Promoting Innovation and Entrepreneurship as part of an Engineering Curriculum

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***Abstract*—This Research to Practice, Work in Progress, paper explores the relationship between entrepreneurship, innovation, and systems thinking, through examining the published work in these areas, and how innovation can be incorporated as part of an engineering curriculum. We identify key common requirements between innovation and systems thinking and propose the idea of teaching systems thinking as a way to promote and enhance innovation, and teaching design process as a practical way to introduce and inspire systems thinking in an engineering curriculum.**

***Keywords*—Entrepreneurship, Innovation, Systems Thinking, Systems Design**

I. Introduction

Promoting entrepreneurship is not a new concept in academia, and it has been embraced by large and small universities. Efforts and approaches, regarding this issue, have become part of many major universities strategic plans. Entrepreneurship is promoted through several means that include dedicated centers, courses, academic minors, and activities and events. Regarding innovation, one can identify two main issues. First, innovation, due to its nature, does not enjoy the same kind of promotion and resource allocation by universities. Second, many universities use innovation in conjunction with entrepreneurship as a natural add-on and then focus on promoting entrepreneurship. This is understandable since it may be difficult to come up with a consensus on how to teach innovation as part of the curriculum. In this regard, before discussing on how to incorporate innovation in curriculum, one needs to answer the difficult questions about the nature of innovation, hereditary or not, and if it can be learned or taught. Like many others, we also believe that innovation cannot be taught, but it can be enhanced for those who have the required natural abilities. We believe that this can be accomplished by teaching systems thinking and design methodology, which can be part of the curriculum. Furthermore, such an addition will also benefit the general student population by introducing them to the aforementioned subjects, which are quickly becoming required skills in today's world. To that end, we start by presenting a brief overview of some of the research works in the subject areas and use their findings and conclusions to identify the common key points. As the research shows, innovation is one of the critical components of entrepreneurship, and there is no established process for teaching it. We then use the published results in the area of innovation to identify its essential characteristics and argue that the same characteristics are associated with systems thinking, and practical implementation of systems thinking can be found in engineering design process. The paper concludes with some remarks about the implementation process in an engineering curriculum.

II. Entrepreneurship in Higher Education

The main goal of the majority of published works in entrepreneurship education is how to promote entrepreneurship and related issues. The references that were considered for this work were categorized into four groups. The first group covers general academic features and requirements; the second group covers specific characteristics associated with entrepreneurship; the third group covers entrepreneurship mindset, and the fourth group has the curriculum delivery as its main focus. Please note that this categorization is done to assist us with our goal in this paper, and do not claim that it covers all related areas. Starting with group one, reference [1] indicates that entrepreneurial education is designed to communicate and include competencies, skills, and values needed to recognize business opportunity, organize, and start a new business venture. [2] points out that entrepreneurship education is an educational program that is focused on influencing students with issues in entrepreneurship. Other studies have also listed out what the contents of a good entrepreneurship education program that is skill-built oriented should include. Including: leadership, negotiation, creative thinking, exposure to technology, invention and innovation [3-4]; opportunity identification, venture capital, idea generation and protection, tolerance for ability, ability to tackle challenges at different entrepreneurial stages, personality traits, ability to write and communicate business plan, new venture development, ability to diagnosis business performance, networking and mentorship, environmental analysis, computer and simulation skills, case studies, films and videoing, field and company analysis [5-6]. As these references show, the general definition is closely associated with business and associated skills with some references to innovation. To understand, better explain, and promote, researchers have identified characteristics and different models of entrepreneurship, which we refer to them as group two references. This group starts with reference [7], which has identified three approaches or models to explain entrepreneurship. These approaches include certain personal traits, events studies, and the venture school. [7] is of the opinion that entrepreneurship is a process of small incremental innovation as opposed to making a giant leap forward and sees an entrepreneur as being very focused, seeing what others have overlooked. The author further argues that most of the widely available resources relating to entrepreneurship curricula are very narrow in their focus and are mainly geared toward

