AC 2007-2793: CREATIVITY AND INNOVATION: CORE CAPABILITIES FOR 6 - 12 ENGINEERING TEACHERS

John Hansen, The University of Texas-Tyler

John W. Hansen is a Professor of Technology at The University of Texas at Tyler. He is the Founder and Executive Director of the Ingenuity Center. The mission of the Ingenuity Center is to enhance the understanding of technological activity in individuals and organizations and to conduct research on the understanding of a technologically literate and creative citizenry. A graduate of the University of Minnesota, Dr. Hansen is active in developing the standards and instructional resources required to support the development of a technologically literate and innovative workforce. He has administered over $3.5 million in grants and contracts and is recognized by the International Technology Education Association as a Distinguished Technology Educator.

Creativity and Innovation:
Core Capabilities for 6 – 12 Engineering Teachers

Postsecondary engineering programs seek students that are prepared, capable, diverse, and informed about the creative field known as engineering. In order to achieve these goals, it is critical that the education of 6 – 12 engineering teachers be "reengineered" to reflect the core capabilities of creativity and innovation rather than the traditional focus on discipline specific knowledge. The Education for Teaching Innovation, Design, and Engineering (ETIDE) program proposes a creativity and innovation-based program that utilizes design and technological literacy as the core elements for teacher preparation. The ETIDE program focuses on developing well-prepared innovation, design, and engineering teachers for 6 – 12 programs and classrooms. Current teacher preparation programs focus on project-based learning, more mathematics and science, or teaching the engineering common body of knowledge. Negligible attention is paid to the development of students' creativity and innovation capabilities. The ETIDE program organizes program content around the following courses; (1) Introduction to 3D Design and Modeling, (2) The Designed World, (3) Systems of Technology, (4) Communications in Technology, (5) Artificial Science, (6) Control Systems, (7) Invention, Innovation, and Design, (8) Industrial Design, (9) Prototyping and Simulation, (10) Human-Centered Design, (11) Technological Research and Development, (12) Teaching Skills for Design and Innovation, and (11) Design and Innovation Studio.

Scene: *The Time Machine*, by H.G. Wells, directed by George Pal (1960).

George, the scientist and time traveler, returns from the future and has explained to his friends the battle between the Eloi and the Morlocks. Failing to convince them, George returns to the future in the time machine, and ...

David, George's friend: *It's not like George to return empty-handed. To try to rebuild a civilization without a plan.*

David: *He must have taken something with him.*

Housekeeper: *Nothing…. Except three books.*

David: *Which three books?*

Housekeeper: *I don't know. Is it important?*

David: *I suppose not. Only……which three would you have taken?*

This scene from *The Time Machine* captures the essence of education, and in particular, teacher education. Our goal, as teachers and teacher educators, is to build civilizations. The question we continually ask is: "What knowledge merits inclusion in our plans to build new worlds, new civilizations, and new tomorrows?" As it relates to engineering we should ask, what engineering knowledge do we consider robust; essential across time, geography, culture, and discipline and ought to be included in 6 – 12 engineering education. Specifically, we might ask, what should teacher education programs concentrate on to prepare teachers who will be able to guide students into design-based, creative professions, such as engineering? The author's suggestion is that the most essential component of 6 – 12 engineering education must be the development of imagination, innovation, inventiveness, and ingenuity capabilities.

The purpose of this paper is to suggest that the hypothetical courses listed in Table 1 would provide a radically better organizational and pedagogical structure for educating 6 – 12 innovation, design, and engineering teachers. This program challenges the prevalent conceptualization that engineering is exclusively focused on the application of mathematics and science to solve problems and that the best way to prepare future engineers is to provide them with *MORE* mathematics and science, while excluding the imaginative and creative capabilities of our children.

In addition, the author postulates that a focus on the creative elements of design, innovation, and engineering education may help students persist through postsecondary engineering programs. This program of study is in contrast to the relatively few pre-service engineering teacher preparation programs, which typically represent adaptations of traditional technology education teacher preparation programs. Traditional technology education programs continue to focus on learning material processing, tool use, and project-based activities directed at making things (Custer and Wright, 2002; Lewis, 2005) and neglect the creative elements associated with inventing, innovating, and designing.

