AC 2010-805: DESIGNING INTERDISCIPLINARY CURRICULUM & TEACHING: INVESTIGATING INNOVATION & OUR ENGINEERED WORLD

Austin Talley, University of Texas, Austin

Austin Talley is a graduate student in the Mechanical Engineering Department at the University of Texas at Austin, a Cockrell Fellow, and a licensed Professional Engineer. His research focus is in design methodology with Universal Design and engineering education. He has received his B.S. from Texas A&M University and M.S.E. from The University of Texas at Austin. Contact: Austin@talleyweb.com

Christina White, Columbia University

Christina White is a doctoral candidate in Curriculum & Teaching at Teachers College, Columbia University and is the senior coordinator for Design, Technology, & Engineering for All Children. Her research is in engineering education with a focus on humanitarian engineering, design, diversity, and the NAE's 21st century grand challenges. She has earned her M. Ed from The University of Texas at Austin. Contact: ckw.columbia@gmail.com

Kristin Wood, University of Texas, Austin

Richard Crawford, University of Texas at Austin

Dr. RICHARD H. CRAWFORD is a Professor of Mechanical Engineering at The University of Texas at Austin and is the Temple Foundation Endowed Faculty Fellow No. 3. He is also Director of the Design Projects Program in the Department of Mechanical Engineering. He received his BSME from Louisiana State University in 1982, and his MSME in 1985 and Ph.D. in 1989, both from Purdue University. He teaches courses in mechanical engineering design and geometric modeling for design. Dr. Crawford's research interests include development of computational representations and tools to support engineering design, geometric modeling, and manufacturing applications of solid freeform fabrication techniques. Since 1992, Dr. Crawford has been involved in the development of design technology training institutes for K-12 teachers. Recent institutes have focused on robotics and automation using LEGO(r) MINDSTORMS(r) NXT. Contact rhc@mail.utexas.edu.

© American Society for Engineering Education, 2010

Designing and Teaching Interdisciplinary Curriculum: Investigating Innovation and Our Engineered World

Introduction

Through a curriculum reform initiative, The University of Texas at Austin is developing "signature courses" for freshman undergraduate students. These courses expose students to a variety of subjects and engage them in a variety of skill sets. These are "signature" courses because they are developed and taught by the university's top teaching faculty, where the goals are to foster a scholarly community and to create the most interesting and meaningful classes possible. Embarking on its third year, *Undergraduate Studies 302: The Engineered World: Products and Innovations*, focuses on innovation in the context of the engineering design process. This course is team taught, featuring two tenured Mechanical Engineering professors and two doctorial candidates (one in Mechanical Engineering and the other in Education, Curriculum and Teaching). Due to the phased implementation of the curriculum reform, the college of engineering does not yet require undergraduate students to take a signature course. Resulting from this situation, non-engineering majors populate this engineering signature course.

As part of the development of this new course, we carefully documented curriculum development and assessment, thereby facilitating communication among the teaching team members. To this end the teaching team maintains a lesson diary of the course. Assessment of the course is continually monitored through directed discussion of the course with students, review of work produced by the students, and written reflection of the course by the students. The written reflections are discussed within the class and show that the students are gaining a deep understanding of the engineering design concepts and are actively engaged in the course. Students connect to this course of study through the use of active learning methods, including hands-on activities, inductive and deductive reasoning opportunities, and multimodal experiences. Further, group work is enhanced by considering ways to group students based upon personality types and other team-formation strategies rather than relying on self-formed teams.

The cumulative research data incorporates the reflections about curriculum and teaching from the students and instructors; an array of pedagogical practices; recognition of varied learning and teaching styles; and multiple literacies practices [1,2,3,4,5,6,7]. We have employed both quantitative and qualitative approaches to understand these data. This mixed-methods analysis offers insights into effective approaches to teaching engineering concepts to non-engineering majors. The course provides a foundation for developing other engineering courses for non-engineers. Our research demonstrates tools that engineering educators and other scholars can apply in designing their own curricula on innovation and serves as a model of co-teaching.

Background of Signature Courses

As part of an extensive curriculum revision effort, The University of Texas at Austin (UT Austin) has developed signature courses for first year undergraduate students. These courses engage students in variety of academic skills. The courses are developed around a variety of academic disciplines, allowing students to select topics that interest them from a large number of sections of the course. All signature courses must incorporate six areas[8].

- Interdisciplinary and contemporary content
- Information literacy
- Written and oral communication
- Top faculty
- The University Lecture Series
- Gems of the University

Each signature course focuses on a particular topic, in our case, innovation. As part of the exploration of the topic, the students work to improve their writing and presentation skills in an alterative setting. This course allows students to learn about a topic that normally would not be part of their chosen majors. Due to the phased implementation of the curriculum reform, the Cockrell School of Engineering at UT Austin does not yet require undergraduate students to take a signature course. Resulting from this situation, non-engineering majors populate this engineering signature course. This dynamic allows students in the course to experience engineering in a unique way. *Undergraduate Studies 302: The Engineered World: Products and Innovations* has now been taught by the same faculty for three years. This course is part of a small group of signature courses offered by the Cockrell School of Engineering.

A review of literature indicates that small focused freshman seminars are gaining in popularity, but long term effects are lacking[9] Studies do indicate that students need to make substantive interdisciplinary connections across their courses[10]. Students who develop meaningful relationships with faculty tend to enjoy more success[11]. The available research supports the effectiveness of such freshman seminar courses[12].

Course Description

In our "flat world" economy, engineered products have a tremendous impact on all aspects of our daily lives. The intent of the undergraduate studies course is to explore the exciting world of engineered products, from the perspectives of history, current markets, and future forecasting. *The Engineered World: Products and Innovations* focuses this exploration on innovations as they have changed the landscape of nations and cultures, especially in the United States. This focus includes hands-on studies of everyday technologies, a review of "Modern Marvels," the translation of societal needs into specifications and ideas for new products, and the study of how to bring together the elements of materials, energy, systems and models to design and manufacture products that are effective, efficient, economical, and ecological. Each student in the class has

exciting opportunities to identify new product ideas, i.e., inventions, and embody these ideas in the development of prototypes and conceptual models.

The course is not structured like a traditional lecture-type course. The classes are intended to be highly interactive, with a mixture of discussions, multimedia presentations (PowerPoint presentations, short videos, DVDs, etc.), and hands-on activities. A collage of images from the course activities is shown in Figure 1.

Figure 1: Collage of Course Activities

Class participation is actively encouraged, highly valued, and key to an optimal experience. Additionally, several out-of-class assignments are required, including short papers (two pages each), attendance at on-campus presentations, and a final team-based product invention project. As part of the invention process, each student keeps a design journal to record ideas and thoughts about possible inventions. The students use the design process to solve one of the problems from their daily life experiences that they identify in their design journal shown in .

