INTERSECTION:
Fostering Innovation in Undergraduate Education Through Thematic Interdisciplinary Programs

David Keck and Ian Cottingham
UNIVERSITY OF NEBRASKA - LINCOLN

Abstract

The increasing focus in higher education on producing outcomes that drive economic development has spurred a move towards the inclusion of entrepreneurship in engineering programs with the goal of training graduates in processes and methodologies associated with creating value in the marketplace using technology. Challenges range from breaking through silos between engineering and business programs to identifying pedagogical approaches that support curricular integration across disciplines. Despite success in many programs, innovation in education remains elusive and, when achieved, often comes at great expense.

In this paper we explore how the Jeffrey S. Raikes School at the University of Nebraska - Lincoln has been able to build a platform for innovation studies by integrating two or more academic disciplines using the themes of model and design thinking. We approach the integration concept using computer science and business as examples, and discuss more broadly how our platform enables the reduction of institutional inertia for innovation programs.

Introduction

As higher education seeks to address the educational needs of the 21st century workforce, there is an increasing focus on the role of the academy in promoting economic development. Innovation and entrepreneurship (I&E) are complementary drivers for economic growth (Weins and Jackson 2015; Warsh 2006) that faculty and administration often attempt to leverage in the development of new curricula. Opportunities range from improved undergraduate outcomes to universities evolving to become the epicenter of regional I&E ecosystems, connecting industry and the academy to serve as the launching point for new high-growth ventures. Despite the significant opportunity that can be created by developing I&E-focused curriculum, the challenges created by traditional disciplinary models can often undermine or obviate the targeted student and community outcomes. Beyond disciplinary barriers, many programs struggle to identify and then develop skills appropriate to the mission of higher education in the context of addressing both formal and experiential learning. When these challenges are overcome, universities are discovering a significant opportunity cost: I&E programs often must complement traditional programs of study while at the same time conforming to the trend for reduction of credit hours required for graduation.

A useful starting point is the identification of skills and experiences that can be grounded in academic foundations and support the development of the innovator and the entrepreneur as part of existing programs in undergraduate education. In successful I&E endeavors, the introduction of curricula designed to promote these skills coexists alongside existing programs, enhancing rather than replacing disciplinary study. The integrative nature of the approach is foundational in the developed curriculum, leveraging in its development the very processes for innovation that are being instructed. Co-curricular concepts for understanding risk and uncertainty, creativity, iterative problem solving, and human-centered approaches to solution development and outcomes are used to support disciplinary studies, creating an innovation context for education that trains students to innovate in any field. This broader view of I&E creates greater opportunity in the academy by incorporating the best practices from multiple disciplines, lowering the disciplinary barriers to the development of innovation-supporting programs.

In this paper we introduce an approach to I&E program development that integrates two or more disciplines using the themes of model and design thinking (Stanford University Institute of Design 2016; Scott n.d.). These integrating themes support the development of co-curricular experiential and formal learning models that introduce an innovation context into existing curriculum. We present this approach in a discussion of one such implementation at the University of Nebraska – Lincoln. The Jeffrey S. Raikes School of Computer Science and Management leverages model and design thinking throughout an honors curriculum focused on the development of innovators through undergraduate education in computer science and management. In its fourteen-year history, the Raikes School has evolved to define a new academic space between colleges that leverages disciplinary partnerships to deliver an innovation curriculum. The transcendent objective of the school is the development of innovators utilizing traditional as well as applied academic models. The results have been significant: a general increase in interest of campus partners in I&E concepts, a platform from which to launch new initiatives within colleges, and the matriculation of over 500 undergraduate students through a program created with the express purpose of integrating innovation education into the academy.

