AC 2012-5418: AN ADVENTURE IN EXTREME CURRICULUM INTEGRATION TO STIMULATE INNOVATION AND COLLABORATION

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Ronald G. Kander is Executive Dean of the College of Design, Engineering, and Commerce at Philadelphia University. His current teaching and research interests are in the areas of design processes, materials selection, engineering education, and composites. He received a B.S. in chemical engineering from Carnegie Mellon University in 1980 and a Ph.D. in chemical engineering from the University of Delaware in 1987. Before becoming Executive Dean at Philadelphia University in 2011, Kander was Director of the School of Engineering at James Madison University (JMU), where his teaching and research interests were in the area of polymer processing, manufacturability, and rapid prototyping/tooling technologies. Kander was also Department Head of Integrated Science & Technology (ISAT) at JMU and a faculty member in the Materials Science & Engineering Department (MSE) at Virginia Tech (VT). While at VT, he was also Director of the College of Engineering's interdisciplinary "Green Engineering" program. Before joining academia, he was employed by the DuPont Company as a Senior Engineer in the Advanced Composites Division of the Fibers Department and in the Polymer Physics Group of the Central Research Department. Kander has taught a wide range of courses. At Philadelphia University, he will be teaching a freshman Integrated Design Processes course and a sophomore Materials Selection and Design course. At JMU, he taught a freshman seminar class to incoming ISAT and engineering majors, a sophomore Instrumentation and Measurement class, a junior Materials & Mechanics course, and a graduate Modeling and Simulation class. He also designed and taught two interdisciplinary, university-wide honors classes. One entitled "Gdel, Escher, Bach" is based on the 1979 Pulitzer Prize winning book by Douglas Hofstadter, and the other is entitled "Aesthetics of Visualizing Information," which was co-taught by Professor Kander (an engineer) and Professor Chad Curtis (a sculptor in the Department of Art and Art History). In this course, students analyzed and interpreted a variety of images and data visualizations (artistic, scientific, and others), examined the interface between scientific and artistic representation, and explored the idea of convergence between artistic and scientific representations. At VT, he taught several sections each of a freshman Engineering Fundamentals course, a freshman Materials in Our World course, a sophomore Elements of Materials Engineering course, a sophomore Analytical Methods course, a sophomore Environmental Life Cycle Assessment course, a senior/graduate Polymer Engineering course and it's associated Polymer Engineering lab, a graduate Polymer Deformation and Fracture course, and a graduate Engineering Mathematics course. While at VT, he received several awards for teaching excellence, including the 1993 College of Engineering Sporn Award, the 1997 Dean's Teaching Award, and the 1998 William E. Wine Award. He was also inducted into the Virginia Tech Academy of Teaching Excellence in 1998 and named a Diggs Teaching Scholar in 1999. Kander has supervised more than 30 graduate students (Ph.D. and M.S.); published more than 50 articles, book chapters, and refereed conference papers; and presented more than 75 invited lectures and conference presentations (including two invited Gordon Conference presentations). According to the Scopus Citation Index, his work has been cited more than 200 times. Kander has secured in excess of $6 million in funded research, approximately half of which was from industrial sources. In addition to his administrative, academic teaching, and research responsibilities, he is also active in industrial consulting and in teaching industry short courses.

An Adventure in Extreme Curriculum Integration To Stimulate Innovation and Collaboration

1. Introduction

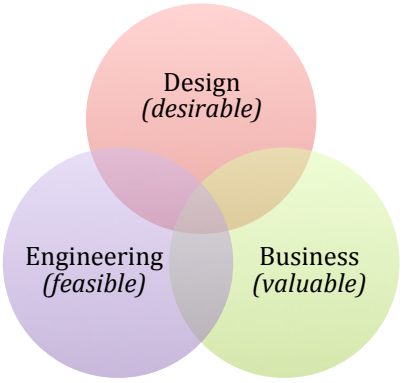
Looking back across the history of science, technology, engineering and math (STEM) education, there have been nearly continuous calls for curriculum innovation and improvement. In the past 20 years, however, many of these calls have intensified and focused on the incorporation of interdisciplinary, problem-based, "real-world" learning in one form or another. These range from more general reports like those coming from the Boyer Commission[1] in the late 1990's, to specific work that led to the restructuring of the ABET accreditation process through EC2000[2]. More recently, publications by the National Academy of Engineering such as "The Engineer of 2020"[3] and "Educating the Engineer of 2020"[4] have reenergized the call for innovation in STEM curricula.