	No	Activity	Problems	Improvements	Potential?
Morning	1	Making bed	Have to make bed each morning	Self-fixing sheets	No
	2	Waiting for friend	Don't know where friend is	GPS to track certain people we program in	Yes
	3	Walking to bus stop	Do not like arriving early and waiting	Calculator based on distance, walk speed, etc.	Maybe
	4	Walking	Umbrella feels like it could blow away	Stronger material; different design	Yes
	5				
	No	Activity	Problems	Improvements	Potential?
Afternoon	1	Eating lunch	Don't have a diverse array of utensils	Pocket-knife-style spoon/fork/knife combo	Yes
	2	Bus rides	Getting hungry on 1+ hour bus rides	Buses with mini snack machines built in	Maybe
	3	Eating chips	Hard for bags of chips to keep fresh	Air tight cabinets in dorm rooms	No
	4	Walking	Weather changes from rainy to sunny	Material for clothes to adapt to changes	Yes
	5				
	No	Activity	Problems	Improvements	Potential?
Evening	1	Cleaning	Desk becomes dirty as day goes by	Self-cleaning desk/non stick material	Yes
	2	Miscellaneous	Getting headaches with activity	Headgear with headache predictor	No
	3	Bus rides	Extremely tired on 1+ hour rides	Chairs that double as reclining sofa	No
	4	Printing	Have to replace paper	Apparatus to store whole reams	Maybe
	5				
	No	Activity	Problems	Improvements	Potential?
Night	1	Sleeping	Blanket always falls off by morning	Bed with alert for when blanket falls off	Maybe
	2	Showering	Clothes fall off the shower rod	Shower with built in clothes dresser	Yes
	3	Dinner	Dorm room smells like food after eating	Scent-free food/odorizers packets with food	Maybe
	4				
	5				

Figure 2: Exemplar Student Design Journal

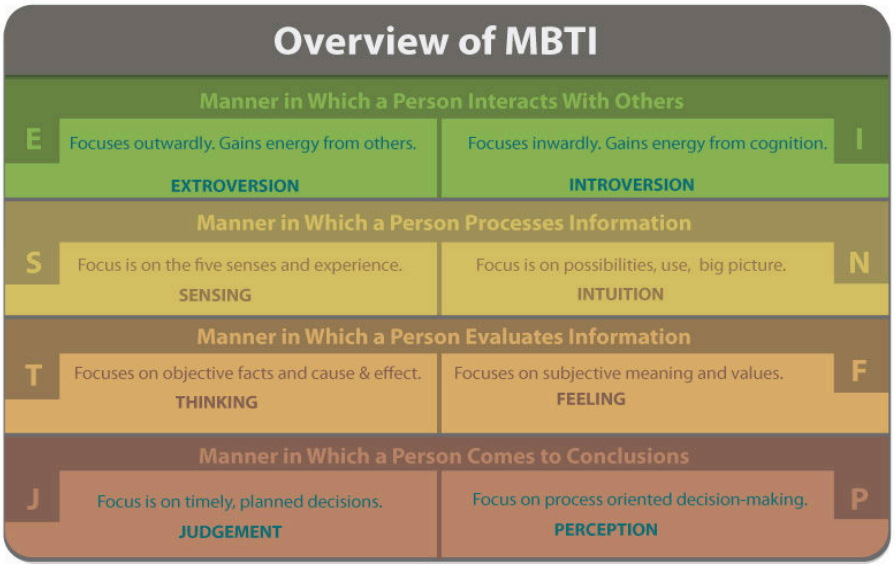
This process creates an inventor, invention, and entrepreneurial environment. At the end of the course each team of two students produces a prototype and poster presentation of their design project.

UT Austin is a large research based university that has a wide variety of majors. The most recent version of course had fourteen students from a mix of majors, ranging from nursing to business and architecture to undecided, all non-engineering majors. The students were all in their first year and selected this section of the course. The class included nine males and five females.

Education Pedagogical Theory

As educators move forward in advancing engineering education, it is important to employ pedagogical approaches that connect with the complex needs of our diverse learners. In our teaching, active learning is the foundation for addressing the broad spectrum of students with varied educational backgrounds and demographics. We adhere to the notion that active learning tools are a viable choice for addressing how students struggle with complex topics in engineering, especially as a function of their backgrounds, demographics, and personality types. In an effort to tightly align active learning experiences with each student, we illuminate their various learning preferences and communication characteristics. These traits are identified after the students complete the Myers Briggs Type Indicator (MBTI) and the 6 Hats assessment[1,2,3,4,5,6,7].

Table 1: Overview of the MBTI Categories



Myers Briggs Type Indicator (MBTI) Personality Type

The Myers Briggs Type Indicator (MBTI) is linked to personality preferences, as shown in Table 1. MBTI summarizes preferences in terms of four categories that represent how an individual processes and evaluates information. The first category describes how a person interacts with his or her environment. People who take initiative and gain energy from interactions are known as *Extroverts (E)*. *Introverts (I)* on the other hand prefer more of a relatively passive role and gain energy internally. The second category describes how a person processes information. A person who relies on her senses is referred to as a *Sensor (S)*, while a person who seeks to interpret and gain insight from information is called an *iNtuitor (N)*. The *Sensor* versus *iNtuitor* category is an interesting area of study when it comes to engineering education, because professors are historically intuitors while most engineering students are sensors[13]. The third MBTI category describes the manner in which a person evaluates information. Those who tend to use a logical cause and effect strategy, *Thinkers (T)*, differ from those who use a

hierarchy based on values or the manner in which an idea is communicated, *Feelers (F)*. The final category indicates how a person makes decisions or comes to conclusions. *Perceivers (P)* prefer to ensure all the data is thoroughly considered, and *Judgers (J)* summarize the situation as it presently stands and make decisions more quickly. The MBTI categories are not binary; generally, a person lies somewhere on a continuum between the extremes of each category.

6 Hats Overview

Each student completes a 6 Hats assessment so that we can better understand roles each student prefers in a design team[14,15]. We apply the results of the 6 Hats assessment with the belief that each individual has established patterns of communication that can be identified using the 6 Hats categories. Once these preferred communication styles/roles are identified, they may be used in a design team formation strategy to balance communication styles/roles as well as to ensure that certain styles/roles are represented. In addition, the communication styles/roles (as identified by 6 Hats) can be used to facilitate effective group communication by identifying strengths, potential areas for growth, and common conflicts that arise between certain 'hats'. Figure 3 shows the different hats and associated characteristics.