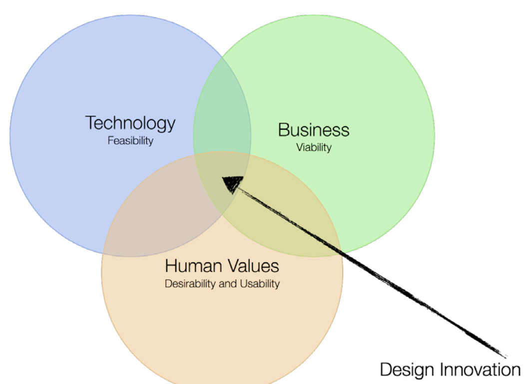
Interdisciplinary Foundations

The early 20th century economist Joseph Schumpeter was the first to describe the drivers of economic development: innovation and credit (capital) (McCraw 2007). In his works, Schumpeter promoted innovation as the driving force of economic progress, describing entrepreneurs as agents of innovation (Economist 2007). In his view, innovation was "the commercial application of something new" and is "the strategic stimulus to economic development." In this capacity—the newness of a commercial application—we can link through Schumpeter the role of entrepreneur and innovator. Beyond viewing entrepreneurship as simply starting a new venture, which can be in support of innovation, we can, again through Schumpeter, explicitly link innovation to the entrepreneurial function in organizations (Schumpeter 1911; Schumpeter 1928; Schumpeter 1934). This concept is critical to fully defining the interplay between innovation and entrepreneurship, a prerequisite to the successful development of curricula to train these skills. Where, since the time of Schumpeter, innovation has been defined as the adoption of something new (Tarde 1890), entrepreneurship and the skills associated with it are closely associated with dealing with risk (Cantillon 1755; Hayek 1985; Say 1803; Say 1821). With this view, innovation and entrepreneurial skill sets mutually enrich each other across the spectrum from the proverbial garage to the board room.

Arguing against the views of earlier economists like Richard Cantillon and Jean-Baptiste Say, Schumpeter (1928) posited that it was the capitalist who incurs economic risk while the entrepreneur incurs legal risk, except in those cases where the entrepreneur is also a capitalist. Capitalist, in this sense, means the owner of the concern. This distinction allows us to view the entrepreneur in a different light. The entrepreneurial skill set need not be limited to those abilities which allow for the successful management of a concern in and of itself. Training skills for managing risk—rather than the concern—then becomes key in evaluating which formal academic models should be included in I&E curricula. Former University of Chicago economist Frank Knight (1921) makes the important distinction between economic risk and uncertainty: risk can be managed with quantitative methods, while the source of entrepreneurial profits is the successful management of uncertainty. Not only does this establish a basis for the inclusion of quantitative methods in I&E curriculum, it supports the role that entrepreneurship plays in shaping innovation and provides a foundation for the integrating themes discussed later.

So what, then, of the innovator? Everett Rogers popularly characterized innovators by their "venturesomeness" (1963), and differentiates them from venturesome entrepreneurs by identifying them as the first to adopt something and adopting it earlier than his "early adopters." By the 1980s, the study of innovation began to focus on the development of innovation, which leverages not only the understanding of the adoption process, but on increasingly rapid technological change. More contemporary studies have resulted in the concepts of disruptive innovation (Christensen 1997) and exponential technologies which leverage digitization of product and value chain (Diamandis and Kotler 2015). In the early 21st century, it is virtually impossible to separate the concept of innovation from technology. While it is certainly possible to adopt something new outside of the sphere of technology, the complex nature of the problems that we look to innovation—or, more importantly, innovators—to address, generally outpaces the nature of human capability alone. Technology, and the evolutionary advantage we gain in our ability to enhance and extend our natural capabilities, becomes a core component in both the study and development of innovation.

The progression of our view of technology in our lives from the orthogonal to the integrative has shaped the way technology can be successfully deployed in the marketplace (Norman 2010). Famed designer Donald Norman presents, by way of the Encyclopedia Britannica, a definition of technology (emphasis ours) as "the application of scientific knowledge to practical aims of human life or, as it is sometimes phrased, to change or manipulate the human environment." Norman provides the more practical definition of technology as "new stuff that doesn't work very well or works in mysterious, unknown ways." Here, Norman identifies an often found barrier to the survival of innovations in the marketplace: human beings. Companies strongly associated with innovation, those who have succeeded in the marketplace like Apple, Google, and Tesla, have reframed their understanding of the use of technology to drive innovation in user-oriented, human terms. As we continue to progress into the 21st century, human-centered technology continues to drive business, organizations, and models with greater frequency.