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teaching students survival skills. [8] indicates that pedagogic conception of entrepreneurship studies for engineering students is based on the following four modules: (i) personal development, (ii) from idea to innovation, (iii) public relations and media, and (iv) executing an idea – business plan. [9] argues that engineering entrepreneurship education should focus on teaching young adults, at earlier ages, about innovation and the associated challenges and presents a good review of literature that is focused on sustainable engineering entrepreneurship education. The authors indicate that problem solving, and the creation of physical spaces where students can tackle related problems together is crucial in sustaining entrepreneurial education. [10] describes Pathways to Innovation, a national program that uses a team-based guided change process to help faculty and institutions introduce an embed innovation and entrepreneurship into formal and informal educational experiences for undergraduate engineers. The authors indicate that students in addition to their technical an analytical expertise, they need to be flexible, resilient, creative, empathetic, and can recognize and seize opportunities. The Key takeaway from the first two reference groups is the necessary inclusion of business process and innovation/problem-solving characteristics. These groups cover many required actions and structure, but not so much of activities that focus on promoting an entrepreneurial mindset. A mindset can be defined as a framework for making predictions and judging the meanings of events in one's world [11]. Understanding intention and mindset will help us to obtain a better understanding of how to more effectively promote entrepreneurship and obtain answers to some key questions such as, with all the efforts, why only 20-30% of engineering students participate in the process, and many of them never pursue an entrepreneurial work after completing the program. The third reference group starts with reference [12], which presents assessing the entrepreneurial mindset based on the learning outcomes that were developed by Kern Entrepreneurship Education Network. The outcomes are a combination of good teamwork and problem-solving methods. [13] studies the effect of entrepreneurship education on student's entrepreneurial intentions and concludes, in line with previous research in this area, that participating in entrepreneurial education may not necessarily lead to entrepreneurial intentions, it has a way of motiving students in initiating entrepreneurial venture. Furthermore, there is a tendency that not all the students who had the intention to start an entrepreneurial venture will end up as entrepreneurs. [14] identifies educational support, self-confidence, and structural support as significant predictors of entrepreneurial intentions. Structural support refers to public support. [15] based on their empirical results concludes that promoting entrepreneurship policy that would go beyond "already-convinced" people requires an educational initiative that requires raising awareness, steady growth and development, innovation, creativity and opportunity recognition, and knowledge of the business environment. Finally, the last group of reference in this area covers how to incorporate entrepreneurship into engineering education by, offering related courses, integrating entrepreneurship case studies in technical courses, extracurricular activities such as participating in fairs/competitions, minors, and establishing entrepreneurship centers. This group starts with reference [16], which offers a model that incorporates entrepreneurship into capstone design sequences. [17] presents several reasons why a university should teach entrepreneurship to engineering students. [18] Describes inviting students to participate in a campus fair, "Neat Ideas Fair," and selecting the right courses as ways of promoting entrepreneurship. [19] presents a redesigned course based on experiential and project-based learning to improve understanding of entrepreneurial competencies, presentations skills, and evaluation of new venture opportunities. [20] discovered that integrating entrepreneurship case studies in a mechanical engineering class would increase entrepreneurial self-efficacy and not diminish engineering skills, but does not necessarily increase interest in pursuing entrepreneurship as a career. Other universities have expanded the entrepreneurial activity to included students from diverse disciplines [21-22]. For example, Virginia Tech uses the spiral curriculum, the process of offering a series of authentic activities in increasing complexity, to provide an immersive entrepreneurship experience featuring courses, and a summer program to students [23]. [24] presents a model that would include entrepreneurship-related topics in some engineering courses, by trimming less than 10% of the material. The authors argue that this will convey a message that entrepreneurship is a topic that is inside the normal engineering world and deserves a place in the engineering curriculum.

As a summary, based on published works, key components and characteristics of entrepreneurship education, as well as some of the challenges, have been identified. We saw that innovation was mentioned as a critical component but was not explicitly covered in the curriculum. Next section presents sample works that would further explore the relationship between innovation and entrepreneurship and focuses on the characteristics associated with innovation.