Rigby and Harrell (2005) suggest that there is an accepted understanding of "pre-engineering concepts" that should be taught at the secondary level, however, the details of these concepts are not provided. They also state, as a goal of their program, increasing and enhancing "…awareness of the field of engineering among high school students, develop problem solving skills and critical thinking, and increase hands on experience with real world problems" (p. 27). These goals are typical of most projects directed at increasing the interest of children in engineering. Scant mention is ever made of developing the imaginative and creativity abilities of children and, specifically, how to prepare teachers for these tasks.

Although many would suggest that the best preparation for 6 – 12 engineering teachers would be an engineering degree supplemented with a pedagogical professional development program, the author suggests that this strategy would result in a program that focuses on a particular field of engineering rather than the universal and enduring concepts that should be developed prior to a student entering a postsecondary engineering program. In particular, it is suggested that neither the current pre-service "pseudo" engineering programs (i.e. technology education) nor the "engineer-to-teacher" model would address the need to create a more imaginative and inventive engineering workforce. The intense interest in Science, Technology, Engineering, and Mathematics (STEM) education has created a significant number of student-based, informal education 6 – 12 programs seeking to increase a student's interest and awareness in engineering (Rigby and Harrell, 2005) and few, if any, initiatives at the postsecondary level for preparing teachers to teach 6 – 12 engineering. A notable exception is the collaboration between Project Lead The Way and Purdue University. This PLTW model relies on the existing structure of the Technology Education certification program and incorporates the contents of the PLTW curriculum into its existing courses. The structure of the program is quite similar to the decades old technology education model, which is based on the career areas of construction/architecture, communications, computers, energy/power/transportation, and manufacturing. Graduates of this program are "authorized" to teach PLTW courses without having to complete a PLTW summer training program for the courses they intend to teach.

In addition, the interpretation of the core concepts of engineering is determined by the course developer's orientation to engineering. A manufacturing engineer will tend to believe that an understanding of computer-integrated-manufacturing is more important than heat and mass transfer calculations, or vice-versa. An aerospace engineer would believe that aerodynamics is more important than computational algorithms developed and used by a software engineer. It is clear that an emphasis on a particular arena/discipline of engineering, *at the middle and high school level*, might be inappropriate and could contribute to the poor retention rate of freshman engineering students. Shuman, Delaney, Wolfe, Scaliese, and Besterfield-Sacre (1999) study suggests that although approximately 25% of their freshman attrition could be attributed to poor academic performance in mathematics and science, another 25% was attributed to the loss of interest in the engineering professions by the students. Addressing the application of creativity and imagination to real problems might help address this latter problem as well as creating a reason for "enduring" the mathematics and science education required for an engineering degree.

The conceptual model for this degree plan is based on the elements of the majority of undergraduate education-focused degrees (Custer and Wright, 2002), (1) a general education formation (which is mandated by each state, with local variations, (2) a pedagogical component (which is required by state departments of educator preparation, (3) content specific components of the discipline (i.e. engineering and technology), and (4) the pedagogical components needed to teach the content. The section reported in this paper is the content specific components of engineering and technology that specifically relates to the generalized foundational concepts that would be sufficient to ground a student in the development of their imagination, invention, innovation, and ingenuity capabilities as prerequisites for careers involving design thinking.

This program model is based on a 120-semester credit hour (SCH) program (new state requirements) designed to prepare pre-service teachers to teach the robust components of engineering and technology, develop their professional pedagogy, and meet the state's general education requirements for undergraduate students. The innovation, design, and engineering content area represents 42 SCH, 47 SCH of general education, 21 SCH of teaching professional development, and 10 SCH of mathematics and science elective courses. Students are required to take algebra, trigonometry, statistics, and calculus. In addition, completion of chemistry, physics, and a science elective is required.

The genesis of this program began as the author developed the STEM career cluster for the state of Texas (Hull, 2006; www.careerclusters.org; www.AchieveTexas.org). The process for developing the engineering and technology career pathway involved intense reflection on the uniqueness of engineering and technology as a career pathway in the STEM career cluster. Career clusters, developed by a national collaborative effort, are designed to assist students prepare for future careers. The career clusters categorize careers into 16 clusters and over 100 pathways.

As the analysis of the career clusters progressed, it was clear that the conceptualization of the clusters was not well thought out. The STEM career cluster includes the conceptual area of "technology," however; technology-based careers are also included in many of the other 15 career clusters (e.g. manufacturing, transportation, information technology). Students seeking to pursue a career in manufacturing, for example, would pursue a pathway identified in the manufacturing career cluster not in STEM. Yet, how does one prepare for a career in manufacturing engineering that would be different from what a student should study to become a machinist or a quality assurance technician. The essential questions became, what is unique about the engineering and technology pathway in the STEM career cluster? What is it that should be included in a student's preparation for an engineering career prior to the start of their postsecondary studies? What separates engineering from other technology-based career emphases?