The well-known Stanford Design School Venn diagram illustrates the relationships between these various aspects of innovation, defining Design Innovation as the intersection of feasibility, desirability, usability, and viability. The innovator's skills exist not in a singular understanding of a process but rather in the space at the intersection of many processes and domains spanning business, technology, and human values (Stanford University Institute of Design 2016). The space in which innovation is studied and trained must, by definition, be interdisciplinary.

The skill sets required for success in the space from which innovation can emerge must certainly include understanding technology, especially computing and digital technology, as well as business models, both grounded in human sciences and values. Such an understanding ultimately manifests itself in the ability of a design to conform to the customer requirements and organizational dynamics, while maintaining the "newness" of an innovation. The nature of the space is characterized initially by uncertainty and a lack of information. Keen insight and prediction are needed not only for product innovation considerations, but also to understand the human considerations of markets, teams, and organizations.

Attempting to partition skills that intersect to create innovation is as futile an exercise as attempting to define one in the context of the other. In order to fully leverage the benefits provided by these skills, one must successfully train each in the context of the other. It is here where the institutional nature of the academy begins to present barriers to the development of successful I&E programs. Organized into disparate disciplines, each advancing knowledge within the silo, the modern university is not well organized to embrace concepts, or to apply funding, at the intersection of disciplines that have been relegated to rigid institutional structures. Much effort has gone into advocating for a new structure that eschews academic silos (Kirschner 2012). This effort, in the short term, tends to ignore the inertia or even value that exists within the structure. We propose that there is an alternative solution, one that leverages the structure to create intersection points within the academy to overcome institutional inertia. These points serve not only the goal of successfully deploying new I&E programs, but act as links through which successful programming can be redeployed, enriching the disciplinary aspects of the academy and benefiting the university as a whole.

Integrating Themes

Skills related to understanding risk and uncertainty, creativity, iterative problem solving, and human-centered approaches to solution development certainly exist in all disciplines. We propose, however, that there are themes common to each these skills that transcend disciplinary boundaries. Because these themes distill disciplinary skill sets related to innovation into core concepts, they can be used to form the foundation for the development of a context in which innovation can be presented across many disciplines. Such a context can provide for the successful integration of two or more disciplines toward training students in the skills required to transform them into innovators. It is here that we propose a solution to the problem of disciplinarity in the development of academic I&E programs.

Thematic models for integration must focus on common processes and abstractions in order to transcend disciplines. Rather than identifying disciplinary best practices and then attempting to export them into a multidisciplinary context, we identify processes, concepts, and models that are common to many disciplines and which support the previously discussed innovation skills. When distilled to a common set of concepts, themes emerge of human-centered approaches to problem solving and development of information from data to gain insight. Processes and methods for framing complex problems and developing human-centered solutions, products, and services we classify as "methods of creative action" or "design thinking" (Patnaik 2009). Models are useful simplifications of reality that provide the insights necessary for the development of information and insight is addressed by data, models, and processes. Models have been described as "tools for thinking" (Diamandis and Kotler 2015); this way of thinking is at the core of not only of the engineering, science, and business disciplines, but probably all disciplinary and interdisciplinary pursuits.

From this set of core skills, we leverage design and model thinking as thematic models for integration of disciplinary concepts to create an innovation context for I&E programs.

Design Thinking

Design as a concept is as central to innovation as the adoption of something new. In his work *Design Method*, Jones defines design in terms of the "newness" of something. He differentiates it from art, science, and math by describing it as "ways in which the foreseen thing can be made to exist" and arguing that design does not operate in the physical world (Jones 1992). As a discipline, design concerns itself with "appropriateness," valuing practicality, ingenuity, and empathy, utilizing modeling, pattern-forming, and synthesis (Cross 1982). Leveraging alternating models of divergent thinking for ideation and problem exploration and convergent thinking for discovery of a correct solution, design processes are strongly iterative. The iterative nature of these processes is ideal for operating in environments characterized by uncertainty.