Philadelphia University is a small, private university with a long tradition of professional technical education and an emerging focus on innovation and interdisciplinary education. The newly formed College of Design, Engineering and Commerce (C-DEC) at Philadelphia University is the home to a revolutionary, interdisciplinary curriculum that responds to the call for innovation in STEM curricula by retaining the core learning of the three disciplines within the college (design, engineering, and business) while forging collaborations between the disciplines.

2. Integrated Organizational Structure

Philadelphia University formed C-DEC in November of 2010. In the formation of this new college, the university combined the School of Design, the School of Engineering and the School of Business to form an exciting new academic unit that focuses on teaching innovation, collaboration and leadership in the context of a student's individual major in one of these three disciplines.

If you think about innovative products and services, and the innovation process itself, it really comes down to envisioning products and services that are *desirable*, *feasible* and *valuable*. The disciplines of design (*desirable*), engineering (*feasible*) and business (*valuable*) uniquely come together to address all three of these attributes. Therefore, teams of experts from these three fields of inquiry are uniquely qualified to drive the process of innovation if they are properly educated to work together effectively and efficiently in interdisciplinary teams.

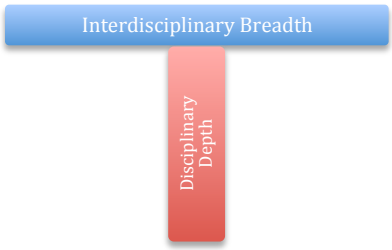


This is the ultimate vision of C-DEC: to produce graduates that have deep disciplinary training in one of the design, engineering or business fields combined with deep appreciation and understanding of the power of interdisciplinary teams and the ability to collaborate and innovate in order to develop the next generation of products, processes and services to address global human needs.

There are 16 different undergraduate majors in C-DEC, along with 8 graduate programs (listed below). C-DEC educates more than 1,500 students (more than half of the university's student body) and has a faculty of over 125 full-time and part-time professors and instructors, many of which are also practicing professionals in their fields. The professional majors range from engineering and industrial design, through graphics, animation and interactive design, to a host of textiles, fashion and business majors.

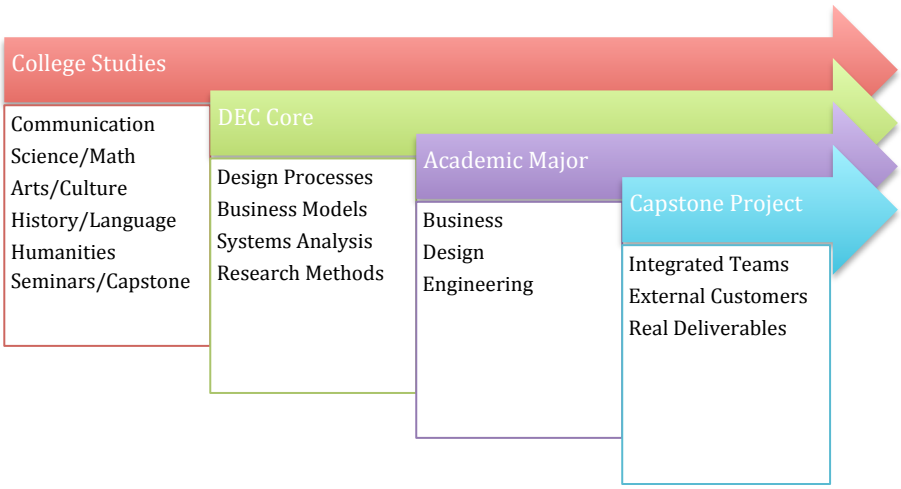
College of Design Engineering and Commerce BS/MS/PhD Degree Programs		
BS Mechanical Engineering	BS Accounting	PhD Textile Engineering & Science
BS Engineering	BS International Business	MS Textile Engineering
BS Industrial Design	BS Finance	MS Industrial Design
BS Interactive Design & Media	BS Management	MS Interactive Design & Media
BS Graphic Design Communication	BS Marketing	Master of Business Administration
BS Digital Animation	BS Fashion Industry Management	MS Taxation
BS Textile Design	BS Fashion Merchandising	MS Textile Design
BS Fashion Design	BS Textile Materials Technology	MS Fashion Apparel Studies

One thing all of these majors have in common in preparing for the 21st century job market is the need to develop deep disciplinary professional expertise while also developing an understanding and appreciation of the other disciplines in order to be innovative, creative leaders in their fields. In short, they need a "T-shaped" education that gives them a balance of disciplinary depth and interdisciplinary breadth. After all, given the rate of change of industry (and society at large), the college is actually preparing students for jobs and careers that probably don't even exist yet. So, while a deep disciplinary understanding in one's major will help a student secure their first job; creativity, critical thinking, problem solving and lifelong learning skills will help them secure their career.



