AC 2009-371: COGNITIVE-PROCESSES INSTRUCTION IN AN UNDERGRADUATE ENGINEERING DESIGN COURSE SEQUENCE

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Cognitive Processes Instruction in an Undergraduate Engineering Design Course Sequence

I. Introduction

Critical to effective and innovative design are the intentional thinking practices that go into the analysis and evaluation of a problem as well as the conception and development of a product or process. Using a variety of metacognitive processes promotes adaptive cognitive flexibility student designers need to design in a variety of contexts that address the inevitable problems the environment, human nature, and community needs precipitate. These skills are central to design instruction in *sustainable societies* in the new James Madison University School of Engineering.

Our six-course, three-year developmental studio design sequence includes instruction in cognitive processes, that is, *the intentional and directed intellectual processes and habits that foster effective thinking* a designer employs to generate an idea or solve a problem. Learning to think well requires intentional changes: changes in thinking processes, and changes in everyday habits and routines. One does not employ new thinking skills in isolation; rather, it requires developing a lifestyle, behaviors, and attitudes that inspire and support the process of thinking and effective design problem solving.

Design instruction in our six course undergraduate design sequence spans sophomore through senior years and focuses on sustainability in four contexts: environmental, socio-cultural, economic, and technical. Students learn to design (and re-design) for sustainability in all contexts and are required to build their designs. Throughout the program, students are required to design or re-design products and processes that are subject to sustainability criteria we developed for student projects. All our students are trained in the use of design tools, both electronic programs as well as hand tools and power tools.

More specifically, following a general introduction to the foundations of cognitive processes found in psychology, and creative process found in two- and three-dimensional art instruction, we offer developmental instruction in the following areas:

Metacognition and thinking processes—students engage in activities that require them to plan, reflect upon, and modify their own thinking processes and strategies, as well as adapt these methodologies to meet the needs of a specific design problem.

Structured and unstructured thinking strategies—students practice and *personalize* (adapt to their own habits and lifestyle) such strategies as focused reflection, brainstorming, writing as thinking, systems thinking, drawing as thinking, visualization, listening, and non-argumentative conversation.

Behavioral and lifestyle changes—students modify their daily habits and personal demeanors to more effectively conceptualize and utilize their time, as well as adjust their attitudes and learning style.

Barriers to thinking—students identify and develop strategies to overcome personal and collaborative habits, attitudes, and thinking styles that tend to prevent good thinking in order to develop a highly individualized design process as well as a collaborative design process.

The evaluation of student design projects is performed using an original assessment rubric that includes the four contexts noted above (as well as ethics and aesthetics).

II. Literature Review

Most published work and university instruction in engineering related to creative and critical thinking skills in design is vague on the detailed practices of individual thinking processes. Many methods suggest a product (or goal) of thinking, leave students to their own devices on exactly *how* to do the thinking to reach this goal and then, apparently, hope for the best. These activities may stimulate thinking in general, but they do not offer the "means" for generating new ideas or solving problems. More specifically, they do not foster *the intentional and directed cognitive processes and behavioral changes that foster good thinking.* It is certainly legitimate to assign students the following exercises that require higher order thinking skills: "Evaluate the design and function of an automobile braking system," "Redesign a manufacturing process," or "Design an improved computer keyboard." These may be interesting assignments, but they largely miss the point of helping students develop the intellectual habits and skills, and other intentional habits (dispositional processes) necessary to explore an idea or solve a problem in design courses. In addition, it may also be of some use to tell students that innovative thinkers are dynamic, daring, resourceful, hardworking, reflective, and independent. But what this approach typically doesn't offer is any sort of instruction in how these behavioral characteristics and dispositions might be developed, practiced, and integrated into one's daily life and work. Suggesting meaningful change and leaving students on their own to develop such skills won't work for most individuals. Students need more than a description of what a final product looks like.