Many processes for design in various fields have been developed and successfully deployed toward the creation of new products, services, and problem solutions (Simon 1969; McKim 1973; Liedtka 2011). Through their iterative natures, these processes support the innovator with short discovery periods characterized by learning from failure. In environments of uncertainty, frequent measurement of sought-after outcomes allows for a reduction of risk by increasing the availability of actionable information and data. Successfully deployed design processes ultimately develop a culture and experience that leads to confidence needed for innovation and entrepreneurship.

Design can be further characterized as a search process. When practiced, the designer is in search of a desired solution or outcome. It is here that design ties together concepts related to both innovation and entrepreneurship. Entrepreneur Steve Blank defines a startup as "a temporary organization in search of a scalable, repeatable business model" (Blank and Dorf 2012). Insofar as innovation is the search for something new, any organization, whether a new venture or existing concern, can be thought of as a startup. The temporary nature of the activity is characterized by successful identification of a known problem (market opportunity) and discovery of an unknown solution (product) (Reis 2011). The successful outcome of search is execution. Failure to discover the market opportunity or develop the product necessarily ends the process. Innovation, when viewed as closely related to search, is well supported by design thinking processes.

Model Thinking

The concept of model thinking has emerged over the last decade. Motivated by the work of Scott E. Page, this concept views models as supporting "thinking more clearly, understanding and using data, and strategizing, deciding, and designing" (Page n.d.). Model thinking complements design thinking by defining the analytical nature of the search process with broader clarity and purpose. The relationship between the two concepts is similar to that between analysis and design. By applying both general and domain-specific models, the innovator is able to better understand the nature of a problem and the efficacy of a solution.

Modeling provides a complementary process to design. Design methods provide iterative processes for reducing uncertainty in a search space by allowing for rapid development/test cycles geared at increasing information. These cycles, however, benefit significantly from models when considering the nature of design. Of many directions that a design can take, which is the most effective? By modeling systems, behaviors, and outcomes, the innovator is better equipped to make decisions. Furthermore, models support reasoning about data collected during test phases in design, and provide a repeatable and quantifiable way to measure progress and make information-driven decisions. This is particularly the case early in the design process when direct outcomes are difficult to observe. Models provide a framework in which designs can be evaluated through the development of actionable information in the face of a human-centered opportunity.

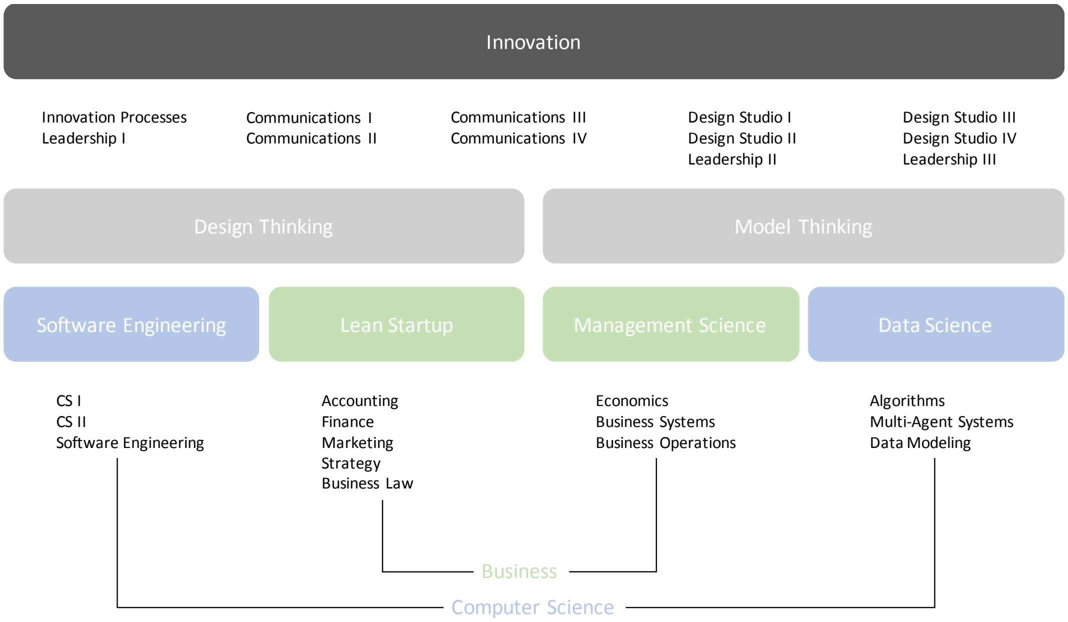
Models exist in all domains, including engineering, as part of the analysis and design lifecycle. A singular domain-driven approach to modeling, however, is insufficient in the context of human-centered approaches to problem solving. The design search space is characterized by uncertainty, but also by complexity (Norman 2010). Insights, estimations, and predictions about such a space are improved with a diversity of independent models. In a complex system, unexpected behaviors can occur, such as tipping points and self-organization. Using multiple models—perhaps from different disciplines—allows the innovator to gain better insights from observations.

