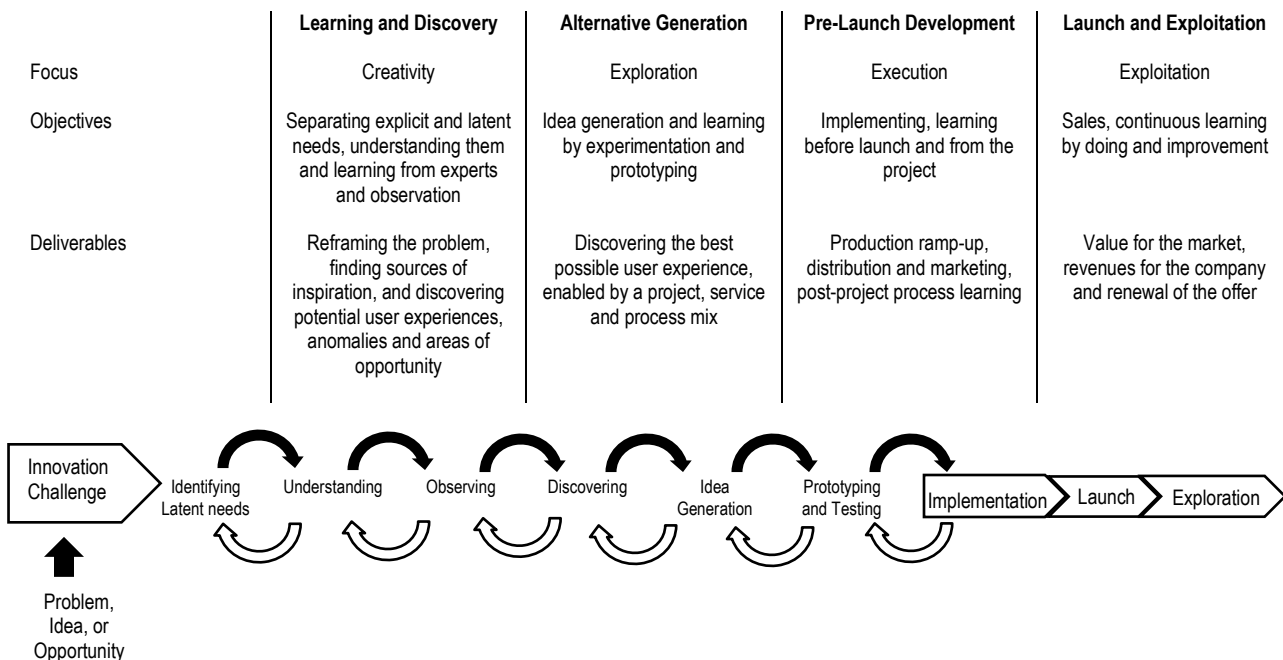


Figure 1. General Model of Innovation Process Based on Design Thinking (Osorio, 2009)

Given the definitions of innovation, at the program-level, the teaching of innovation can be considered part of, or spanning across, an innovation/commercialization continuum that ranges from the topic of creativity on one end, to entrepreneurship and management on the other (Figure 2). Using this framework, creativity and product development are considered the inputs or “innovation process” and the consequences of innovation, including entrepreneurship, intrapreneurship, and business/technology management are the innovation “outcomes.” Although in the real world these are often overlapping activities and iterative processes, in this paper they will be considered distinct topics for the purpose of describing and analyzing the emphasis of educational programs that purport to be focused on innovation.