3. Integrated Curriculum

The new C-DEC curriculum accomplishes this through four primary elements that combine to balance disciplinary depth with interdisciplinary breadth to form that "T-shaped" education mentioned earlier. These four elements are represented schematically at the top of the next page and then briefly described.



First, College Studies is the portion of the general education curriculum that every student at Philadelphia University takes. It gives students a broad exposure to the liberal arts and humanities, while honing their critical thinking, information literacy, and written and oral communication skills. This is a critical component in becoming a successful leader in one's discipline and becoming an effective member of an interdisciplinary team. Unlike programs at many universities, the College Studies curriculum is distributed over the entire four years of the undergraduate degree experience and includes the opportunity to take upper level courses. There is also a requirement to complete a capstone College Studies project in order to integrate and apply one's learning (this is in addition to the requirement of a C-DEC Capstone Project).

Next, there are four required C-DEC core courses that, combined with a C-DEC Capstone Project, make up an 18-credit common curriculum that every student in every C-DEC major must take. The four core courses, which are spread over a student's first three years, are: a "Design Processes" course, a "Business Models" course, a "Systems Analysis" course, and a "Research Methods" course. These four core courses (and the Capstone Project course) are described in more detail later.

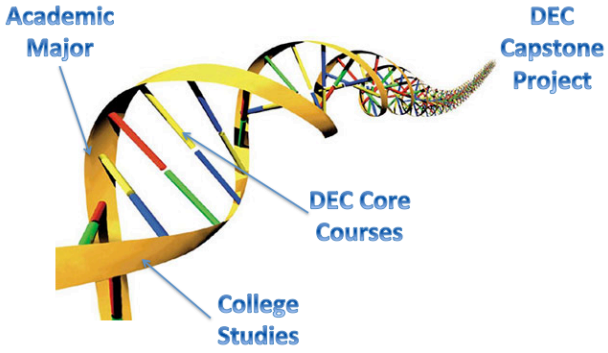
The next part of the C-DEC curriculum is a student's academic major. This is where a student develops the disciplinary depth necessary to be successful in a chosen field of study. This is an absolute necessity in that a professional cannot contribute effectively on an interdisciplinary team if they do not bring the skills and knowledge associated with their specific discipline to the team. This is the point in the curriculum where the student takes a "deep dive" into courses in their specific design, engineering or business major. In the case of the relatively new Engineering programs, Philadelphia University has a BS Mechanical Engineering degree program and a BS Engineering degree program. The latter, more general, program has "career pathways" in Architectural, Composites, Industrial and Textiles Engineering. These undergraduate programs received ABET accreditation in 2011. In addition, there is an MS and a PhD degree program in Textile Engineering.

Finally, the Capstone Project is where the college core curriculum culminates in a six-credit capstone experience in which C-DEC students are brought together in interdisciplinary teams (chosen from majors across the entire college), with one or more faculty advisors, to work on a real-world problem for a real external customer with the expectation of delivering real solutions. Recent projects have been completed for companies such as Federal Mogul, QVC, DuPont, and many other local, national and international companies. In addition, projects have also been completed for non-profit organizations and government agencies.