III. INNOVATION

Beginning by giving a brief overview of some of the research works related to innovation and use their findings and conclusions to justify our proposed plan that would come later in the next section. As it was mentioned, the subject of innovation is frequently mentioned in works that are related to entrepreneurship, but as [25] indicates much remains unknown about the interrelation between engineering, entrepreneurship, and innovation education and how to prepare undergraduate engineers for the contemporary workforce and economy and more work focused work is need to explore how to motivate new engineers to be innovative. For example, [26] talks about innovation and entrepreneurship through industry-academic collaborations but the focus of the paper is entrepreneurship. [27] covers innovation, design, and entrepreneurship for engineering students and proposes, based on the published works, a collaborative and experiential course on innovation for engineering students. The authors suggest a multi-year coverage of concepts and integration of the innovation, entrepreneurship, engineering design in a 4-year engineering major. Their proposed innovation course, based on the theory of innovation, includes such concepts of incremental, radical and disruptive innovations underpin skill development and tool implementation. They add that skills implementation is the key to practical application in engineering design. [28] presents an alignment of an engineering course in design thinking and a marketing course, focused on consumer behavior, as a way of promoting innovation and entrepreneurship. [28] also describes the development of an innovation course that students learn tools that help them work through the five parts of the innovation model: idea finding, shaping, defining, refining, and communicating. The authors' results show a positive impact on the innovation skills that were mentioned but did not have a test to evaluate the impact the course was having on student's ability to innovate. The authors indicated a need for an effective innovation assessment. Although, [28] provides a good discussion about innovation, but the model that it present is mainly a linear approach, with feedback, and we consider innovation to be a nonlinear problem.

Next, we will review several published works, which describe different models of innovation and engineering innovativeness. Identifying the characteristics that are associated with innovation, essential traits of engineering innovativeness and corresponding skills and behavior will enable us to provide feedback to students and practitioners, which will enable us to inform them about the innovative skills they can improve upon, as well as the characteristic that cannot be changed or easily changed. [29] presents an innovation self-efficacy survey, which mostly is on problem-solving skills. [30] based on open-ended interviews with a diverse set of innovation, experts presents a "mental model" to describe the innovation and innovation education. A mental model captures a connected set of observation, assumptions, and beliefs about a domain-specific situation that people draw upon when they think of a situation. The authors indicate that with some variations in specific words, the experts consistently named the same set of key concepts: something new that is implemented and provides value, to describe innovation. They also presented an example of attributes (personal attributes, skills, the process of innovation, and environment of innovation) of elements that act as promoters or inhibitors of innovation. The elements under the process of innovation included: systems understanding of the organization and related spheres and decision making with an understanding of the system. [31] explores engineering innovativeness from a set of eight interviews of experts. The authors indicate that the six most important innovative behavior attributes of engineers suggested by the interviewees were: domain knowledge, opportunity, recognition, teamwork skills, the willingness to listen to other strengthened by curiosity, risk-taking or the willingness to risk failure, and persistence. Creativity was seen as essential to jump-start the innovation process but not sufficient for getting an idea successfully introduced into the marketplace. [32], a continuation of Ferguson-2012 research [31], identified five critical characteristics of an engineering innovator: deep knowledge, active learner/curious, vision/caring, team manager/leader and risk taker. [33] examines innovativeness assessment and analyzes ten measures and models of innovativeness through two lenses: (i) their attributes vs. actions and (ii) their relationship to cognitive level, style, and effect. They concluded that a comprehensive rigorously validated psychometric instrument does not yet exist to assess the aptitudes, skills, knowledge, personality traits, and behaviors that are indicative of an innovative engineer. The paper references [34] that describes innovativeness as a general personality trait that can be defined as a predisposition to accept innovation. The authors then indicated that the aforementioned definition helps make two important distinctions: first, that general innovativeness is related to personality, and second, that it is centered on the acceptance of "new" things. [35] describes the findings of workshops focused in integrating innovation in engineering education, where they concluded that there are five skills associated with innovation: an open mind; no fear of rejection; curiosity; passion; and a breath of knowledge as opposed to specific and focused knowledge. The authors proposed reverse engineering and design competitions as effective methods to promote innovation in engineering education. [36] examines the changes over 2012-2015 in Innovation and Entrepreneurship (I&E) initiatives within the National Center for Engineering Pathways for Innovation's community. The authors indicate that in engineering, innovation is associated with design. They also reported that there is a high level of agreement that I&E should be offered as part of the required curriculum. In a more recent work [37] indicated that they had identified the most important characteristics of engineering innovators. The authors define the innovation process to have a beginning (discovery), a middle (development) and a completion phase (implementation). They also add that evidence does not connect claims on how to create innovations or be more innovative to engineering student learning experiences and outcomes. They present their five-year study in a table (Table 1 in [37]; copied below) and identify twenty characteristics related to innovative behavior. The table includes alternative seeker, analytical (separate something into parts or constituent elements), creative, curious, developer, experimenter, implementer, knowledgeable, visionary, among the twenty identified characteristics. Furthermore, they indicated that courses with titles like 'Innovation and Creativity for Engineers' have not provided assessment evidence that these courses positively impact or enable the characteristics that we now know comprise engineering innovativeness.