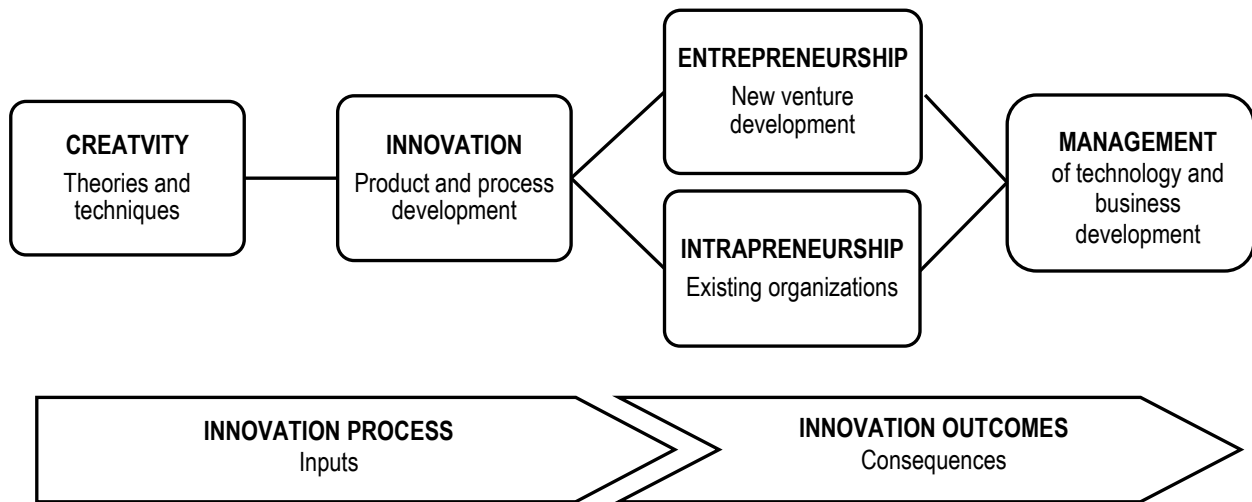


Figure 2: The Innovation Education Continuum Framework

Similar to art, design, and entrepreneurship education, innovation education is considered more effective if it includes a strong experiential component. With the field of entrepreneurship education, Falkäng and Alberti make the distinction between courses *about entrepreneurship* in contrast to courses *for entrepreneurship* highlighting the value of both theory and practice.¹⁹ The authors also point to the very different teaching and assessment methods needed to address the differing approaches.

Purpose of the Paper

The purpose of this research is to explore the nature of educational programs focused on innovation offered by various colleges and universities. Research questions include:

1. What are the characteristics of educational programs that offer a unique academic credential focused on innovation?
2. What are the stated program-level or overarching objectives of these programs?
3. To what extent do programs address the innovation process relative to innovative outcomes?
4. What are the innovation-related topics and competencies addressed?

5. To what extent do programs focus on experiential learning?

The impetus for this research is a desire to examine how a College of Technology at a major research-intensive university might integrate more innovative and innovation-related curriculum and experiences into its degree programs in a way that complements existing programs in entrepreneurship, business, and engineering. It also reflects a need to develop a body of knowledge in this area which addresses a desire of the administration to “move beyond the narrow definition of Technology as artifacts, systems, and processes to a much broader meaning that includes leadership, innovation, commercialization, emerging technologies, entrepreneurship, applied and use-inspired research, industry engagement, professional training and education, STEM education, computational thinking and systems integration” as well as create programs and graduates that “reflect relevance and the emerging needs of business and industry” (p. 9).²⁰

Methodology

This research examined the characteristics of undergraduate programs at various institutions that offered a unique academic credential focused on innovation, which included majors, minors, or certificate programs. Programs were identified by doing a web-based search of undergraduate programs which contained the word “innovation” in their names. Names that included the word *entrepreneurship* were excluded in order to isolate programs that emphasized product or process development (innovation process) over business skills (innovation outcomes). Publicly available program overviews, requirements, course descriptions, and detailed course outlines were reviewed and analyzed to answer the research questions.

Results

Question 1: What are the characteristics of educational programs that offer a unique academic credential focused on innovation?

The study identified only eight academic programs focused on innovation offered at different institutions (Figure 3). They included three bachelor degree programs, three minors, and two certificate programs. These innovation-related academic credentials were offered by colleges and departments of engineering, business, technology, as well as two centers for innovation. All but one program appeared to be multidisciplinary, involving students from majors including engineering, computer science, communication, arts, and management. The three bachelor’s degree programs can be characterized as embedding innovation education with an in-depth technical core. The emphases of the various minor and certificate programs were innovation (general), global leadership and innovation, innovation engineering, innovation with creativity, and innovation with product development.

Analysis of program requirements focused primarily on courses that were related directly to the innovation process and innovation outcomes. General business (non-entrepreneurship) courses and technical courses, that may or may not include innovative approaches or activities, were not included in the analysis. Innovation-related courses required to earn these academic credentials ranged from 3 to 12 classes. In many cases, they consisted of a majority of required “core”

courses, coupled with elective options. Among institutions in the sample, five out of the eight also offered an entrepreneurship program, four of which were multidisciplinary.