The Raikes School

Our approach to the development of I&E programs leverages the institutional structure of the university to deliver interdisciplinary content in an innovation context using integrating themes. This approach allows developed I&E programs to more easily integrate with existing programs and into existing academic structures. As an example of such a program, we present the Jeffrey S. Raikes School at the University of Nebraska – Lincoln. The Raikes School is an interdisciplinary program that sits between the Colleges of Arts and Sciences and Business Administration to develop high-ability students into innovators using computer science (technology) and management (business). Our perspective has been not to focus on the adoption of innovation processes but to focus on the academic foundations of innovation, especially on the innovation process as technological development and on insights gained from uncertainty. In this capacity, we leverage the study of computer science and management to achieve objectives outside of the normal realm of either discipline.

The challenge that ultimately influenced our model for integration was not to teach electives or certificates, but to bring innovation and entrepreneurship themes and topics to the core of a computer science and business education curriculum for which traditional credit is awarded. The Raikes School does not offer a degree, major, or minor. Our program integrates with various engineering and business programs of study to replace a core curriculum within a major and offer a minor in computer science and business. In this way, we are able to modify but not redirect the core curriculum, offering the benefits of a distinct I&E program in a credit-hour-neutral way. The result is an undergraduate curriculum that integrates with the existing and distinct computer science and management programs to provide an innovation-focused education.

The academic model for the Raikes School is characterized by three core components: cross-listed sections of core courses based on co-curricular design; an interdisciplinary teaching faculty to coordinate curriculum



and work with faculty from partner academic units; and the use of the integrating themes of design and model thinking to create pedagogical connections between courses over four years. In addition to core academic components, the Raikes School employs a learning community model, with undergraduate students matriculating through the program in cohorts in common residence. Each of these components works with the other to provide a unique learning environment fostering innovation through culture, traditional and applied academics, and experiential learning.

Curriculum

To design courses in the Raikes School, we partition the core disciplines of computer science and management into four topic areas that support training I&E skill sets and align with our integrating themes. Courses in the Raikes School provide formal academic instruction in software engineering, data science, lean startup, and management science. The software engineering and data science courses represent design and model thinking respectively in computer science, with lean startup and management science representing design and model thinking management. These core disciplines are then supported by innovation-themed courses teaching communications, leadership, and process. The curriculum is completed with a two-year capstone sequence to provide an experiential application of innovation skills in solving a real-world problem.

Computer science courses focus on applied computing methods and software engineering, while the business courses have a dual focus on data analytics and machine learning – valuable when extensive data are available, but little realized information or knowledge, and a focus on startups for which little data exists and thus information and knowledge are developed iteratively. Exploiting applied computing skills on the business side, coursework introduces data analytics and machine learning in business scenarios, where there exist significant volumes of data and innovation processes to develop data and insight where little is associated with innovation and startups. In each course, students are asked to develop and present solutions using tools and techniques found in the business and software development world. It is commonplace to see the use of the R language augmented by knitr (Yihui n.d.) to communicate results and share insights.