Creative engineering design instruction is at the center of our efforts to design for sustainability. In the past two decades, engineering design instruction has evolved into an integrated and cross-disciplinary endeavor. While many engineering programs have developed design courses and programs to better reflect the needs of society and the environment, perhaps one of the first academicians to note the interdependence among technical engineering skills, and the arts and social sciences is Duke University Professor of Civil Engineering Henry Petroski. Although much of his work has addressed the role of failure in design, Petroski was one of the first to consider engineering an integrated discipline. In what many consider his seminal work, *To Engineer is Human*, Petroski refers to engineering practice as a *human* endeavor, a practice of both science and art, one that is "part of our human understanding and experience."[1]

Petroski is particularly referring to working in an interdisciplinary manner, especially integrating artistic skills into the design process, stating that "…the *conception* of a design…can involve as much a leap of the imagination and as much a synthesis of experience and knowledge as any artist is required to bring to his canvas or paper."[2]

Others, including Joseph Bordogna, former deputy director of engineering for the National Science Foundation, agree: "The engineer must be able to work across many different disciplines and fields—and make the connections that will lead to deeper insights, more creative solutions, and getting things done."[3] William Wulf, former president of the National Academy of Engineering (NAE), and George M.C. Fisher, former chair and CEO of the NAE council, call for a "major shift in engineering education's center of gravity" toward creative design and cross-disciplinary teaching practices.[4] In addition, the ABET 2000 "a-k" criteria confirm these conclusions and require an increasingly design-based and interdisciplinary approach to engineering education.[5]

Current trends in engineering design education in academia and industry over the past decade have continually stressed the importance of innovation, writing and communication skills (especially for team-based projects), and interdisciplinary collaboration skills. The topography of progressive engineering programs varies dramatically from university to university, as professors draw inspiration from non-traditional sources including the social sciences (especially psychology), philosophy, business, architecture, and art.

The need for innovation in teaching engineering design has been noted in educational and industrial sectors for years;[6,7,8,9] some university educators have lamented the fact that too many colleges of engineering have become complacent in teaching design, creating an "unfortunate gap that too often exists between industry and academe."[10] Progressive engineering educators and industry leaders both stress that critical and creative thinking skills are at the center of design instruction, and are key to the continued success of American industry.[11,12,13] Noted author and product designer Robert G. Cooper sums up the dilemma well, stating that "most companies lack much in the way of effective product innovation and technology strategy, and worse yet, seem at a loss for developing such a strategy."[14]

Obviously, universities are, at least in part, as much responsible for this problem as they are for the solution. The Accreditation Board for Engineering and Technology recognizes this shortcoming in engineering programs, and has clearly outlined the technical and non-technical skills necessary for success in an increasingly complex and interdisciplinary workplace environment.[15] Teaching cognitive processing skills, communication and team working skills, ethics, global awareness, and environmental awareness now punctuate, and temporarily overshadow, teaching the technical skills engineering educators have long thought to be the most central pedagogical issue in engineering education.

Noting the important role university and industrial training programs have in addressing this dilemma, Penn State Professors Salamon and Engel suggest that design instruction cannot be successful without academic instruction that "exercises student creativity and other non-analytical talents."[16] Several authors and educators note the importance of colleges and universities teaching effective writing skills, interpersonal communications, and collaborative working skills as a necessary foundation for learning effective design skills.[17,18,19]

Responding to the needs well-expressed by industry, some engineering programs have begun teaching problem solving,[20] critical writing skills,[21,22] interpersonal skills as related to creativity,[23,24] perception skills[25] and reflection[26] over the past few years.

Effective cognitive processing skills integrate students' understanding of and ability to apply most of the skills noted above, not just the structured critical thinking "tricks of the trade" noted in many trade and academic publications. Fostering *truly* effective and versatile cognitive processes requires behavioral and interpersonal changes that produce the cognitive flexibility required to face the serious problems facing engineers in the workplace. Engineering problems are now "human problems," and the structured and linear approaches to thinking in academic design curricula no longer yield solutions that work across human and engineering contexts.