Profound insights were gained from *The Engineer of 2020: Visions of Engineering in the New Century* (NAE, 2004) which emphasized the increased need for creativity and imagination in engineering practice. Chapter 4 "Attributes of Engineers in 2020" (pp. 53 – 57) lists the following attributes that should support the engineering professional in the future:

- *Strong analytical skills*: applying science, mathematics, and domains of discovery and design to a particular challenge and for a practical purpose. … the core analysis activities of engineering design – establishing structure, planning, evaluating performance, and aligning outcomes to a desired objective – will continue.

- *Practical ingenuity*: skill in planning, combining, and adapting. Using science and practical ingenuity engineers identify problems and find solutions.
- *Creativity*: (invention, innovation, thinking outside the box, art) is an indispensable quality for engineering and … creativity will grow in importance.
- *Communication*: interdisciplinary teams, globally diverse team members, public officials, and a global customer base. Listen effectively and communicate through oral, visual, and written mechanisms. Effective use of virtual communication tools. Ability to shape opinion and attitudes of other engineers and the public.
- *Mastery of the principles of business and management*: Ability to understand the strengths and limitations of science and technology.
- *Leadership*: increase the practice of leadership skills as careers advance.
- *High ethical standards and a strong sense of professionalism*: Effective and wise management of technological resources. Recognize the broader contexts that are intertwined in technology and its applications in society.
- *Dynamism, agility, resilience, and flexibility*: It is not this or that particular knowledge that engineers will need but rather the ability to learn new things quickly and the ability to apply knowledge to new problems and new contexts.
- *Lifelong learners*: Learn continuously throughout his or her career, not just about engineering but also history, politics, business, and so forth.

From these attributes, a theme of creativity, innovation, invention, ingenuity, and design emerged that provided a focus for identifying the characteristics of a 6 – 12 engineering teacher preparation program. To better prepare students for postsecondary engineering studies, a focus on developing students' creativity and practical ingenuity skills may be as important as developing their analytical skills in mathematics and science. If this is true, the development of 6 – 12 innovation, design, and engineering teachers should include knowledge and skills critical to the development of students' creativity and ingenuity skills. It may be, that the development of the cognitive abilities to invent, innovate, and create may be more important, *at the secondary level*, than the pursuit of advanced mathematic and scientific knowledge and skills.

In addition, a supporting content knowledge base needed to be identified that would provide the foundation for successful creative endeavors. This knowledge should be robust, able to span all engineering disciplines. This knowledge base was provided by the *Standards for Technological Literacy: Content for the Study of Technology* (2002).

The revised Engineering and Technology pathway knowledge and skills developed by the States' Career Clusters (www.careerclusters.org) in addition to a strong mathematics, science, and information technology foundation emphasize *The Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2002) as a component of the academic foundations for the engineering and technology pathway. Significantly, the pathway also recommends that a student's preparation include design education. Thus, the essential question is how should teachers be prepared to teach the design components of engineering education. Should the education of teachers be based on the courses they will teach, or should the teachers' understanding be more profound than what is expected in the 6 – 12 classroom? It is the author's supposition that to prepare a teacher to teach students in a 6 – 12 engineering program, the current conceptualizations of teacher preparation and professional development are inappropriate and a more adequate foundation must be provided. Within education, the adage "we teach like we were taught" should be extended to "we teach what we were taught." In other words, many teacher preparation programs replicate the middle and high school courses in the university setting and do not provide the deep understanding that is required to develop adequate capabilities in students. If the teacher can pass these courses, it is assumed she/he has sufficient knowledge and skills to teach the concepts. This model is based on the idea that the teacher is medium for transferring information and knowledge to the student, i.e. the teacher is nothing more than the conveyor of information and knowledge, a living textbook, and not someone who adds value to the educational process.

Tables 3 – 7 provide a matrix of the knowledge and skills identified in the STEM Career Cluster that should be addressed in the proposed Education for Teaching Innovation, Design, and Engineering program. The reader will note that the knowledge and skills are not exhaustive and the author has suggested additional courses that will introduce the practice of innovation, design, and engineering (e.g. communications in technology, intellectual property).