Table 1. Innovation Education Programs, Originating Department, and Target Audience

Type of Credential	Originating College, Department or Center	Target Audience
Bachelor of Innovation	College of Engineering and Applied Science and College of Business	Business, Computer Science, Computer Security, Game Design and Development, Electrical Engineering
Bachelor in Design, Innovation and Society	Department of Science and Technology Studies	Management, Communication, Web Design, Graphic Arts, Computer Science, Arts, Mechanical Engineering
Bachelor in Computer Science and Innovation	Division of Information Technology and Sciences	Computer Science
Innovation Minor	College of Technology	Unknown
Global Leadership and Innovation Minor	College of Business	Multidisciplinary
Innovative Engineering Minor	Center for Student Innovation	Multidisciplinary
Certificate in Creativity and Innovation	School of Technical and Professional Studies	Multidisciplinary
Certificate in Product Innovation	Center for Innovation	Arts, Business, and Engineering

Question 2: What are the stated program-level or overarching objectives of these programs?

Program descriptions, which varied greatly in length and scope, were analyzed to examine their emphases, objectives, and value they propose to students. This analysis involved extracting and organizing stated program objectives and organizing them by theme into nine categories that included creativity, problem solving, context/environment, communication, the innovative process, leadership, professional development, and experiential learning. They are presented in Table 2, where they have been edited for person and verb tense.

Table 2. Program-level Learning Objectives

Creativity	<ul style="list-style-type: none"> - Learn a systematic approach to creativity - Provide knowledge of the major creativity theories - Enhance one's latent creative strengths - Foster the ability to apply creativity in the workplace - Present methods for assessing creative strengths
Problem solving	<ul style="list-style-type: none"> - Recognize the broader issues in engineering technology-related problems or in global innovation problems - Integrate skills to solve long term and emerging problems of society - Address large systemic problems to small focused problems to have a broad exposure to the broad spectrum of design practice - Address the need to use innovation to solve many pressing problems in manufacturing, science, business and technology
Context/Environment	<ul style="list-style-type: none"> - Understand business, legal, and societal constraints affecting technology - Put creativity to work as leaders of design and innovation, whether it be multinational corporation seeking ways of addressing diverse markets or finding innovative solutions to local community problems

Communication	<ul style="list-style-type: none"> - Communicate key issues, needs, potential options, and final solution to a challenge - Demonstrate communication and presentation skills
Innovative process	<ul style="list-style-type: none"> - Develop, refine, communicate and successfully implement new ideas - Come up with ingenious ideas for things never done and figure out the complex mathematics and technological mechanics required to make them happen
Interdisciplinary team skills	<ul style="list-style-type: none"> - Develop strong multi-disciplinary team skills - Acquire depth of knowledge in a major and a cross-discipline core that complements the ability to function on multi-disciplinary teams - Bridge disciplines to create new products, services, and media in the context of social needs and environmental concerns - Develop creative thinking skills and multi-faceted team oriented skills - Research different aspects of problem in teams and contribute knowledge and creativity towards synthesizing a team solution
Professional development and preparation	<ul style="list-style-type: none"> - Prepare students for successful careers and lifelong learning - Provide a basic innovation background to ensure the ability to effectively compete in a changing career landscape in areas driven by innovation - Acquire management, communication and team skills that prepare students for industry - Network with employers through career fairs and company tours, and turn internships into full-time jobs at large and small software firms - Develop tools and confidence to create one's own opportunities, and to realize a prosperous and sustaining future within or outside organizations, businesses, or institutions
Leadership	<ul style="list-style-type: none"> - Students see themselves as leaders and innovators, capable of visualizing future leadership roles in their profession and other spheres of life - Lead change within their education, their careers, their affiliations, their communities and their personal lives - Prepare students to serve effectively in formal and informal leadership roles and make innovative contributions throughout their lives
Experiential learning	<ul style="list-style-type: none"> - Learn by doing via undertaking projects to create graphical user interfaces, develop advanced mobile programming, experiment with the untapped potential of robotics, and explore other futuristic technologies - Immersive learning that will teach you to design, develop, test, manage and maintain a full range of software systems

To highlight the terms and concepts most often used to describe these programs, a word cloud was created. This was done by removing prepositions, articles, conjunctions from program descriptions, making adjustments for plurals and verb tenses, and entering it in to the “Wordle” online application. This tool generates an image, which gives greater prominence to words appearing most frequently in a given text (Figure 3). Although a simple form of content analysis, it shows that the terms most used to describe programs were: global, creativity, technology, leadership, skills, problem, learning, needs, knowledge, create, develop, team, design, software, diverse, complex and career.