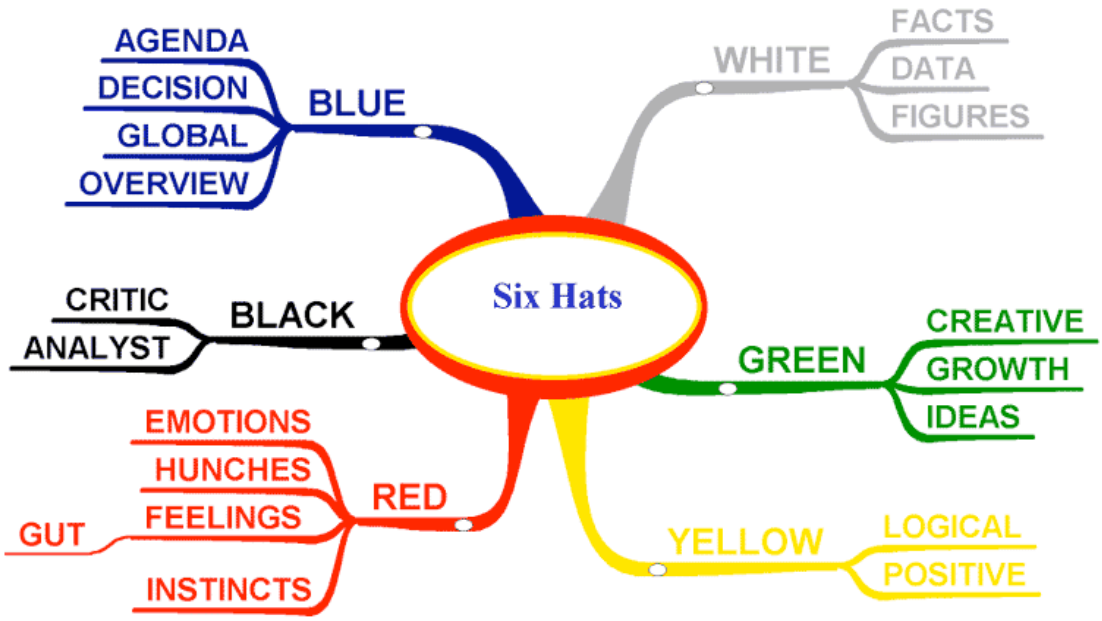


Figure 3: Summary of 6 Hats[16]

With deeper understanding of the complexities of our students, we are better able to develop and implement curriculum that enriches engineering education. Our curriculum, design team formation, and active learning experiences directly relate to the learning preferences and communication traits indicated in the MBTI and 6 Hats assessments. We believe that consideration of the diversity in our students provides a forum for more

successful collaborative learning situations and improves the opportunity for developing engineering literacy.

Scientific Literacies

> *In a world increasingly shaped by science and technology, scientific and technological literacy is a universal requirement…it is vital to improve scientific and technological literacy*[17].

Engineering education and the realization that engineering is an integral part of our daily lives are key components in developing educated persons in the 21st century[18]. Our educational systems and curricula must consider new ways to cultivate a broadly inclusive science and engineering workforce and expand the scientific literacies of all citizens. One of the ways that this can be achieved is through the implementation of active learning experiences that address a variety of learning preferences and communication styles in engineering education.

Reform in engineering education emphasizes the need for engineering to be accessible to all students and for all students to have the opportunity to attain high levels of scientific literacy[19]. Engagements in engineering experiences provide ways to address developing science literacy that involve not only skills and concepts but also multiple perspectives and types of text (graphical and written media) in engineering. These different and multiple understandings create dynamic forms of science literacies and inclusion of diverse values[20]. The experiences of becoming literate reflect back to how individuals negotiate among the sense-making worlds in which each lives. Indeed, Dewey claimed that all literacies involve the action of problem solving[21]. In our course, we consider and include acts of multiple and different literacies for reading, speaking, and writing about salient engineering resources such as: Pugh charts, patents, S-curves, customer needs charts, mission statements, product designs, poetry, images, biographies, and computer aided drawings to name a few[22].

Social Constructivism

Our curriculum is designed within a social constructivist framework in an effort to create engineering education experiences that (1) foster learners' capabilities and dispositions for engaging in collaborative project-based inquiry and critical thinking skills; (2) facilitate learners' practical engineering skills; and (3) support learners in constructing more depth and breadth of understanding of theoretical concepts in connection to practical experiences[23]. Our students are able to restructure their knowledge for themselves by assimilating new information and incorporating it into the existing knowledge[24]. With this social constructivist approach to teaching engineering, we support the notion that students learn most effectively by engaging in carefully selected collaborative problem-solving activities. During the semester, we are facilitators and coaches instead of being transmitters of knowledge.
Indeed, in science education, "scientific inquiry is at the heart of science and science learning" and "inquiry into authentic questions generated from student experiences is the central strategy for teaching science"[25]. Our curriculum provides forums for students'

own authentic interests in engineering problems to be sparked. Although there are many variations on the use of small group and collaborative problem solving in education, most share common characteristics[26]: (1) the foundation of learning is anchored in the first-hand experience of engaging with real world problems, projects, cases, simulations and experiments; (2) concepts are constructed and/or restructured by elaborating and explaining them to others in order to resolve conflict and controversy[27,28]; or to co-construct conceptions[29]; (3) discourse, dialogue, and negotiation to generate shared understanding are central to the process; and (4) the purpose of the experiences is not merely to solve a problem, but as important is to learn through the co-construction of knowledge that may be generalized beyond the specific problem[30].

Course Diary

The class is outlined in a collaborative course lesson diary composed by each of the four instructors. We describe content and pedagogical approaches for each class throughout the semester. This written tool facilitates communication among the instructors. This planning also allows reflection on the students' learning experiences in the class. Figure 4 shows a representative sample of the diary.

14 September 28, 2009	CN Analysis: Wok product; Techniques for CN's; Like / Dislike Method Show Redesign of Wok based on CN Analysis	Brain Teaser: SLS Parts from Dr. Seepersad
15 September 30, 2009	Finish CN Analysis; Understanding Customers and Design Teams. MBTI and Six Hats Pairs: each pair discusses MBTI ratings and what they think it means and implies	Brain Teaser: Alarm Clocks Web Site
16 October 2, 2009	Finish MBTI and Six Hats Student teams; distribute types of integral and modular multi-purpose tools Four teams discuss: why innovative, how are they architected.	Brain Teaser: Austin's small house web site; Dr. C's energy harvester web site

Figure 4: Course Lesson Diary Sample

Innovation Portfolio of Design Methods and Tools

The Engineered World: Products and Innovations focuses on engaging the student in using the engineering design process. For this course, the design process is presented as a series of innovation steps, as represented in Figure 5.