III. Sustainable Societies Engineering Program Description

The James Madison University School of Engineering offers students a unique engineering product and process design program focused on *sustainable societies*. The focus of the program is on sustainability and design. Defining "sustainability" for sustainable societies is tricky business and depends entirely upon one's perspective (or perhaps, investment). Rather than attempt to define sustainability per se for the current effort, we offer instead the following description:

> A sustainable society possesses the ability to continue to survive and prosper indefinitely, not just with respect to resources and economic development, but with quality of life as it pertains to conditions that promote general human prosperity and growth (e.g. opportunity, safety, privacy, community, education, and health). A sustainable society meets these needs simultaneously, and in the context of human respect and the ability to negotiate differences without violence.

Our program is integrated and interdisciplinary, and we expect our pioneering efforts to serve as a test bed for other programs wishing to focus on this broader concept of sustainability and design. Design, for our purposes, falls into the following two categories:

> *Product Design*: process engineering that includes designing, developing, implementing, evaluating, and revising a process to manufacture a product or material. This includes the sequence of design steps, operations, and the selection of tools and materials necessary to manufacture a product.
>
> *Process Design*: may refer to designing the process flow (people, materials, money, information, testing, and marketing) associated with manufacturing a product or material. This term is sometimes referred to as business process engineering or "management of technology," approaches that enable an organization to define and understand its business processes, organization, strategies, and technologies to achieve improvements in operating results.

A significant component of this integrated program is the six semester 10-credit design studio sequence that stretches from sophomore year to graduation (in addition to a five-credit freshman class that focuses largely on design and thinking skills). Students graduating from the design program demonstrate competencies in product and process design along with significant emphasis on and rigorous coverage of technical skills that facilitate ABET accreditation as well as prepare students for the Fundamentals in Engineering Exam – General Engineering.

Topics in the design curriculum in the Sustainable Societies Program include the following:

Environmental Sustainability: An approach to the engineering of processes, products, and structures which has, indefinitely, a less negative, neutral, or benign effect on all environmental systems.

Economic, Cultural, and Social Sustainability: Understanding the far-reaching influence design has on the individual, communities, geographic regions, and cultures is central to instruction. Topics of instruction include sustainable economic and business practices, cultural sustainability, social contexts in sustainable societies, human prosperity, and community well-being.

Cognitive Processes, Creativity in Design: Established critical analysis and evaluation instruction has been limited to linear forms of thinking. How a designer thinks—the actual cognitive processes a designer employs to generate an idea or solve a problem— is central to design instruction.

Aesthetics of Design: Logic and utility are not the central or only factors in the design of a product; a product must speak to culturally and historically accepted norms of beauty, value, balance, harmony, proportion, and natural body movement.

Design Ethics: Design ethics in the program go beyond environmental issues and include instruction in the consequences design has on human and social contexts, especially the environment, the conditions under which humans work and live, profit, marketing and advertising, and the equitable use of global resources.

IV. Design Program Description

Design *is* problem solving and idea generation, and more specifically, relies upon successful *assessment* and *evaluation*, whether it be addressing an existing design condition or a flaw (as in redesign), or generating an idea from which a new design may emerge. Instruction in assessment and evaluation for problem solving in sustainability is central to our overall program efforts. From our point of view, students can employ a series of design skills they have practiced and "personalized" (adapted to their own thinking style and habits) in order to develop an *individual creative design process* they document in all their studio projects. The design program is interdisciplinary and utilizes faculty from business, art, and social science disciplines; and employs a variety of innovative instructional methodologies.

Student take a design studio class each of six semesters beginning sophomore year that features 1) moderate instruction over a long period of time in the curriculum , 2) liberal faculty-directed practice in the design studio, 3) real-world application, and 4) collaborative and individual design instruction.

Students apply their growing cognitive expertise and experience to increasingly more complex and sophisticated problems related to sustainability. Early in the design curriculum, students solve problems or generate ideas in one or two sustainability contexts; later they are required to include all four contexts (environmental, socio-cultural, technical, economic) in developing designs or negotiating redesign projects. As noted just below, students are required to document their thinking processes in a personal design journal. This journal serves as a developmental history for each student.