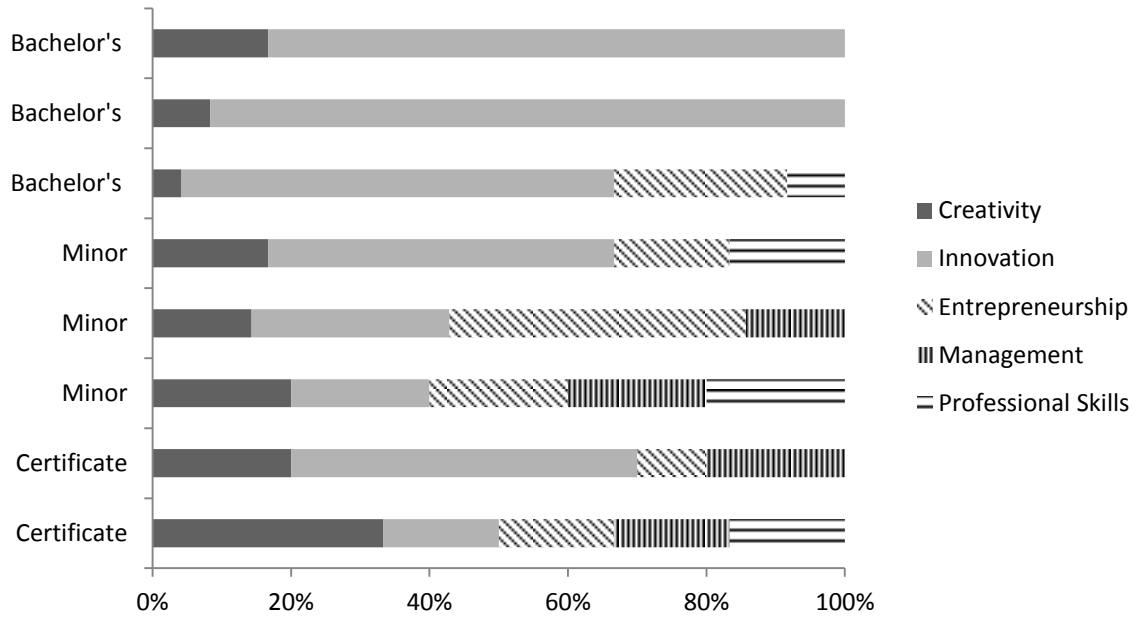


Figure 4: Emphasis of Courses Required by Educational Credential Offered

Question 4: What are the innovation-related topics and competencies addressed?

To examine *innovation process* topics addressed in the program curriculum more closely, course descriptions were analyzed and course topics were categorized according to whether they were more closely associated with creativity (Table 3) or innovation (Table 4).

Table 3: Creativity Topics Addressed in Innovation Education Courses in Sample

<ul style="list-style-type: none"> - Brainstorming - Conceptual blockbusting - Creative problem solving - Creative thinking and invention - Observation - Perception - Communication - Visualization - Open-ended exploration - Systematic approaches to creativity - Creativity theories - Practices and tools to generate unique ideas - Creative stimulus, diversity, and mining for technology, economic, social and cultural trends - Creativity theorists - Creativity in different fields 	<ul style="list-style-type: none"> - Creative characteristics including: <ul style="list-style-type: none"> Originality Fluency Flexibility Elaboration Resistance to premature closure Tolerance to ambiguity - Tools for enhancing creativity <ul style="list-style-type: none"> Role play Simulation Synetics - How creativity, personal maturity, and spirituality inter-related - Principles for infusing creativity into an organization - Systemic creativity at the individual, team, and leadership levels
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Table 4: Innovation Topics Addressed in Innovation Education Courses in Sample

<ul style="list-style-type: none"> - Product development process - Model making - Social science methods of observation and the role they play in discovering and defining problems - Impact designer has on final outcome - Combining technologies - How to turn an idea into a prototype - Create working prototypes - Find flaws of a design quickly and inexpensively - Application of the scientific method to prototyping process - Open-source technology - Patent searching - Provisional patent writing - Analyze technical and marketing data - Engineering design - Relation between social and technical aspects of design - Relationship between design culture and society (product/industrial, urban, alternative approaches such as ecological and feminist design) - Definition of user needs 	<ul style="list-style-type: none"> - Role of design in contemporary culture - Appreciation of design as a cultural practice in the professional work of engineers, architects and business managers - Reach and interconnectedness of technology - Conditionality of design selection criteria - Relationship of race, class, and gender to technology - Potential of design to address societal problems - Study of past and emerging technologies - Understand key components in the innovation process - Study examples of major innovations throughout history - Examine the interdisciplinary nature of innovation - Definition of engineering - How engineering fits into society - Role engineering designers play in society
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Question 5: To what extent to programs focus on experiential learning?