The proposed teacher development program synthesizes the knowledge and skills identified in the cited documents and focuses on the development of a teacher's abilities to teach 6 – 12 students to design, invent, and innovate, in addition to the application of mathematical and scientific knowledge and skills. The traditional model for encouraging children to consider engineering studies relies on the development of science and mathematics skills as the exclusive preparation for entering postsecondary engineering studies. Research projects seeking to increase the number of students pursuing engineering majors focus on improving students' understandings of mathematics and science and tend to ignore the elements associated with creativity. In other words, students are not encouraged to apply their mathematics and science skills through the application of their creative abilities to solve problems. Engineering is about designing solutions and it would seem appropriate that students be the opportunity to develop their designing skills in multiple and diverse situations prior to enrolling in engineering colleges. This may actually foster a better understanding and application of mathematics and science.

As important as the content knowledge base, teacher educators must consider the strategies for teaching and learning the content knowledge base. Essentially, are there instructional strategies that should be used to foster a climate of creativity and innovation in the classroom and that will persist through a student's academic and professional careers? Creative classroom environments support risk taking, problem posing, diverse learning and thinking styles, and intrinsic and extrinsic motivation. It is clear from the studies of creativity in business environments that it is easier to destroy creativity through ignorance or poor management than it is to foster it. These issues have not been addressed in this paper but are essential to develop a solid content and pedagogical foundation for 6 – 12 design, innovation, and engineering teachers.

Conclusion

What ought to be the underlying structure and goals for Science, Technology, Engineering, and Mathematics (STEM) teacher education program? Teacher education ought to be connected to the fundamental issues of public education, which include issues of student preparation and societal expectations. With the critical nature of America's economic power dependent on invention and innovation through the work of scientists and engineers, it is imperative that we increase the teaching of creativity, innovation, invention, and ingenuity in public schools through the development of a new model for 6 – 12 innovation, design, and engineering teacher preparation.

Engineering and technology is not about the application of mathematics and science principles. It is about imagining solutions, constraining our imaginations with reality, and using what we know about the natural and social world to predict, with reasonable levels of certainty that the designs we develop will lead to a better tomorrow. In essence, the core of engineering is, and ought to be, the development of imagination and creative abilities balanced with the constraints of the physical and social worlds. This ought to be the content of 6 – 12 engineering, not just more mathematics and science courses. Let us capture the imaginations of our children and use that as their motivation for learning more about their natural and created worlds. Creativity and innovation may be the key to increasing student interest in science, mathematics, and engineering; certainly, the current course of action has been insufficient and has led the United States into an innovation crisis.

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References

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Table 1

Major 6 – 12 Engineering Courses for Preparing Teachers

Introduction to 3-D Design and Modeling

Principles of sketching and three-dimensional computer design as a problem-solving process. Sketching and computer design skills as strategies for enhancing communication, visualization, ideation, optimization, and evaluation of designs. Introduction to rapid prototyping technology.

Human-Centered Design

Application of design to meet human needs, expectations, and use. Accessibility design for the physically challenged.

Prototyping and Simulation

Application of prototyping practices using various materials and rapid prototyping. The utilization of computer simulations as a process for refining design projects. Prerequisite: Concurrent enrollment in TECH 3360.

Control Systems

An introduction to electrical, electronic, and computer-controlled systems.

Industrial Design

Basic principles of design and processes of production and their influences on design. Materials, processes, techniques, and equipment commonly used in the manufacture of products. Prerequisite: Concurrent enrollment in TECH 3360.

Systems of Technology I

An overview of mechanical, electrical, and fluid power systems as they relate to extending human potential.

Systems of Technology II

An overview of the thermal and optical technologies. Prerequisite: TECH 2365.

Information and Communication Techniques

Opportunity for development of clear and persuasive writing skills, study of interpersonal communication channels in internal and external environments, and experience in writing business letters, reports, and other written communications.

Technological Research and Development

Processes for guiding research and development of technological activities. Prerequisite: Senior standing.

Information and Communication Technology

An investigation of the concepts behind modern telecommunications systems. Students will explore the means by which systems are interconnected. Information will be provided regarding emerging developments in telecommunications hardware and software.

Invention, Innovation, and Design

Invention/creative processes and their role in economic-value creation. How humans use “design thinking” to create change. Protection of intellectual property.

Teaching Skills for Design and Innovation

Processes and strategies for creating design and innovation environments that foster innovation, research, and development.

Design and Innovation Studio

Directed research and design projects. A jury-reviewed assessment of the process and products of student work. Prerequisite: TECH 3365 and 3367.