4. C-DEC Core

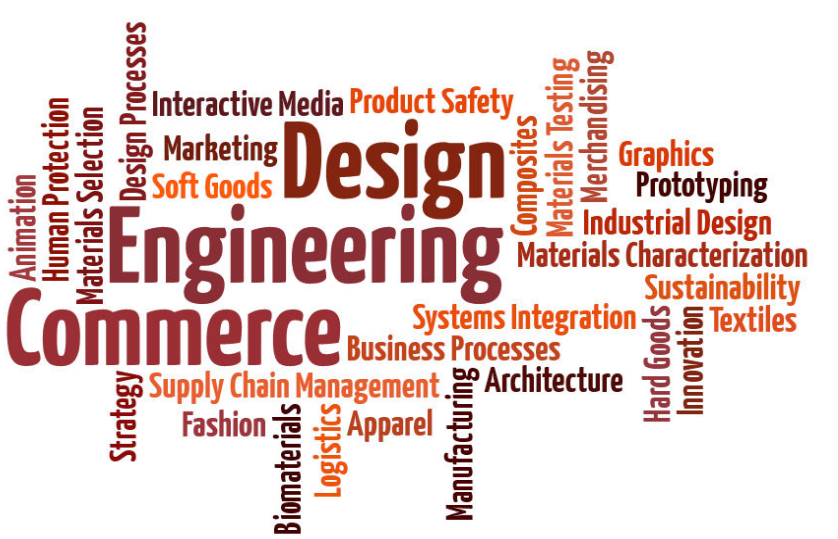
The four C-DEC core courses and the Capstone Project work together as a five-course sequence to give students a distinct competitive advantage when they compete for their first job or for a position in a professional graduate program. These five courses help the student answer five key questions about themselves. The Design Processes course asks the question: *How do I discover opportunities?* This course helps a student understand their own creative processes and how to unleash them through design thinking. Next the Business Models course asks the question: *How do I create value?* Where the word *value* is taken in the broadest sense. "Creating value" can mean making money, generating recognition, stimulating happiness, solving social problems, helping disadvantaged people, etc. Next, the Systems Analysis course asks the question: *How do I deal with complexity?* This is an important question because real, important problems are always complicated. This course allows students to recognize and appreciate the emergent properties that evolve from real complex systems. The Research Methods course asks the question: *How do I ask the right questions?* Another way to ask this is: *How do I gather the right information?* In today's world of information overload, the ability to properly gather, analyze and critically think about the right information is paramount. Finally, the Capstone Project course asks the question: *How do I put it all together to solve real-world problems?*

Five courses, 18 credits, and five reflective questions: *How do I discover opportunities? How do I create value? How do I deal with complexity? How do I ask the right questions? How do I put it all together?* Imagine if a student leaves college with deep disciplinary knowledge in their major combined with the ability to reflectively answer these five questions about themselves. Such a student has a distinct competitive advantage in the workplace, and also has what it takes to be a transformative leader in their chosen profession.



These elements all come together to form the C-DEC curriculum's "DNA". Picture a spiraling DNA double helix. One leg of the DNA spiral is the College Studies curriculum spiraling through a student's four-year curriculum. Simultaneously, a student will take in-depth courses in their major (the other leg of the DNA spiral). Linking these two "strands" together are the four C-DEC core courses, which supply periodic links between these two spiraling strands (like the base pairs linking the two legs of a DNA strand). These elements all spiral forward, together, through a four-year curriculum that culminates in the C-DEC Capstone Project.

Because of the interdisciplinary nature of the curriculum, and the vast expertise of the faculty project advisors, the technical areas for the Capstone Projects can vary widely: ranging from design, animation and graphics; to human protection, fashion, and supply chain management; to engineering, composites, sustainability, and business processes. The following image illustrates just a small sampling of the topics a student can choose from for their yearlong capstone project. Remember, these projects are done for customers from local, national and international companies, non-profit organizations and government agencies under the guidance of faculty advisors with experience in professional practice.



5. Engineering Outcomes and Assessment

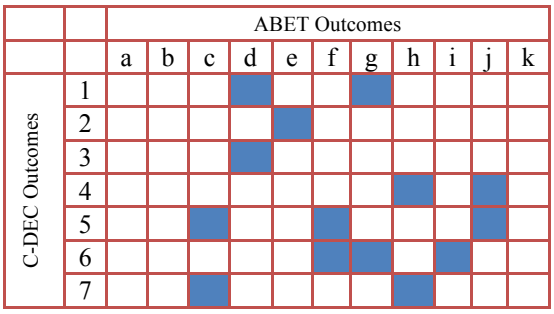
The new college and its interdisciplinary core curriculum is particularly important for the engineering programs within C-DEC. Engineering students gain important critical thinking, problem solving, collaboration and communication skills that are essential to their development as practicing engineers and leaders in their professions. Furthermore, as ABET accreditation standards focus more and more on the assessment of measurable learning outcomes, the C-DEC core curriculum provides an opportunity for the engineering programs within the college to address and assess, in part, student learning in a wide range of areas that are relevant to the ABET "a-k" learning outcomes (ABET's "Criteria 3: Student Outcomes"[5]). Specifically, students completing the five-course C-DEC core curriculum are assessed by the college to determine if they attain the following seven core learning outcomes.