To measure the emphasis on practical application or experiential learning, programs and courses were examined and judgments were made as to the extent to which activities within them were experiential. These activities included utilizing creativity techniques, creating a prototype, or student projects conducted with industry partners. Given the difficulty of evaluating this without full syllabi, the only judgment made was whether over 50 percent of courses or course activities appeared to focus on experiential activities. Four programs were considered over 50 percent and four under. All the bachelor’s degree programs had a strong experiential component.

Discussion

This study presents a useful starting point for describing what teaching innovation means by examining programs that offer a unique educational credential related to innovation. The intent of the research was to begin to identify the objectives and topics addressed in these programs to understand how they may be applied to technology-related disciplines and how they might complement existing programs in entrepreneurship, business, and engineering.

The research identified three types of academic credentials focused on innovation: bachelor degree, minor, and certificate programs. The bachelor degree programs were strongly aligned with a core technical competence and focused predominantly on the innovation process including creativity, product development and prototyping, rather than the outcomes of innovation. They

involved a strong experiential component consisting of design projects or projects with industry partners. These appeared to align well with needs articulated in the *Engineer of 2020* report, in which there was a call to go beyond “reforming one course, one program, one department at a time, developing isolated instances of success here and there” in order to create educational programs that are necessary to strengthen the U.S. engineering community.²¹

In contrast, courses included in minor and certificate programs appeared to place emphasis on a broader range of topics on the innovation education continuum. More research is necessary to understand why this is the case and the depth to which each topic is addressed. One reason might be that more emphasis is placed on innovation outcomes due to challenges inherent in creative substantive experiential projects in certificate and minor programs. Another might be that they reflect the different interests and technical backgrounds of the students and faculty involved. It may also reflect a desire to develop curriculum that appeals to a wider range of students.

Certificate and minor programs may be an efficient way to deliver innovation education to students given the challenges associated with changing curriculum in bachelor’s degree programs. Overhauling curricula, particularly within engineering, science, and technology disciplines at large institutions is a daunting task given the large number of factors that must be considered and accommodated. This is especially true in light of funding constraints, faculty expertise, and professional priorities which often favor obtaining research grants over transforming education. Research is necessary to measure the degree to which different program models are effective in fostering innovative behaviors and more innovative graduates.

The terms and statements used to describe innovation education programs which included *global, leadership, teamwork, and creativity* were more general than technical. Somewhat surprisingly, program descriptions made few references to specific technical competencies students would obtain or specific jobs and careers for which they would be prepared. Only through course descriptions does one get a sense of the technological skills, knowledge, and activities on which they focus. Whether this is a missed opportunity is unknown. Using more precise language related to curriculum and program outcomes could provide a stronger value proposition to students and might provide opportunities to engage more closely with industry, in areas such as student projects, internships, and employment. On the other hand, more generic communication approaches may be more efficient and appealing to a multidisciplinary target audience, given their varying interests and career paths.

It may be somewhat artificial to separate out programs focused solely on innovation given that the number of programs purporting to cover both innovation and entrepreneurship is much larger than our sample. There are also many technology entrepreneurship academic programs which focus on the innovation process. This was done to isolate the competencies associated with the *innovation process* from the business skills often emphasized in entrepreneurship programs. More research is necessary to compare the nature of these programs and their emphases on product development versus business development.

Why programs choose to include the word innovation but not entrepreneurship in their name is yet another question. Given that entrepreneurship education has historically been the domain of business schools at many universities, it may be a way to differentiate programs that have similar

goals. The extent to which this is the case, and the manner in which separate and distinct entrepreneurship and innovation programs courses co-exist at universities, requires more research.

The authors acknowledge several limitations to this study. For example, it did not address innovation education increasingly embedded into major degree programs, such as engineering, science and technology. Nor did the scope of this initial study explore the objectives and content of graduate or overseas programs, which are important to address. Additionally, there are clearly challenges associated with attempting to characterize the content and courses from program overviews and course descriptions. More in-depth content analysis of syllabi would provide a more comprehensive view of the skills and knowledge covered in courses.

Conclusion

Given the growing emphasis on teaching students to be innovative and innovators, this study was designed to be a first step at understanding the characteristics of programs leading to undergraduate academic credentials in the area of innovation. The results provide an overview of what is being emphasized by these programs and the value proposition they communicate to students. More research is necessary to refine program-level frameworks for teaching innovation, program and course-level course competencies, and the manner in which teaching innovation can be applied to different disciplines.

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