Our program focuses on *process* in all topics and methodologies, and instruction in cognitive processes related to design problem solving and idea generation is central to our efforts. Instruction in the following topics is also included in the design curriculum (and will be the topic of future papers):

Process in Design
Design Assessment and Evaluation (redesign)
Redesign
Iterative Design
Technical Construction Design Skills (computer and manual)
Conceptual Design vs. Construction Design
Design History
Design Research
Design Theory
Aesthetics
Design Ethics
Testing (functional and marketing)
Product Cost and Accounting

As noted above, our approach to teaching design is developmental, and topics of instruction are presented in a holistic manner so that students understand well the relevance of all instructional topics to each other as well as to the overall objectives of the design program and those of the School of Engineering.

V. Instruction in Cognitive Processes and Thinking Skills

Briefly, our approach to teaching cognitive processes that support design instruction includes 1) examining, understanding, and changing thinking processes and practices; 2) developing processes that support personal and academic growth; 3) practicing and revising thinking and problem solving processes to meet the needs of a design problem; 4) "personalizing thinking skills" (integrating behavioral and cognitive skills into everyday professional and personal lives); and 5) developing life long behaviors and habits that maintain good thinking.

Following classroom instruction, readings, and discussions in the foundations of cognitive processes found in psychology, and creative process found in two- and three-dimensional art, we offer developmental instruction in the following areas:

A) Metacognition and Thinking Processes

General Objectives: to help students 1) develop the basic skills and awareness necessary to reflect upon one's own thinking processes and strategies, 2) monitor and modify their own learning processes, and 3) develop strategies that work well in individual and collaborative settings.

Selected Projects and Assignments:

1) Personal Design Journal

Objective: to document and adjust individual and collaborative thinking process as related to specific design projects

Methodology:

Students document individual thinking and collaborative processes in a personal design journal meant to keep track of their thinking processes—the methods they use to think, when they think, and where and under what conditions (mood, time of the day, etc.) as they work through the process of solving problems and generating ideas during a product or process design assignment. In addition, students are required to show evidence in the journals of making intentional changes to their thinking processes. The journal documents students' efforts in applying and evaluating the results of thinking strategies, matching thinking strategies to specific problems and idea generating scenarios, and determining whether one's intentional approach to a problem is linear or abstract. Students are required to submit their design journal to faculty each semester for review and one-on-one discussion with a faculty advisor.

2) Individual and Collaborative Thinking Processes

Objective: to understand one's own thinking style, adopt and practice new thinking skills, and develop personal and professional habits the support effective thinking

Methodology:

In class discussion and in design teams, students exchange ideas on cognitive processes (especially the ones they are practicing) and apply these skills to developing individual and collaborative thinking strategies. Results of these exchanges are documented in students' Personal Design Journal. Thinking process topics include the following:

1) Understanding one's own thought processes—thinking, writing, collaborating

2) Understanding one's thinking style

3) Analyzing and understanding a thinking task: thinking about the processes one uses to think about a specific topic or problem

4) Thinking about a problem from a variety of perspectives using writing, thinking, drawing, collaborating

5) Listening to others (and to one's self)

6) Taking charge of a thinking task and completing it in a reasonable amount of time

7) Recording ideas/results appropriately/clearly for one's self and specific audiences

9) Identifying the next step or task after one's work is completed as a bridge to future work

9) Being open-minded / Dispelling stereotypes

3) Reflection Exercises

Objective: to develop and practice reflection and focused reflection to solve problems, generate ideas, and reduce stress

Methodology:

Reflection is the principle springboard for metacognition, and in these exercises, students are required to be entirely silent for an hour once each week for the whole semester. The process for the assignment is strict—students must just sit entirely undisturbed: no cell phones, television, radio, stereo, ipods, Facebook, video games, or surfing the net. No cleaning, sleeping, talking, eating, or reading. Students must *just sit* undisturbed for an entire hour (in one sitting). Following that hour, they write about what happened during the reflection. Further assignments are on focused reflection, during which students learn to concentrate on a particular design problem or idea generating situation for the hour. Students document their results and use this information when working an a design project.