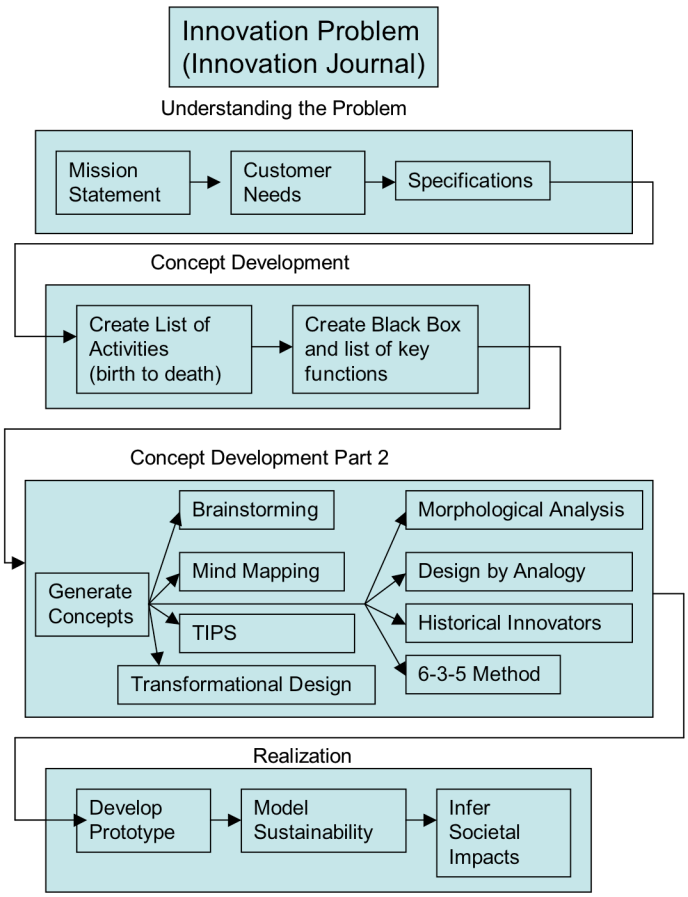


Figure 5: Innovation Process

The product design process is based on engineering design research[22,31,32,33,34]. Throughout the course the students understand and align what they were learning that day in class in relation to the design process. The elements of the design process are referred to as the innovation portfolio. As the class progresses, the students are given the course project rubric shown in appendix A. The rubric is an outline of the elements of the course and innovation portfolio. The rubric could be used by others to assist in developing a similar course. The rubric represents the main elements of skills that the students are asked to demonstrate in the final project.

The innovation portfolio comprises all work the students complete in the course. The portfolio corresponds to the course rubric for the class final product. The rubric incorporates the students' demonstration of active use of the skills fostered in the course. Representative examples of elements of the innovation portfolio are shown below through photographs, samples of course work, course feedback and samples of students' final presentations.

- Mission Statement – The mission statement is the students' first critical step toward defining the problem they are going to solve. The students also must demonstrate the ability to create concise writing while conveying a complete

thought. Figure 6 shows a representative sample of a student mission statement that was presented in a final presentation.

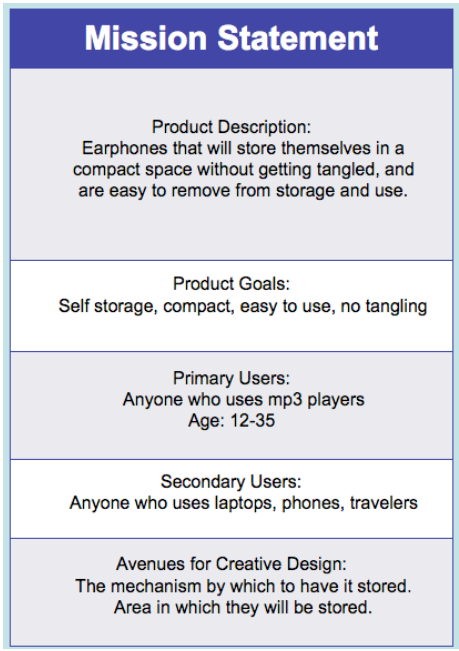


Figure 6: Student Sample of a Mission Statement

- Black Box – The black box is exercise to define the energy, materials and signals that enter and exit the product. This activity defines the interface between the device and the user and outer world. Figure 7 shows a representative sample of a black box the students created for their product.

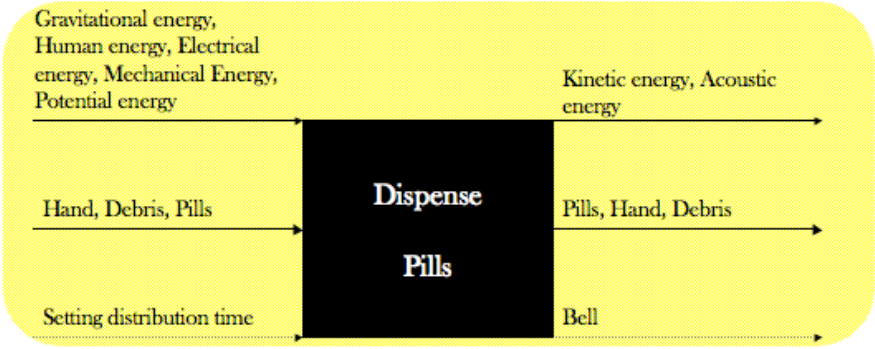


Figure 7: Student Sample of a Black Box

- Customer Needs – Understanding what the customer needs and wants is an important step in the development of the product. The students investigate what customers want in their product and develop an interpreted, prioritized list of

customer needs. Figure 8 is a representative sample of a customer needs table created by one student team.

Needs	Importance (1-5)
1. Aesthetics	3
a. Compact	4
b. Eye pleasing	2
c. Multi-function look (room décor)	1
2. Ergonomics	5
a. Easy to load/unload	5
b. Dispenser receives hand well	5
c. Easy to program (electronic)	5
3. Functionality	5
a. Delivers clean pill	5
b. Machine easy to clean	5
c. Travel component	2
d. Easy to maintain	5

Figure 8: Student Sample of a Customer Needs Chart

- Activity Diagram – The activity diagram allows the students to analyze how the product will be used by the customer from the creation to the retirement of the product. The analysis allows the students to make distinctions between what the customer will do versus what the product will do for the customer. This leads to decisions concerning, e.g., the level of automation in the product. Figure 9 provides an example of an activity diagram for combination tongue scraper and toothbrush project.

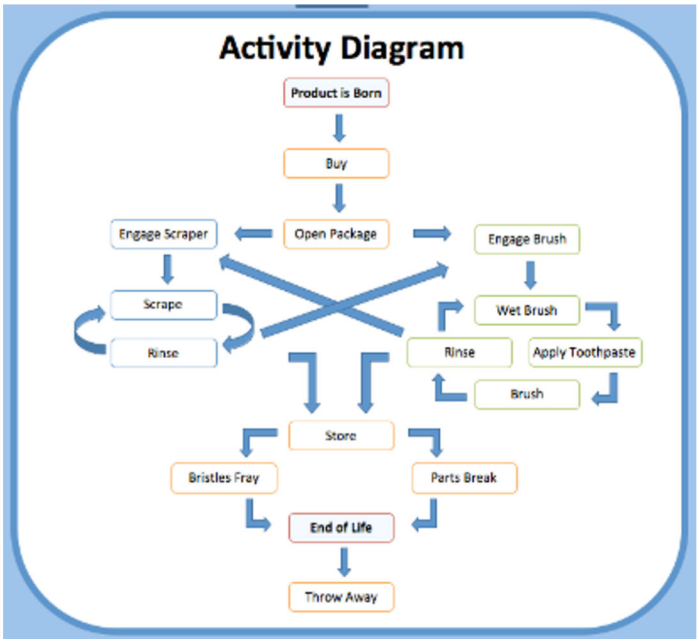


Figure 9: Student Sample of a Student Created Activity Diagram

- Top Five Functions – Identification of the top five functions in a product focuses attention on how the product will perform. The activity broadens the design effort so that students' efforts result in a more complete product. Figure 10 is a representative sample of functions that a team selected for their project that was to create a laundry carrying system.