TABLE 1 [37]: Engineering Innovator Characteristic Definitions

Characteristic	*In vivo* Definitions Based on the Grounded Theory and Delphi Studies
Alternatives Seeker	Actively searches for multiple choices or solutions or new non- obvious options to make something better.
Analytical	Separates something into component parts or constituent elements.
Associative Thinker	Joins or connects together ideas or facts from different domains or experiences.
Challenger	Questions the current state of things.
Collaborator	Actively networks with people in or supporting the project.
Communicator	Explains the idea, the concept, and the opportunity by speaking, writing, gestures or use of pictures or diagrams.
Creative	Invents a new product, process, or concept that has value to a community.
Curious	Actively challenges themselves to learn or know more about something.
Developer	Enables self and others by breaking down barriers and obtaining sufficient resources to move something ahead.
Experimenter	Performs a series of actions and carefully observes their effects in order to learn about something.
Implementer	Takes an idea from development into an end product.
Knowledgeable	Possesses information, understanding, or skill that spans a significant number of different subject areas.
Market/ Business Savvy	Possesses practical understanding or knowledge of [business or market] and able to use this knowledge to identify unmet needs.

Passionate	Expresses strong emotions or beliefs about something.
Persistent	Continues to do something even though it is difficult or other people want you to stop.
Risk Taker	Doesn't think failure is bad, but that failure provides for learning.
Self-Reliant	Confident in own abilities and able to do things for yourself.
Leader	Inspires other individuals and facilitates achieving a key result or a group of aligned results.
User Empathetic	Understands the feelings, thoughts or experiences of another person/group
Visionary	Has ideas about what could/should happen or be done in the future based on an understanding of user needs.

Summarizing the findings of the references mentioned in this section, we can say table 1 in [37] captures a significant number of innovation characteristics suggested in various papers, understanding of systems and engineering design have been mentioned in two references, and there is no uniform definition for innovation and innovativeness across the board. It should be mentioned that although the references for this section capture innovation characteristics but they do not provide a clear pathway on how to achieve it. Furthermore, using reference [37] as an example, it is unclear the proportion and relative importance of these innovation characteristics in an innovator. For example, for an inventor, being a "visionary" is more important or being an "associated thinker?" Nevertheless, we believe these references have identified many essential characteristics of innovation that are useful in our discussion, and in the next section we present sample results regarding systems thinking that would show it includes the same general characteristics, and innovation can be promoted/enhanced by using a system thinking approach.

IV. Systems Thinking

[38] states that systems thinking refers to conceptual understanding or mental constructs of the system of interest that enables perception of it as a holistic entity situated in a specific environment. Systems thinking involves perception and conceptualization processes that apply systems thinking rules which include: questioning the system boundary, system structure, and interrelationships; adopting multiple perspectives; considering change over time (dynamic characteristics); and applying holistic and big-picture thinking [39]. Comparing the definition of systems thinking to the characteristics mentioned in [37] we can see that "knowledgeable," "challenger," "alternative seeker," "analytical," and "visionary," closely cover the same things.