B) Structured and Unstructured Thinking Strategies

General Objectives: to develop and practice the basic skills necessary to identify and describe the nature and function of solving problems and generating ideas, and to employ these skills in professional and personal settings; to practice and *personalize* such strategies as focused reflection, brainstorming, writing as thinking, systems thinking, drawing as thinking, visualization, listening, and non-argumentative conversation

Selected Project and Assignment Examples:

1) Freewriting / Writing as Thinking

Specific Objectives: to generate alternative ideas for solving a problem or generating ideas; to integrate writing as a form of thinking into one's academic life and practices; to recognize that writing accesses different parts of the brain; and to experience the quality of ideas that emerges while writing

Methodology:

These exercises require students to write on an assigned problem or idea generating scenario.

Freewriting: Students are asked to solve an assigned problem by writing continuously for 15 or 20 minutes without stopping (keeping pen to paper and writing non-stop on the assigned topic for the entire time).

Writing as Thinking: Students are asked to solve an assigned problem over a series of days using writing as their primary source for thinking. Each day, students must devote at least a half hour to thinking about the assigned problem and writing about it. (In this case, students are not required to "keep pen to paper" and write for a specified time.) This assignment teaches students to develop the habit of using writing in conjunction with thinking to solve problems and generate ideas, and to move easily between these processes.

2) Analysis of Contexts

Objectives: to compare, contrast, and distinguish contexts; to understand and explain an issue orally and in writing from a variety of perspectives

Methodology:

Students are given a short article to read on a design problem. Students consider the problem in *each* of the sustainability contexts (environmental, social, economic, technical). The analysis is a written homework assignment, followed by small group and class discussion, or the written analysis of another student's paper.

3) Visualization

Objectives: to visualize thoughts, ideas, and designs and describe them orally and in writing; to move thoughts and ideas among writing, thinking, and "seeing"

Methodology:

A typical introductory assignment: "Think about a house you'd like to design or live in, and describe the house in writing." Following this part of the exercise, students are told: "Close your eyes for five minutes and *visualize* this house (create a mental picture); when the five minutes are up, again describe the house in writing" (this second description must be in writing, so students learn to move between their vision and their writing). A class discussion follows.

4) Brainstorming

Objectives: to brainstorm a problem; to learn the procedures for conducting a brainstorming session; to practice openly expressing and sharing ideas; and to stimulate thinking using others' ideas

Methodology:

Brainstorming is a group activity characterized by the open oral submission of ideas in a large group setting (in short…simply calling out ideas in a group in response to a workplace-related problem or idea generating situation). There are two essential rules to unstructured brainstorming: 1) "Say what's on your mind" and 2) "Judge no one else's ideas." Of course, brainstorming will work in most all large or small group situations for generating ideas and solving problems.

It is important to document what transpires during a brainstorming session and to keep the group on task. One individual (the instructor, usually) acts as a facilitator, calling on students who have ideas and making connections among ideas to inspire more suggestions. One student acts as secretary and writes down the ideas on the blackboard as other students call them out. A good brainstorming session should become a fast-paced "free for all" of ideas, as students learn to use each others' ideas and thoughts without restraint. Smaller groups can often come to a consensus following a brainstorming session, but larger groups need to approach the task in a more structured fashion, eliminating ideas that are unworkable, and selecting the three or four ideas they support the most. Following a discussion, students can concentrate on developing the most "workable" ideas.

5) Structured Problem Solving

Objective: to solve problems in a group setting using a linear approach; more specifically, to learn the skills in "a-k," below

Methodology:
Students work in small groups and follow the approach below for solving an assigned design-related problem (of varying degrees of clarity).

a) Determine whether a problem exists
b) Define the problem
c) Research the problem
d) Explore possible solutions
e) Evaluate the pros and cons of possible solutions
f) Choose a solution
g) Devise a plan for implementation
h) Carry out the plan
i) Assess and evaluate the results
j) Evaluate the problem solving process
k) Revise the problem solving process for next time

Students document their ideas and findings in detail, and present them to the class for further discussion and revision.