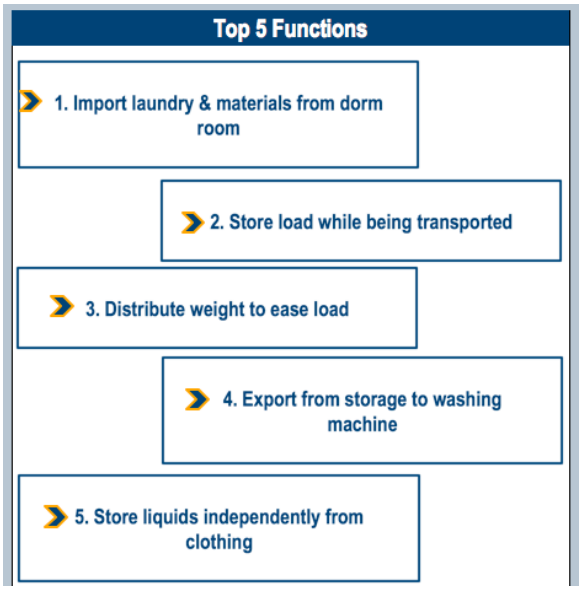


Figure 10: Student Sample of a Top Five Functions Chart

- Concept Generation Techniques – In the course the students were exposed to a variety of ways to generate concepts. Studies have shown that there are many different ways to generate concepts[35].

- Historical Innovator – Studying innovators from the past provides clues for how to innovate today. Figure 11 is a representative sample of how students used a historical innovator to assist them with concept generation of a self storing headphone set.

Historical Inventor: Zvi Yemini

A mechanical engineer trained at the Technion Israel Institute of Technology, with a masters in marketing from Baruch College, the 53-year-old Yemini started out designing massage showerheads and children's educational toys. His moment came when he designed an award-winning series of butterfly tool boxes for Home Depot. Then in 2002, Ehud Nagler had invented a water-powered engine, but couldn't figure out what to do with it. He brought the idea to Yemini, who came up with the idea for storing the engine in a hose reel.

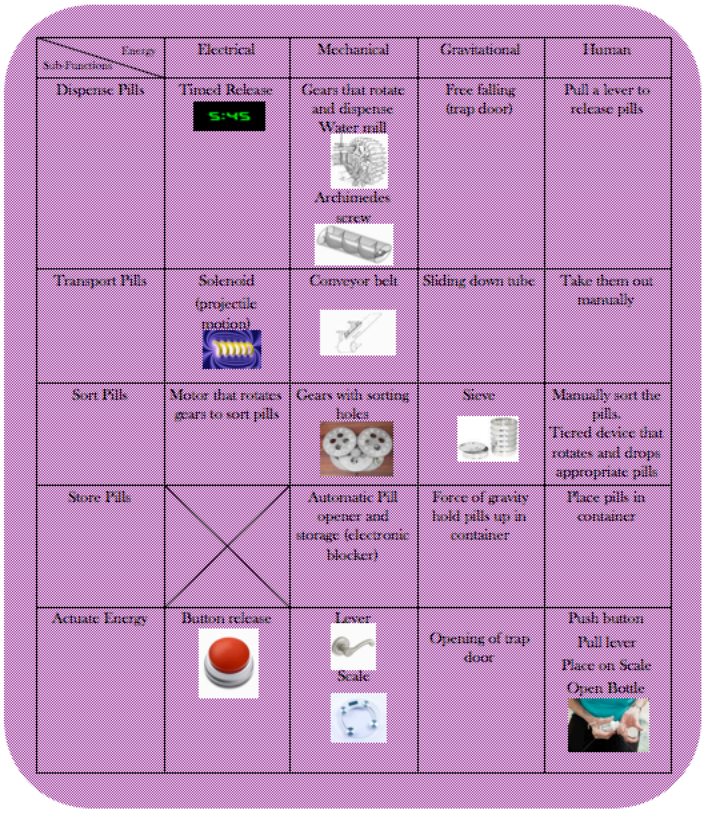
Operating the reel is pretty simple: After using the hose, a flick on the well-marked lever on the side of the reel activates the winding process by using the power of the water flowing within the hose to haul the hose back inside. Because it relies on water power, the reel doesn't require batteries, electricity or springs to operate.

Zvi Yemini's design principles that are similar to our design

-The products ability to retract
- The winding process doesn't rely on much human capability, batteries, or electricity.
- Products ability to prevent tangling.

Figure 11: Historical Innovator - Yemini

- Morphological Matrix – A morphological matrix organizes potential design solutions according to function and energy domain. Figure 12 shows a morphological matrix students created when working on a pill dispenser design.



Energy / Sub-Functions	Electrical	Mechanical	Gravitational	Human
Dispense Pills	Timed Release	Gears that rotate and dispense Water mill Archimedes screw	Free falling (trap door)	Pull a lever to release pills
Transport Pills	Solenoid (projectile motion)	Conveyor belt	Sliding down tube	Take them out manually
Sort Pills	Motor that rotates gears to sort pills	Gears with sorting holes	Sieve	Manually sort the pills. Tiered device that rotates and drops appropriate pills
Store Pills		Automatic Pill opener and storage (electronic blocker)	Force of gravity hold pills up in container	Place pills in container
Actuate Energy	Button release	Lever Scale	Opening of trap door	Push button Pull lever Place on Scale Open Bottle

Figure 12: Student Sample of Morphological Matrix

- Design by Analogy – The use of products with analogous functions facilitates concept generation. Figure 13 shows the different ways to retract and store, these analogies were used on a project to created headphones with self storing cables.

Figure 13: Student Sample of Design by Analogy

- Mindmap – The mindmap, or concept map, organizes the results of brainstorming and suggests categories that can lead to further concept generation, as shown in Figure 14 and Figure **15**.