[40] indicates that there are three ideas at the heart of delivering systems thinking. They are thinking in layers, thinking in loops, thinking about new processes. The author indicates that a systems thinker starts by knowing that everything has a life cycle – but one that is set in the context of a system containing other processes – some at higher and some at lower levels of definition. All processes have attributes that are characterized using why, how, who, what, where, when; and elaborates on how those attributes are obtained. The author also indicates that systems thinking is not simply an engineering approach; it is a philosophy for solving many practical problems. Again, using Table 1 of [37], we can see that these characteristics are very close to "alternatives seeker," "analytical," and "associate thinker."

[38] explains the five learning disciplines and how they come together to form a system. The five disciplines are Personal Mastery, Mental Models, Building Shared Visions, Team Learning, and Systems Thinking. The characteristics close to these disciplines are: "knowledgeable, creative, developer," "alternative seeker, analytical, associate thinker, challenger," "collaborator, communicator, developer," and "implementer, visionary, leader."

The referenced works regarding the systems thinking identify the alignment of the innovation characteristics and system thinking. The characteristics associated with the systems thinking are also aligned with the ones in the engineering design process. In general, engineering design is a complex process, which contains multiple systems themes: optimization, global perspective, and complex variables, such as social, political, environmental, and economic factors and it often requires systems thinking [41]. [42] defines engineering design as, "a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints," and provides the following characteristics for design thinking that are often associated with good designers: (i) tolerate ambiguity that shows up in viewing design as inquiry or as an iterative loop of divergent-convergent thinking; (ii) maintain sight of the big picture by including systems thinking and systems design; (iii) handle uncertainty; (iv) make decisions; (v) think as part of a team in a social process; and (vi) think and communicate in the several languages of design. A quick comparison of these characteristics with the innovativeness characteristics presented in table 1 of [37] reveals a substantial similarity, which supports our claim regarding promotion of innovation through teaching engineering design.

V. Remarks and Conclusion

In this paper, based on published works in this area, we briefly presented an argument in support of teaching systems thinking to promote innovation. We believe, by just teaching systems thinking courses the goals may not be achieved since systems thinking is a mental construct that would take a right amount of studying and practice. Engineering design was then presented as a practical way that systems thinking could be included in the curriculum and promoted. A combination of an introductory systems-thinking course and more than one systems design course or courses will provide adequate exposure to the topic. We hypothesize that over time with practice if a systems' thinking paradigm can be attained, it will strengthen one's innovation characteristics. Finally, it is worth mentioning that the new ABET [43] accreditation guidelines, under student outcomes, includes requirements such as, "ability to design a system", "understand the impact of engineering solutions in a global, economic environmental, and societal context", which, we believe, can be efficiently addressed by including systems' thinking and systems design courses as part of the curriculum.

REFERENCES

[1] Brown, C. *Entrepreneurial Education Teaching Guide.* Kauffman publication, 2000.

[2] Gorman, G., D. Hanlon, and W. King, "Some Research Perspectives on Entrepreneurship Education, Enterprise Education and Education for Small Business Management: a Ten-Year Literature Review," *International Small Business Journal*. Vol. 15, No.3, 1997.

[3] McMullan, W.E., and W. Long, "Entrepreneurship Education in the Nineties," *Journal of Business Venturing*, Vol. 2, pp. 261-275, 1987.

[4] Vesper, K.H., and W.E. McMullen, "Entrepreneurship: Today Courses, Tomorrow Degrees?" *Entrepreneurship Theory and Practice,* Vol 13, No 1, pp.7-13, 1998.

[5] Brawer, F. B., "Simulation as a vehicle in entrepreneurship education," *ERIC Digest*, Vol. 97, No. 1, pp. 433-69, 1997.

[6] Kuratko, D.F. The Emergence of Entrepreneurship Education: Development, Trends, *Entrepreneurship Theory and Practice*. Sept. 2005.

[7] Gunderson, G. *Thinking about Entrepreneurs: Models, Assumptions, and Evidence*. Quorum Books, NY, pp. 41, 1990.

[8] Binder P. and J. Knauder, *Entrepreneurship in Engineering Education, Modular Curriculum and Practical Evaluation of the Model*. Springer 2017.