C) <u>Behavioral</u> <u>and</u> <u>Lifestyle</u> <u>Changes</u> ("dispositional skills")

General Objectives: to modify daily habits and personal demeanors to more effectively conceptualize and utilize time, and communicate with others—as a method of creating a foundation of behavioral skills that support effective thinking, and as a way of adjusting attitudes and learning style

Selected Projects and Examples:

1) Listening Project

Objectives: to develop focused listening and questioning skills through practicing and evaluating questioning strategies; to discover the increased information one gains from listening; and to understand the nature and benefits of more intimate and respectful professional and personal verbal exchanges

Methodology:

In this very closely monitored project, students are required to do the following over the duration of seven weeks in stages lasting a week or two, depending upon their individual progress:

Stage One: Students choose three "subjects" (individuals) they see most days; and when conversing with these individuals, be about 20% quieter (but not so much so as to arouse suspicion or concern—students are not to reveal this project to their subjects). The objective here is to learn to focus on listening and allow a subject to talk without being interrupted.

Stage Two: Students engage in the topic of conversation started by the subject, and subtly ask for more information or explanation on the topic.

Stage Three: Students ask specific and pointed questions of their subjects meant to help their subjects go into greater depth or explore a topic.

Stage Four: Students learn to "steer" conversations in order to stay on a specific topic or move the conversation to more interesting material.

All stages are comprehensive; for example, during Stage Three, students are still employing the skills they learned in Stages One and Two. By Stage Four, students are instructed to begin to employ all four stages of the process with an increasing number of friends, family, and professors as a way of integrating these dispositions into their daily lives. Students submit progress reports each week and participate in small group and large group class discussion on their progress.

2) Time and Technology Project

Objectives: to identify and examine how personal electronic habits (such as television, stereo, radio, computer, Facebook, video games, and cell phone overuse) and cultural and professional norms (being busy all the time) distract one from clear and self-directed thinking and action; and to refocus this time on more personally productive thought and action

Methodology:

This assignment is closely related to the Reflection Exercises (above), and because of its focus on time, is a topical component of all the projects. The Time and Technology Project is simple: No television, radio, cell phones, video games, stereos, ipods, social networks, or surfing the net for three consecutive days of typical activities (with exceptions for school work, employment, and family responsibilities). This assignment is the *process*, that is, experiencing their daily lives on the "other side" of their electronic habits and voluntary distractions of life. Students have to spend some time with their own thoughts, experience a new way of thinking and looking at themselves and their world, and adjust their daily routines and habits *away* from constant electronic stimulation. Students submit progress reports each week and participate in small group and large group class discussion on their progress.

D) Barriers to Thinking

General Objectives: to identify intellectual, social, cultural, and personal barriers to effective thinking, problem solving, and idea generation; to identify and develop strategies to overcome personal and collaborative habits, attitudes, and thinking styles that tend to prevent good thinking

Selected Project:

1) Barriers to Thinking Exercise

Objective: to help students identify and change their personal barriers to thinking

Methodology:

Following readings on barriers to thinking and creativity in James Adams' *Conceptual Blockbusting*, for example, students reflect upon their own barriers to thinking in the following contexts: intellectual, social/cultural, personal, philosophical. Following discussion in small groups and in the class, students use writing as thinking and reflection to propose changes they can make in their day-to-day thinking to overcome these barriers. Students use intentional change strategies learned in class to overcome these barriers, keeping track of their progress in writing over the next six weeks. Each week, students discuss and report on their progress in small groups and in class.

E) Issues Related to Time as a Barrier

General Objectives: to develop a personal awareness of time conceptually as well as practically; to balance and prioritize one's use of time in a variety of personal and academic contexts; to recognize when one performs certain tasks most effectively; to understand and practice having control of one's time ("owning time"); and to understand philosophically the centrality of time to human existence as well as everyday life

Methodology:

All the projects related to time are dependent upon students' conceptual understanding of time. These are not "time management" exercises; they are more about one's relationship with time and conceptual understanding of the nature of time. The following four assignments require students to experience time in a manner different than usual—rushing all the time and feeling controlled by time. Students reflect and write following each exercise. Most of these assignments appeal to an individual's common sense about time, which accounts for students' very high degree of commitment to these assignments.