1. An ability to collaborate on multidisciplinary teams
2. An ability to describe the value of different problem solving and decision making styles
3. An ability to identify the unique contributions and limitations of specific disciplinary perspectives
4. An ability to gather insights from people, their behaviors, and their cultural practices
5. An ability to evaluate the ways in which natural and man-made systems (technical, political, social, cultural, economic, etc.) shape, and are influenced by, new products, process and services
6. An ability to adapt behavior in response to continually changing professional challenges
7. An ability to integrate knowledge in new ways in order to find new opportunities and create new value

Recall that the 2012-2013 ABET Student Outcomes[5] are:

a. An ability to apply knowledge of mathematics, science, and engineering
b. An ability to design and conduct experiments, as well as to analyze and interpret data
c. An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d. An ability to function on multidisciplinary teams
e. An ability to identify, formulate, and solve engineering problems
f. An understanding of professional and ethical responsibility
g. An ability to communicate effectively
h. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i. A recognition of the need for, and an ability to engage in life-long learning
j. A knowledge of contemporary issues
k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

A comparison of these two lists of learning outcome reveals a significant overlap. This overlap is best seen graphically, at the top of the next page. Note that more that 70% (eight of eleven) of the ABET outcomes are addressed, in part, by the C-DEC core curriculum.



Assessment instruments have been developed specifically for the C-DEC core curriculum by the university's Office of Institutional Research, and are being deployed at the college level in each core course, and holistically to the entire C-DEC student body, on an annual basis. These instruments track the attainment of each of the seven learning outcomes, longitudinally, through each student's four-year curriculum. These instruments also measure the development of 24 specific student behaviors that are positively correlated with attainment of the learning outcomes. These 24 student behaviors are listed below.

24 Student Behaviors Measured in Longitudinal Assessment Instrument

Work on a class project or assignment in a student team.
Act as team manager or leader for course team projects or assignments.
Participate on a team in the role of coordinator.
Participate on a team in the role of researcher.
Participate on a team in the role of facilitator.
Use observations, research and the ideas of other students to help complete an assignment.
Apply material learned in one course to other courses in your program.
Change your approach to a problem based on the input of others from different disciplines.
Discuss course assignments, problems, or projects with students from different disciplines.
Compare and contrast at least two strategies from different disciplines to solve a complex assignment.
Work on a course assignment that requires integrating ideas from different disciplines and sources.
Seek ideas from people from different disciplines to help complete an assignment.
Mediate opposing views among team members.
Work as a group to develop consensus.
Measure the impact of a proposed solution on other systems.
Change your proposed solution due to impacts on other systems.
Change your approach to a problem based on unforeseen circumstances.
Change your approach to a problem based on the type and context of the problem.
Consider that solutions have multiple impacts.
Recognize that changes in one area impact other areas of inquiry.
Develop realistic and practical solutions to classroom assignments.
Credit others from different disciplines when completing classroom assignments.
Change your solution to a problem to address the requirement of an external stakeholder.
Consult with others outside of the project team before making a decision.

Preliminary assessment results were obtained by surveying the 167 freshmen that took the first C-DEC core course (Design Processes) during the fall of 2011. (This is approximately half of the total freshman C-DEC class, as the other half of the freshman class took the course during the spring of 2012.) The survey response rate was greater than 65%. Results showed a strong correlation between frequency of performing the 24 behaviors and attainment of the seven student learning outcomes. For example, Pearson correlation coefficients above 0.4 were

obtained for 65 specific pairings of behaviors and learning outcomes, with several correlation coefficients greater than 0.5 reported. Since there are 168 possible behavior/outcome pairings, this means that more than 38% of the possible pairings are significantly correlated. Ten of the behaviors strongly correlated with a majority of the seven desired learning outcomes, and are therefore considered "key behaviors" to reinforce during in-class activities, assignments, and projects in all of the C-DEC core courses. These key behaviors are listed below.

Top 10 Student Behaviors That Strongly Correlated With Multiple Learning Outcomes

(Number in parentheses indicates the number of different outcomes each behavior strongly correlated with.)