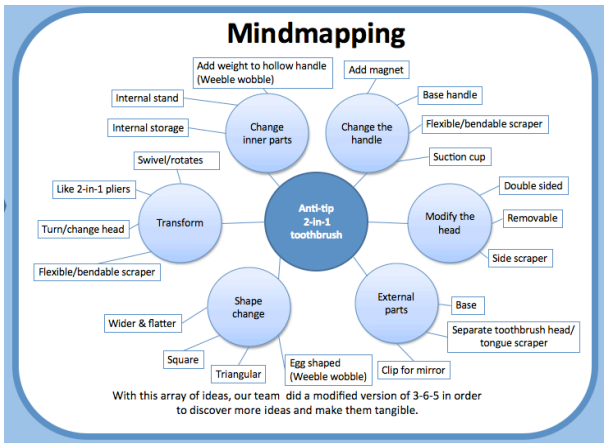


Figure 14: Student Sample of Mindmap Example One

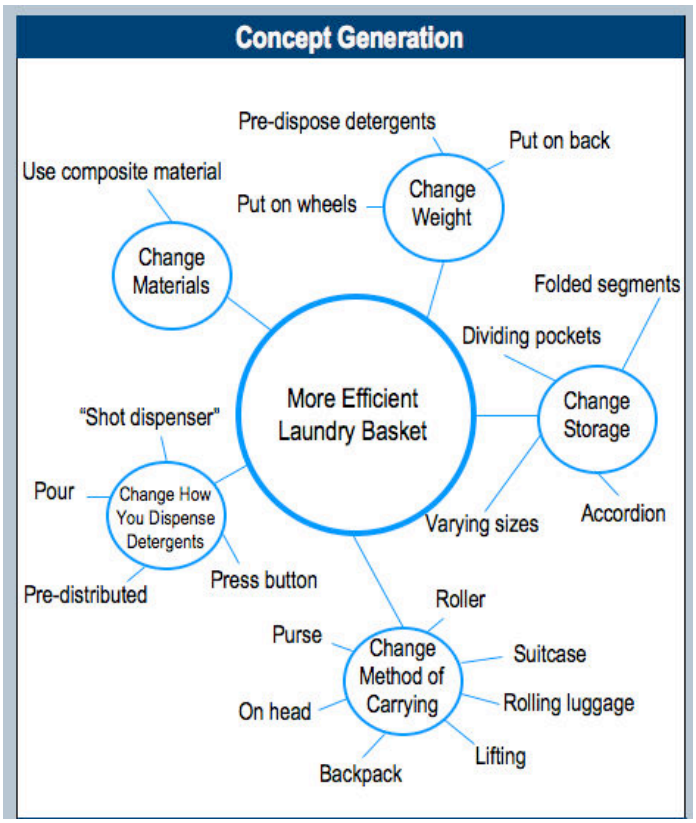


Figure 15: Student Sample of Mindmap Example Two

- 6-3-5 Method – This graphical concept generation technique complements brainstorming (which is verbal). The 6-3-5 method forces designers to think in terms of the physical world and how each function will be physically realized. An

example of a student 6-3-5 drawing is shown in Figure 16. The figure illustrates a several ideas of concepts to dispense pills. Each drawing represents different ways to funnel or push pills out of a dispenser. One of the differentiating aspects of the 6-3-5 technique is that the students silently rotate and draw on other students' concepts, thereby merging ideas in a visual format. The drawing in the center left is set of three pill dispensers that closely resembles the prototype the students later created.

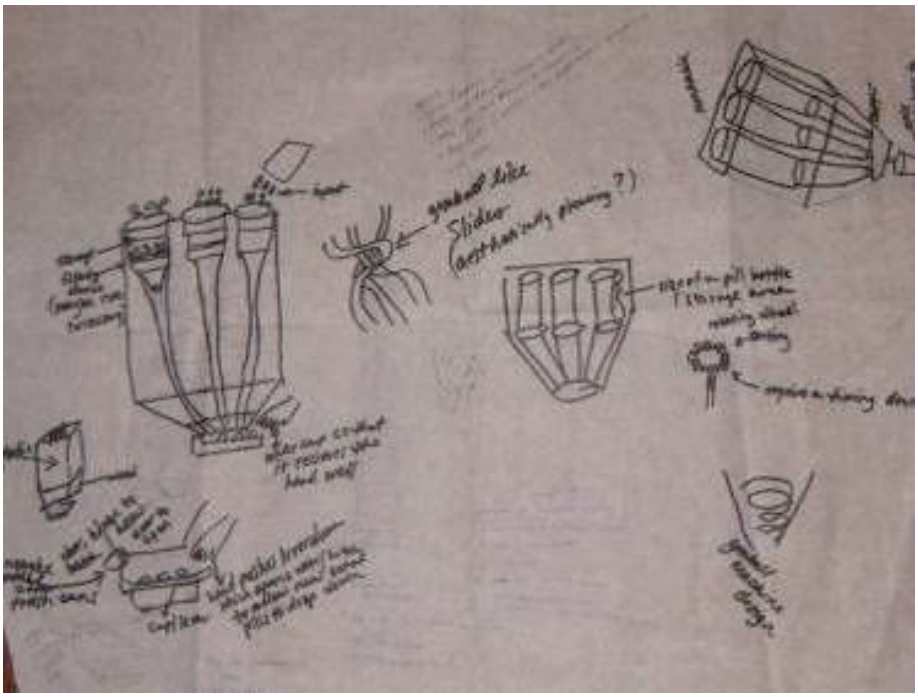


Figure 16: Student Sample of 6-3-5 Example

- Concept Selection – Pugh Chart – The students used Pugh charts to assist with selection of the design they would prototype. An example is shown in Figure 17.

Solution\ Function	Standard Basket (reference)	Backpack Basket	Basket w/ Wheels	Round, Modular Basket
Import laundry & materials from dorm efficiently	0	0	0	0
Store load while being transported	0	0	0	0
Distribute weight to ease load	0	-1	1	1
Export from storage to washing machine	0	-1	0	0
Stores washing liquids independently from clothes	0	1	-1	1
Total	0	-1	0	2

Figure 17: Student Sample of Pugh Chart

- Presentation Posters – To present all the work students completed on their projects, they created presentation posters. A representative poster is shown in Figure 18.

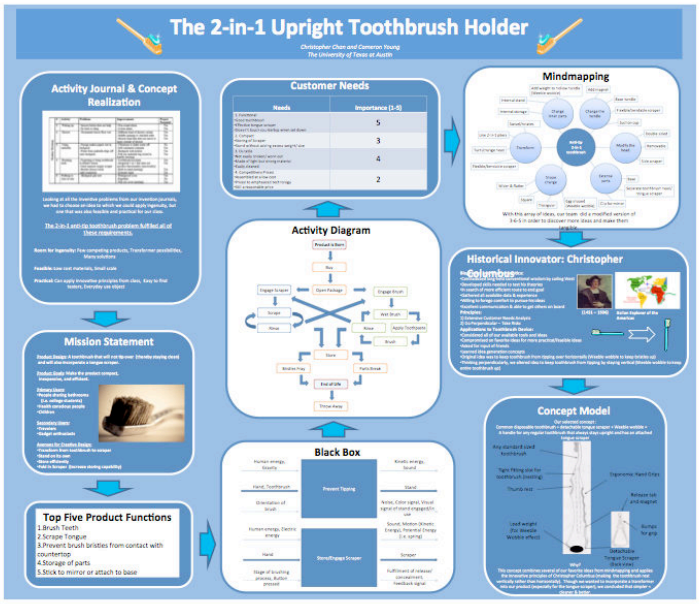


Figure 18: Student Sample of Design Poster

- Prototypes – Students created physical prototypes of their designs using supplies from a prototyping kit developed by the instructors. Figure 19 and Figure **20** show examples of prototypes built by students.