The Designed World

An introduction to the human systems used to modify the natural world. These systems include construction, information and communication, energy and power, manufacturing, medical and health, agricultural and bio-related technology, and transportation systems.

Table 2

General Education and Teacher Professional Development Courses (47 SCH and 21 SCH)

General Education (47 SCH)
- Freshman Seminar (3 SCH)
- Grammar and Composition I (3 SCH)
- Grammar and Composition 2 (3 SCH)
- World Literature since the Renaissance (3 SCH)
- United States History I (3 SCH)
- United States History II (3 SCH)
- Introductory American Government (3 SCH)
- Introductory State Politics (3 SCH)
- College Algebra (3 SCH)
- Trigonometry (3 SCH)
- General Chemistry I (3 SCH)
- General Chemistry I Lab (1 SCH)
- University Physics I (3 SCH)
- University Physics I Lab (1 SCH)
- Introduction to Ethics (3 SCH)
- Introduction to Art (3 SCH)
- Introduction to Economics (3 SCH)

Teacher Professional Development (21 SCH)
- School and Society (3 SCH)
- Educational Psychology: Adolescent Development and Learning (3 SCH)
- Teaching Skills (3 SCH)
- Managing and Instructing Diverse Learners (3 SCH)
- Reading in the Content Area (3 SCH)
- Student Teaching (6 SCH)
- Education Capstone Seminar (0 SCH)

Required Electives (10 SCH)
- Statistics (3 SCH)
- Calculus (4 SCH)
- Science elective (3 SCH)

Table 3

Standards for Technological Literacy Knowledge and Skill by Course Matrix

Knowledge and Skills	Introduction to 3D Design	The Designed World	Systems of Technology I	Systems of Technology II	Info. & Com. Techniques	Info. Technology & Com.	Control Systems	Invention, Innovation, and Design	Industrial Design	Prototyping and Simulation	Human-Centered Design	Technological R & D	Teaching Skills for Design & Innov.	Design and Innovation Studio
1. Use mathematics, science and technology concepts and processes to solve problems quantitatively in engineering projects involving design, development, or production in various technologies.	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2. Explain and apply concepts in medical technologies.		x												
3. Explain and apply concepts in agricultural and related biotechnologies.		x												
4. Explain and apply concepts in energy and power technologies.		x												
5. Explain and apply concepts in information and communication.		x												
6. Explain and apply concepts in transportation technologies.		x												
7. Explain and apply concepts in manufacturing technologies.		x												
8. Explain and apply concepts in construction technologies.		x												
9. Apply the core concepts of technology and recognize their relationships with engineering, science and math, and other subjects.					x									
10. Explain and apply the core concepts of systems in technology and engineering projects.			x	x										
11. Explain and apply the core concepts of resources in technology and engineering projects.			x	x										
12. Explain and apply the core concepts of criteria and constraints in technology and engineering projects.	x							x		x				
13. Explain and apply the core concepts of optimization and trade-off in technology and engineering projects.	x							x		x				
14. Explain and apply the core concepts of processes in technology and engineering projects.			x	x										
15. Explain and apply the core concepts of controls in technology and engineering projects.							x							

Table 4

Apply Technical Skills Knowledge and Skill by Course Matrix

Knowledge and Skills	Introduction to 3D Design	The Designed World	Systems of Technology I	Systems of Technology II	Info. & Com. Techniques	Info. Technology & Com.	Control Systems	Invention, Innovation, and Design	Industrial Design	Prototyping and Simulation	Human-Centered Design	Technological R & D	Teaching Skills for Design & Innov.	Design and Innovation Studio
1. Discover how things work.									x		x	x		x
2. Demonstrate knowledge of technology and troubleshooting.							x			x		x	x	x
3. Use problem solving in engineering and technology.	x								x	x	x	x		x
4. Be able to distinguish between hardware/software problems.						x								
5. Use appropriate "tools of the trade."														
6. Apply concepts of planning.									x		x	x	x	x
7. Apply concepts of designing.	x							x	x	x		x		x
8. Apply concepts of building.									x	x	x	x	x	x
9. Apply concepts of testing.									x	x	x	x		x
10. Apply concepts of quality assurance.									x		x			x
11. Apply concepts of customer needs.									x		x			x
12. Use measuring systems, devices.	x		x	x			x		x	x		x		x
13. Correlate quality practices with business outcomes.									x					
14. Use appropriate modeling tools.										x	x	x		x
15. Differentiate between related elements of engineering and technology.						x								
16. Conduct research and development.											x	x		x
17. Conduct experimentation and application.												x		x
18. Practice invention and innovation.									x	x	x	x		x
19. Apply principles of theory and fact.											x			