Work on a class project or assignment in a student team. *(4)*
Use observations, research and the ideas of other students to help complete an assignment. *(6)*
Apply material learned in one course to other courses in your program. *(6)*
Compare and contrast at least two strategies from different disciplines to solve a complex assignment. *(4)*
Work on a course assignment that requires integrating ideas from different disciplines and sources. *(6)*
Seek ideas from people from different disciplines to help complete an assignment. *(4)*
Change your approach to a problem based on the type and context of the problem. *(4)*
Consider that solutions have multiple impacts. *(7)*
Recognize that changes in one area impact other areas of inquiry. *(4)*
Develop realistic and practical solutions to classroom assignments. *(6)*

Self-reported attainment percentages for the seven learning outcomes were also measured and showed significant development after the first core course (see table below). Note that 33% of the students reported "high attainment" of the outcomes, on average, and 43% reported "moderate attainment". Since this assessment instrument will be administered to all C-DEC students every year, it will be interesting and informative to watch the (presumed) upward trending of these percentages toward "high attainment" as a student progresses through the five-course sequence. In the future, we will be developing correlations between these self-reported data and direct measures of student performance (i.e., measured performance on specific assignments and projects throughout the core curriculum, portfolios of student work, alumni performance in the workplace, etc.).

Self Reported Learning Outcome Attainment Percentages	*Degree of Attainment*			
	High	*Moderate*	*Slight*	*None*
Collaborate on multidisciplinary teams	38 %	42 %	18 %	2 %
Describe the value of different problem solving and decision making styles	34 %	46 %	18 %	2 %
Identify the unique contributions and limitations of specific disciplinary perspectives	28 %	44 %	25 %	3 %
Gather insights from people, their behaviors, and their cultural practices	44 %	34 %	18 %	4 %
Evaluate the ways in which natural and man-made systems (technical, political, social, cultural, economic, etc.) shape, and are influenced by, new products, process and services	30 %	44 %	20 %	6 %
Adapt behavior in response to continually changing professional challenges	24 %	51 %	20 %	5 %
Integrate knowledge in new ways in order to find new opportunities and create new value	36 %	42 %	17 %	5 %
Average Degree of Attainment	*33 %*	*43 %*	*19 %*	*4 %*

Direct evidence of the impact of the first C-DEC core course was also obtained by monitoring the half of the freshman class that completed the first core course in the fall semester and measuring their performance in subsequent classes in their major. This performance was compared with the other half of the freshmen class that had not yet completed the first core course. For example, second semester freshman Industrial Design students participated in a one-week industry-sponsored "design sprint" project in which they were places in teams with upper class students and asked to solve an industry-provided design problem in one week and present their results to an industry sponsor. Faculty, industry, and peer evaluations of freshman performance on these "sprint teams" showed a distinct and significant improvement in performance for the freshmen that had already completed the first C-DEC core course as compared with the freshmen that had not yet completed the first core course.

Results from these and other similar assessment instruments will be invaluable for the continuous improvement of the engineering programs in our college, and will better prepare them for the next ABET accreditation cycle starting in 2016.

6. Summary

In summary, as a model for professional university education in the 21st century, Philadelphia University's College of Design, Engineering and Commerce is focused on providing graduates with the skills necessary to be leaders in their professions at every level of their careers. By bringing these three disciplines together (design, engineering, and business), the new College will push students to think beyond the boundaries of existing disciplines and focus on market-driven innovation through teamwork, collaboration and connections with industry partners.

Students will gain expertise in their disciplines and a fluency in the interdisciplinary ways of the 21st-century work world on a much larger scale than what has been seen in higher education to date. The new College is a forward-thinking and timely concept because it combines the best aspects of these three disciplines to focus on innovation and entrepreneurship. This is happening at a time when innovation is universally recognized as a critical element in global economic recovery, as well as in solving today's complex, world-scale "grand challenge" problems.

This exciting new college is being strongly and actively supported by Philadelphia University in ways ranging from the hiring of new interdisciplinary faculty; to the recruiting of a new generation of students who are interested in innovation, collaboration and leadership experiences; to the building and equipping of new labs and studios. In fact, Philadelphia University is in the process of building a brand new building to house the key activities of the new college. This exciting 40,000 square-foot building will be in the center of campus, and will house new studios and classrooms, new prototyping spaces, and a range of new collaborative workspaces for students and faculty to work on real-world projects for external customers. It will be an amazing collaborative workspace, and will be ready for occupancy in late 2012.

So, the adventure in extreme curriculum integration to stimulate innovation and collaboration has begun at Philadelphia University, and initial assessments indicate that it is working extremely well. However, the real proof will be when the inaugural graduating class of the College of Design, Engineering, and Commerce begin their careers in 2015 as entrepreneurs and leaders of innovation, doing amazing things in their chosen fields.

An architectural rendering of the new DEC Center building along with a construction camera shot taken March 14, 2012.

Inaugural C-DEC freshman class at opening orientation meeting (August 19, 2011)

7. Bibliography

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