Figure 19: Student Pill Dispensing Prototype

Figure 20: Students Prototype of Assistive Needs ATM Arm Extender.

Analysis

During the course the students were evaluated in multiple ways, including direct discussion with the students, review of work produced and written reflection of the course. This formative evaluation allowed the instructors to revise the course during the semester.

To gain a better understanding of why the students (all non-engineers) take this engineering course, the students discussed their enrollment in the course verbally in class. The two most common answers are that it fits into their schedule and that they are interested in innovations.

As a part of the class the students were given assignments that allowed the instructors to evaluate the depth of understanding of the course materials. One topic the students learned about was the product S-curve[22]. In a written assignment the students were asked to give an example of a product family and its S-curves. Figure 21 illustrates one student's concept of an S-curve for a camera. This student shows deep understanding of the concept presented. The student understood the general, abstract concept and applied it the camera product line. The student's use of separate S-curves for film and digital development is excellent example of effectively using the concept.

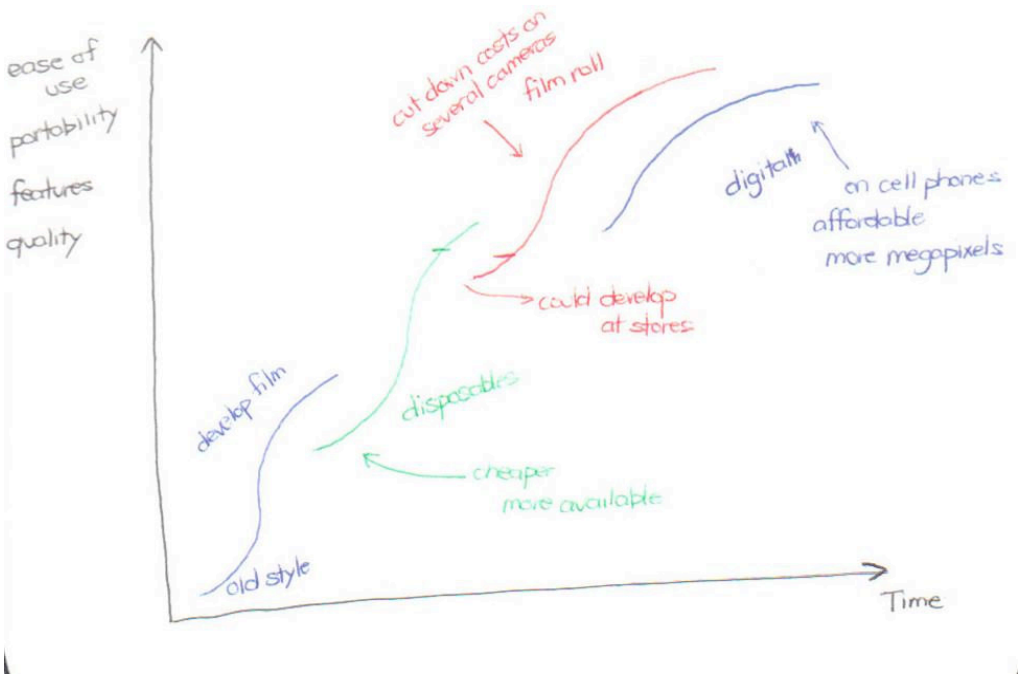


Figure 21: Student Sample of S-curve on Cameras

The students were also surveyed both at the beginning and at the end of the course. These results provided immediate feedback to the instructors. Figure 22 shows the results for one of the survey questions. This analysis gave feedback to the instructors on what classroom techniques the students liked. The y-axis of the Figure 21 graph is number of students that thought the teaching type was effective. One unexpected insight was that the students liked having lectures during the class and asked for more instructor-led discussion in the classroom. This information allowed the instructors to adjust the class during the semester.

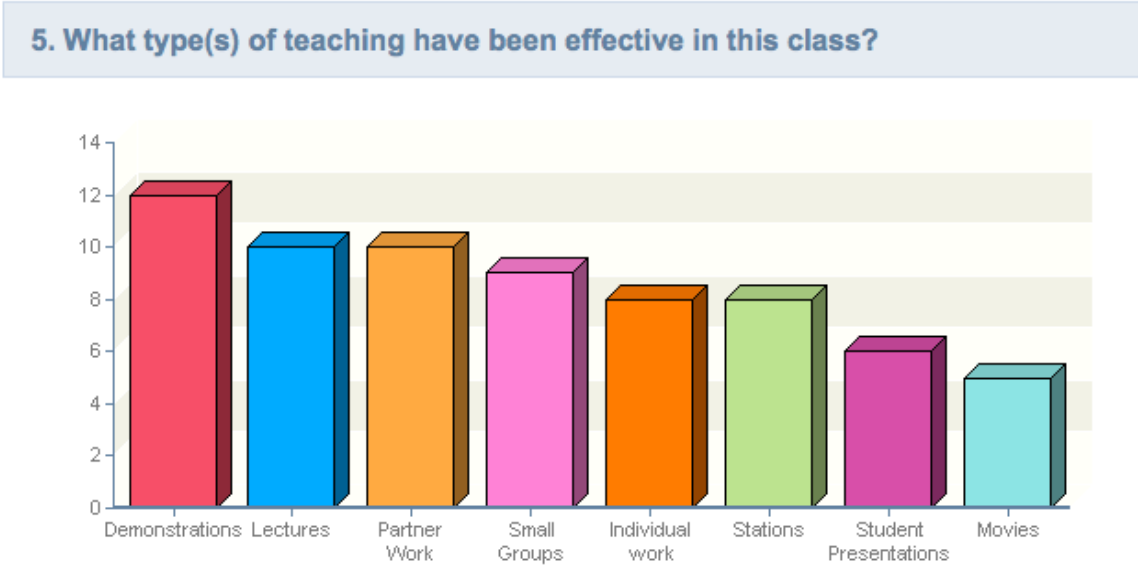


Figure 22: Representative Example of a Survey Feedback Question

At the end of the semester a final course survey was given to the students to assess their overall feelings and to provide feedback on the course. The survey covers a series of items; Table 2 highlights some of the more interesting items.