1) Time Log

In this simple assignment, students keep track of their activities (studying, attending class, eating, being on-line, talking on the phone, socializing, etc.) for an entire week, by the half hour. They are then asked to analyze their log in such contexts as 1) time spent alone, 2) time spent on the computer, 3) time on the cell phone or otherwise "plugged in," and 4) time spent studying, etc. in order to get a more comprehensive understanding of how they spend their time.

2) The Best Time to Do Things

Students are asked to reflect upon and analyze the times of the day they most effectively and efficiently perform certain tasks such as studying, socializing, reflecting, writing. The objective of this exercise is to help students determine the time of day they do their best thinking and studying, so the work they do is completed most efficiently, pleasurably, and effectively. Students are then directed to adjust their daily schedules for three weeks to reflect their findings, and then report the results in writing.

3) Waking up Two Hours before Class

Students report normally awakening each morning with barely enough time to rush to class. In this assignment, for one week, students are required to wake up two hours before they have to be in class and keep track of their activities and thinking during that time and throughout the remainder of the day.

4) *Half Speed Day*

In this not-quite-appropriately named assignment, students are asked to allot a specific, and more than ample, amount of time to perform certain tasks they've planned for a day (e.g., studying, cleaning, eating, walking to school). We suggest they do these tasks uninterrupted by electronic social networking and cell phone use.

VI. Assessment of Current Students' Perceptions of Exercise Effectiveness

Survey Description: A simple fixed-response four question survey assessed the perceived effectiveness of design course assignments (Reflection, Structured Problem Solving, Brainstorming, Visualizing). All responses were made on a six-point, Likert-type scale, with six being the highest score.

Data Collection: Surveys were administered in a single session to all students who were enrolled and present in class during the spring 2009 semester. A total of 71 students completed and returned the survey during class.

Results: For each of the four exercises, we used the entire sample (N = 71) to calculate mean levels of perceived exercise value. The mean-level scores are as follows: Brainstorming (M = 5.39), Structured Problem Solving (M = 4.89), Reflection Exercises (M = 5.01), and Visualizing (M = 5.12).

In this freshman-level course, the majority of students "moderately to strongly agreed" the four design methodologies they learned and practiced in class were valuable to their early efforts in design. Also notable here is the fact that these relatively sophisticated skills, originally taught only to junior and senior-level students, can be taught successfully to first and second semester freshmen.

Future methods of assessing cognitive process development will take a variety of forms and occur throughout the design sequence.

Personal Design Journals: The journals allow students to assess their own progress. In addition, journals provide faculty with data from which to assess instruction as well as each student's progress.

Surveys: These surveys assess students' 1) perceived value of instruction, 2) inclination to continue to use the processes they have learned in class, and 3) perception of the value of such skills to the engineering profession.

Portfolios: Most central to design skill assessment involves the use of portfolios, not entirely different than those required of art students. Students are required to document their projects in writing, present to an academic and corporate audience, and display their design projects. While portfolios do not directly assess cognitive process development, they offer information related to the entire design process.

Senior Exit Surveys and Interviews: Included in these assessments are questions related to cognitive process development in design and its value to the individual and collaborative design process.

Two other assessments, both related directly to design skill development, will offer some data helpful to the assessment of cognitive processes. The *Center for Assessment and Research Studies* is currently assisting in the development of engineering design-specific qualitative and quantitative tools for assessing design skills. These assessment instruments will include the evaluation of students' studio skills (e.g. the use of engineering design tools and design software) and their understanding of the math and science competencies that underlie the design conception and construction process.

VII. Conclusion

The program in sustainable societies presents opportunities to innovate, test, and evaluate new approaches to engineering design instruction. The ultimate goal of our efforts to teach cognitive processes is to help students become educated and practiced thinkers who have developed a "personal thinking style," demonstrate cognitive flexibility, and can adapt their engineering skills across a variety of sustainability and professional contexts.

There is much to be gained by young engineers who are well-equipped to determine the sustainability of a process or product, design successfully, and predict accurately the outcomes (a task that is difficult and uncertain, at best). From our perspective, we could ask no more from our graduates.

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