[9] Uzochukwu, B.M., C. Davis, and B.U. Nwoke, "Towards a Sustainable Engineering Entrepreneurship Education," *Proc. of the 123rd ASEE Annual Conference, New Orleans, LA, 2016.*

[10] Nilsen, E., M. Victoria, S. Angela, and T. Monroe-White, "Stimulating and Supporting Change in Entrepreneurship Education: Lessons from Institutions on the Front Lines," *Proc. of the 122nd ASEE Annual Conference, Seattle, WA, 2015.*

[11] Yeager, D. S., and C.S. Dweck, "Mindsets that promote resilience: When students believe that personal characteristics can be developed," *Educational Psychologist*, Vol. 47, No. 4, pp. 302–314, 2012.

[12] Kleine, R.E., and J.D. Yoder, "Operationalizing and Assessing the Entrepreneurial Mindest: A Rubric Based Approach," *The Journal of Engineering Entrepreneurship*, Vol. 2, No. 2, pp. 57-96, 2011.

[13] Isedonmi, P.F, and C. Okafor, "The Effect of Entrepreneurship Education on Students' Entrepreneurial Intentions," *Global Journal of Management and Business Research*, Vol. 10, No. 6, pp.49-60, 2010.

[14] Turker, D., and S.S. Selcuk, "Which Factors Affect Entrepreneurial Intention of University Students?," *Journal of European Industrial Training,* Vol 33., No.2, pp.142-159, 2009.

[15] Linan, F., J.C. Rodriguez-Cohard, and J.M. Rueda-Cantuche, "Factors Affecting Entrepreneurial Intention Level: A role for Education," *Int. Journal of Entrep. Management,* No. 7, pp. 195-218, 2011.

[16] Ochs, J., G. Lennon, T. Watkins, and G. Mitchell, "A Comprehensive Model for Integrating Entrepreneurship Education and Capstone Projects While Exceeding ABET Requirements," *Proc. of the 113th ASEE Annual Conference, 2006.*

[17] Huband, F. L., "Entrepreneurship Education for Engineering Students," http://ed.edu.cn/attachment/Present/EngineeringEd/Frank%20L%20Hubband.ppt.

[18] Patek, M., and B. Anuradha, "How to Weave Entrepreneurship into Engineering Education: the experience at San Jose State University," *Proc. of the 113th ASEE Annual Conference, 2006.*

[19] Ferguson, D.M., J.E. Cawthorne, and R. Streveler, "Designing and Introductory Entrepreneurial Thinking Course, *Proc. of the 120th ASEE Annual Conference, Atlanta, GA, 2013.*

[20] Schar, M., S. Sheppard, S. Brunhaver, M. Cuson, and M. Grau, " Bending Moments to Business Models: Integrating an Entrepreneurship Case Study as Part of Core Mechanical Engineering Curriculum," *Proc. of the 120th ASEE Annual Conference, Atlanta, GA, 2013.*

[21] Boni, A., L.R. Weingart, and S.Evenson. "Innovation in an Academic Setting: Designing and Leading a Business Through Market- Focused, Interdisciplinary Teams," *Academy of Management Learning and Education,* Vol. 8, No. 3, pp. 407–417, 2009.

[22] Cobb, C.L., A.M. Agogino, S.L. Beckman, and L. Speer. "Enabling and Characterizing Twenty-First Century Skills in New Product Development Teams," *Journal of Engineering Education,* Vol. 24, No. 2, pp. 420–433, 2008.

[23] Hixson, C., M. Paretti, J. Lesko, and L. Mcnair. "Course Development and Sequencing for Interdisciplinary Entrepreneurship Education," *Proc. of the NCIIA 17th Annual Meeting*. Washington, D.C., 2013.