Table 5
Model Technical Competence Knowledge and Skills by Course Matrix

Knowledge and Skills	Introduction to 3D Design	The Designed World	Systems of Technology I	Systems of Technology II	Info. & Com. Techniques	Info. Technology & Com.	Control Systems	Invention, Innovation, and Design	Industrial Design	Prototyping and Simulation	Human-Centered Design	Technological R & D	Teaching Skills for Design & Innov.	Design and Innovation Studio
1. Use effective project and system management.										x				x
2. Apply the processes needed to complete a project.	x								x	x	x	x		x
3. Develop and implement a plan for a project.	x								x	x	x			x
4. Contribute as a team member in completing a project.						x						x		
5. Predict end results.									x		x	x		x
6. Determine changes needed in a process or product to meet a change in design, constraints, or requirements.	x								x	x	x	x	x	x
7. Use appropriate time management practices.									x		x			x
8. Apply effective organizational skills.									x	x		x	x	x
9. Use precision measuring methods and instruments.	x		x	x					x	x	x	x	x	x
10. Record data with the correct number of significant figures.	x													
11. Explain the impact of error and uncertainty in measurement.	x													
12. Predict the effect of error propagation in calculations.	x													
13. Safely operate and use a variety of tools, machines, equipment and materials.										x			x	x
14. Handle and store tools and materials correctly.										x			x	x
15. Perform basic maintenance.													x	
16. Describe the results of negligent or improper maintenance or calibration.													x	
17. Apply elements of engineering and technology.	x	x	x	x	x	x	x	x	x	x	x	x	x	x
18. Conduct analysis of costs, resources, production capacity, customer satisfaction, quality.									x		x			x
19. Use appropriate problem-solving techniques.										x				x
20. Use optimization.	x								x		x		x	x

Table 6

Design Knowledge and Skills by Course Matrix

Knowledge and Skills	Introduction to 3D Design	The Designed World	Systems of Technology I	Systems of Technology II	Info. & Com. Techniques	Info. Technology & Com.	Control Systems	Invention, Innovation, and Design	Industrial Design	Prototyping and Simulation	Human-Centered Design	Technological R & D	Teaching Skills for Design & Innov.	Design and Innovation Studio
1. Examine elements of the design process.	x							x						
2. Examine the history of innovation and invention.		x						x						
3. Define innovation and invention.								x						
4. Research the history of inventors and innovators.		x						x			x			
5. Research the interrelationship between society and innovation.											x			
6. Apply concepts of design.	x								x		x	x		x
7. Examine attributes of design in systems.		x												
8. Examine attributes of design in products.	x								x		x			
9. Examine attributes of design in services.	x								x		x			
10. Examine design constraints in regard to manufacturability.	x								x		x			
11. Examine design constraints in regard to testability.	x								x		x			
12. Examine design constraints in regard to maintainability.	x								x		x			
13. Examine design constraints in regard to cost.	x								x		x			
14. Examine design constraints in regard to human resources.	x								x		x			
15. Examine design constraints in regard to environmental factors.	x								x		x			
16. Examine design constraints in regard to technology.	x								x		x			
17. Identify design trends.	x								x		x			
18. Examine trade-offs.	x							x	x		x	x		x

Table 7

Demonstrate and Apply the Design Process Knowledge and Skills by Course Matrix

Knowledge and Skills	Introduction to 3D Design	The Designed World	Systems of Technology I	Systems of Technology II	Info. & Com. Techniques	Info. Technology & Com.	Control Systems	Invention, Innovation, and Design	Industrial Design	Prototyping and Simulation	Human-Centered Design	Technological R & D	Teaching Skills for Design & Innov.	Design and Innovation Studio
1. Design a system, product or service.									x	x	x			x
2. Interpret and produce design criteria.									x		x			x
3. Solve a problem to achieve given specifications with considerations to constraints.									x		x			x
4. Incorporate human, environmental and technological factors in the design process.									x	x	x			x
5. Apply risk analysis in the design process.									x					
6. Employ reverse engineering principles.									x					
7. Access, test, record, organize and evaluate information needed to alter the design of a product, system or service.									x		x	x		x
8. Interpret and evaluate accuracy of information.												x		
9. Improve a product, service or system to meet requirements based on feedback and analysis.									x		x	x		x