The Raikes School curriculum is characterized by the projects that link computer science and business courses each semester. These projects provide an opportunity for students to apply what is learned in the classroom in an integrated context, allowing them to see firsthand how business and computer science topics work together to create innovative outcomes. Each semester project requires students to demonstrate strong communication and leadership skills, as well as to utilize design and model thinking to define and understand a problem and develop a deliver a solution. Coursework introduces students to various design processes ranging from lean startup to agile software development, processes that students use to complete projects.

Students matriculate through the program in a cohort, entering as first-year students and working closely with their peers over four years. This model allows each successive semester to build on the previous, and supports higher-value add projects. Projects for each semester are typically sponsored by a community or industry partner and request the students to implement solutions to problems using design methodologies and insights gained through modeling complex behaviors and systems. For example, students in the second year software engineering course (which is taught parallel to business systems) are asked to build a web-based analytics dashboard for Spreetail, a local e-commerce company. Project teams are given real data sets and asked to create forecast models using Monte Carlo simulations, improve ordering decisions using inventory theory, develop new customer service strategies using machine learning techniques, and identify optimal distribution polies using network graphs. They work with potential users of the system to understand how these analyses impact decisions in the business. Based on this understanding, teams develop software systems that allow encapsulated simple usage models to deliver robust insights from data through analysis and visualization.

Integrated project course work focused on customer-driven solution development prepares students to participate in the capstone program, Design Studio, in their last two years. In Design Studio, students participate in a year-long software development project focused on the design, development, and delivery of a solution for a sponsoring industry partner. Over its fifteen-year history, student teams in Design Studio have completed 166 projects for 69 unique industry partners including IBM, Microsoft, JB Hunt, Mutual of Omaha, Hudl, Box, and PayPal. Teams are self organized, with second-year Design Studio students—Raikes School seniors—playing leadership roles. Over the course of two academic semesters, teams will use an agile process to deliver products to sponsors six times. Our release-driven approach to software development not only focuses teams on high value solutions, but also gives them the unique opportunity to experience the trade-off between new feature development and responding to actual user needs. Many projects go into production by the third release, and all of the teams deliver a final, production-ready solution by the end of the year.

Upon graduation from the Raikes School, alumni will enter the workforce two years ahead of peers, having used their unique knowledge of computer science and management to successfully deliver real products to real customers twice while they are undergraduates. More importantly, alumni have been transformed into innovators who understand how to utilize computer science and management, integrated through a deep understanding of models and design, to bring to market new and revolutionary solutions to some of the most complex problems facing industries today.

Conclusions

Like many other university programs, the Raikes School at the University of Nebraska – Lincoln has endeavored to develop an innovation and entrepreneurship learning experience for its students while satisfying core requirements for a number of degree programs, including computer science and business. The approach has been to combine computer science and business education to create an innovation context using:

- Model and design thinking as integrating themes.
- Project-based curricula that focus on blended computer science and management.
- A focus on leadership and communications as supporting concepts.
- Fostering a strong culture through a learning community and cohort model.
- A residential faculty to coordinate the curriculum and the external faculty to achieve the objective.
- A comprehensive two-year capstone experience.

How has success to this point been assessed? Student outcomes have been significant, including not only the placement of students in nationally competitive positions, but the ability to attract top student talent generally reserved by the nation's most prestigious programs. During the most recent academic year, the average ACT of a student in the Raikes School was 34; third quartile 35. Additionally, industry support has been excellent, with well-funded student projects, oversubscribed recruiting efforts, and a growing interest on campus for expansion and to repeat the model in other academic applications.

The primary driver for these accomplishments has been the success seen in incorporating innovation as a core concept realized by the application of disciplinary concepts in a truly interdisciplinary, co-curricular model. We believe that this can serve as a model for other institutions struggling to incorporate new I&E programs into existing academic units to help them ultimately overcome the inertia found in institutional structures and realize the significant benefits innovation can offer higher education.

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