[24] Johnson, E., M. Budnik, T. Doug, "Integrating Entrepreneurship Throughout an Electrical and Computer Engineering Curriculum," *Proc. of the 116th ASEE Annual Conference, 2009.*

[25] Sheppard, S., S. Gilmartin, H.L. Chen, et al., "Exploring What We Don't Know About Entrepreneurship Education for Engineers," *Proc. of the 122nd ASEE Annual Conference, Seattle, WA, 2015.*

[26] Anid, N.M., M.A. Panero, and B. Carbonette, "Innovation and Entrepreneurship through Industry-Academic Collaborations: A Collegiate Model for Economic Development," *Proc. of the 123rd ASEE Annual Conference, New Orleans, LA, 2016.*

[27] Pech, R., B. Lin, C-K Cho, and H. Al-Muhairi, "Innovation, Design and Entrepreneurship For Engineering Students, Development and Integration of Innovation and Entrepreneurship Curriculum in an Engineering Degree," *Proc. IEEE Global Engineering Education Conference (EDUCON)*, pp. 389-396, 2016.

[28] Lugo, J.E., M.L. Sapata-Ramos, and M.J. Perez-Vargas, "Promotion of Innovation and Entrepreneurship in Engineering Design by Synchronizing Engineering and Business School Courses," *Proc. Of the ASME IDET/CIE Conference,* Charlotte, NC, 2016.

[29] Gerber, E., C. Martin, E. Kramer, J. Braunstein, and A.R. Carberry, "Developing an Innovation Self-Efficacy Survey," *Proc. of the 42nd Frontiers in Education Conference,* Seattle, WA, 2012.

[30] Fisher, E., M. A. Biviji, and I. Nair, "New Perspectives on the Teaching Innovation to Engineers and Exploration of Mental Models of Innovation Experts," *Proc. of the 118th ASEE Annual Conference, 2011.*

[31] Ferguson D.M., and M.W. Ohland. "What is Engineering Innovativeness?" *International Journal of Engineering Education*, Vol. 28, No.2, pp. 253, 2012.

[32] Purzer, S., K. Jablokow, D.M. Ferguson, M.W. Ohland, and J. Menold, "Collaborative research: Identifying and assessing key factors of engineering innovativeness," *Proc. of the 121st ASEE Annual Conference (NSF Grantees Poster Session*), Indianapolis, IN, 2014.

[33] Menold, J., K. Jablokow, S. Purzer, et al., "A Critical Review of Measures of Innovativeness," *Proc. of the 121st ASEE Annual Conference*, Indianapolis, IN, 2014.

[34] Soutar, G.N., and S. Ward, "Looking at behavioral innovativeness: A Rasch analysis." *Journal of organizational and end user computing (JOEUC)* Vol. 20, No. 4, pp. 1-22, 2008.

[35] Spenko, M., and J.S. Yagoobi, "Integrating Innovation into Engineering Education," *Proc. of the 118th ASEE Annual Conference, 2011.*

[36] Peterfreund, P., E. Cosache, H. Chen, S.K. Gilmartin, and S. Sheppard, "Infusing Innovation and Entrepreneurship into Engineering Education: Looking for Change as Seen by ASEE Members, 2012-2015," *Proc. of the 123rd ASEE Annual Conference, New Orleans, LA, 2016.*

[37] Ferguson, D., W. Li, J. Weaver, J.Ochs, K. Jablokow, C. Bell-Huff, and W. Newstetter, "Do Engineering Creativity/innovation Courses Impact Engineering Innovativeness?" *Proc. of the 47th Frontiers in Education Conference,* 2017.

[38] Cabrera, D.A. *Systems Thinking.* Ph.D. dissertation, Faculty Graduate School Cornell Univ., Cornell Univ., Ithaca, NY, USA, 2006.

[39] Cabrera, D.A., L. Cabrera, and E. Powers, "A Unifying Theory of Systems Thinking with Psychosocial Applications," *Syst. Res. Behav. Sci.*, Vol. 32, No. 5, pp. 534–545, 2015.

[40] Senge, P., *The fifth discipline*. London: Century Business Books, 1990.

[41] Lammi, M. "Thinking in Terms of Systems Through Engineering Design," *Proc. of the 118th ASEE Annual Conference, 2011.*

[42] Dym, C.L., et al., Engineering design thinking, teaching, and learning. Journal of Engineering Education, 2005. 94(1): p. 104-120.

ABET. Criteria for accrediting engineering programs, 2018-2019. Retrieved 2018, www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2018-2019/#program