Table 2: Highlights of End of Course Survey

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. Taking the UGS302 class has given me a better understanding to what engineers do.	57% 8	42% 6			
2. After taking UGS302 I have gained a greater understanding of innovation.	71% 10	28% 4			
3. I understand the basics of the engineering design process.	57% 8	42% 6			
4. Having an instructor with an education background makes the class more diverse.	42% 6	42% 6	7% 1		7% 1
5. Concept generation with historical innovators is a useful technique.	7% 1	64% 9	14% 2	7% 1	7% 1
6. How satisfied are you with the real world examples presented in class.	57% 8	42% 6			

Results from the analysis are very intriguing. Items one, two, and three show that all students in the class agreed or strongly agreed that they gained a better understanding of engineering, innovation, and the engineering design process. This is a desirable outcome in relation to the course objectives, especially considering that the students were not majoring in engineering. Item four is worth more investigation since the vast majority agreed that having an instructor with an education background made the class more diverse yet not all students agreed. One of the ways to investigate this area in the future is to reword the question to ask instead if having instructors from different disciplines collaboratively teach a course provides an enriched learning environment. The small sample size of the class also indicates the need for more investigation. During the course a suite of concept generation techniques was presented to the students. Using historical innovators with concept generation is a technique that is in early stages of research development, and was presented to the students as part of the concept generation suite[32]. The results indicate the majority, but not all, of the students felt the technique was useful in it current form. Item six gives evidence that the students are satisfied with the use of real world examples in the class.

Conclusions

The results of our course evaluations, both formal and informal, indicate that, in general, the course was extremely successful as an introduction of the innovation process to non-engineers. While there is always room for improvement and evolution, the structure of the course provides a starting point for others to use in implementing similar courses. In particular, the course rubric in Appendix A lists the major concepts in the class and how they were evaluated. The signature courses at UT-Austin have allowed students to develop a closer relationship with faculty early in their academic careers, have exposed them to topics outside their majors, and have encouraged them to become scholars from the day they step foot on campus, fostering a community of self-learners. This course provides a framework for integrating instruction in writing and communication skills with teaching engineering and innovation concepts to any student. Analysis of this course indicates that students are intrigued with the engineered world, desire to contribute to the engineering world, are passionate about innovation, and are positively affected by non-traditional, active-learning-based classes.

Acknowledgements

This work is partially supported by a National Science Foundation grant under Grant No. CMMI-0555851, and, in part, by the University of Texas at Austin Cockrell School of Engineering and the Cullen Trust Endowed Professorship in Engineering No. 1. Any opinions, findings, or recommendations are those of the authors and do not necessarily reflect the views of the sponsors.

Bibliography

1 Myers, I.B., and McCaulley, M.H., Manual: A Guide to the Development and Use of the Myers-Briggs Type Indicator, Consulting Psychologists Press, Palo Alto, CA, 1985.

2 Human-metrics Jung and Myers-Briggs typing Instruments, http://www.humanmetrics.com/cgi-win/JTypes2.asp, *2009.*

3 Houtz, J.C., LeBlanc, E., Butera, T., Arons, M. F., Personality type, creativity, and classroom teaching style in student teachers. Journal of Classroom Interaction, 29, 21-26, 1994.

4 Jensen, D.D., Wood, J.J., and Wood, K.L., "Hands-on Activities, Interactive Multimedia and Improved Team Dynamics for Enhancing Mechanical Engineering Curricula," *International Journal of Engineering Education*, Vol. 19, No. 6, pp. 874-884, 2003.

5 Linsey, J., Talley, A., White, C. K., Jensen, D., and Wood, K. L., "From Tootsie Rolls to Broken Bones: An Innovative Approach for Active Learning in Mechanics of Materials," *ASEE Journal of Advances in Engineering Education (AEE)*, 2009, Vol. 1, No. 3, pp. 1-23.

6 Jensen, D.L., and Wood, K.L., 2000, "Incorporating Learning Styles to Enhance Mechanical Engineering Curricula by Restructuring Courses, Increasing Hands-on Activities, & Improving Team Dynamics," Proceedings of the 2000 ASME International Mechanical Engineering Congress and Expo., November 5-10, Orlando, Florida.

7 Jensen, D., Feland, J., Bowe, M., Self, B., "A 6-Hats Based Team Formation Strategy: Development and Comparison with an MBTI Based Approach," Proceedings of the ASEE Annual Conference, St Louis, June 2000.

8 University of Texas. Signature Courses, http://www.utexas.edu/ugs/sig, Dec 28, 2009.

9 Schnell C and Doetkott C 2002-2003. First year seminars produce long-term impact. Journal of College Student Retention: Research, Theory and Practice. 4 (4), p377-391.

10 Wolf P and Brandt R 1998. What do we know from brain research? Educational Leadership, 56(3): 8-13

11 Kuh JD 2001. The effects of student-faculty interaction in the 1990s. Review of Higher Education 24 (3), 309-32.

12 Schmidt, K.J. "First Year Seminars: Opportunities for Student Reflection and Discourse," 33rd International Conference on Improving University Teaching, Glasgow, Scotland, 2008.

13 Felder, R.M., and Silverman, L.K., "Learning and Teaching Styles in Engineering Education," *Engineering Education*, Vol. 78, No. 7, pp. 674-681, 1988.

14 Jensen, D., Feland, J., Bowe, M., Self, B., "A 6-Hats Based Team Formation Strategy: Development and Comparison with an MBTI Based Approach," Proceedings of the ASEE Annual Conference, St Louis, June 2000.

15 Jensen, D., Wood, K., "Incorporating Learning Styles to Enhance Mechanical Engineering Curricula by Restructuring Courses, Increasing Hands-on Activities, & Improving Team Dynamics," ASME Publication & Presentation for the Award for the Most Innovative Curriculum for the year 2000, Presented at the ASME Annual Conference, Orlando, FL, Nov., 2000.

16 World Education Council, "Summary of Edward de Bono's Six Thinking Hats", http://dl.wecouncil.com/SerfWeb/User9/cscuploads/MM---Six-Hats.gif, 5 January 2010.

17 Mayor, F. Director-General of United Nations Education, Science, Cultural Organization (1999). *Science and technology in Africa: A commitment for the 21st century*. Retrieved 10 January 2007 from http://www.unesco.org/bpi/scitech/print.htm.

18 Jahnke, T. & Level, A., Expanding your horizons: A program for engaging middle school girls in science and mathematics. *Journal of Women and Science in Engineering, 11*, 171-179, 2005.

19 National Research Council, 1996; American Association for the Advancement of Science, 1989

20 Norris, S. & Phillips, L., What is at stake in knowing the content and capabilities of children's minds? *Journal of Theory and Research in Education*, *2*(3), 283-308, 2004.

21 Dewey, J., *Democracy and education: An introduction to the philosophy of education*. New York: Macmillan, 1944.

22 Otto, K. N. and Wood, K. L., *Product Design: Techniques in Reverse Engineering, Systematic Design, and New Product Development*, Prentice-Hall, NY, 2001.

23 Hanson, J. and Sinclair, K., Social constructivist teaching methods in Australian universities- reported uptake and perceived learning effects: A survey of lecturers. *Higher Education Research & Development, 27* (3), 169-186. 2008.
24 Marland, M. & Barnes, D., *Language across the curriculum: The implementation of the Bullock Report in the secondary school.* London: Heinemann Educational Publishing, 1977.
25 National Research Council, *National science education standards*. Washington, DC: National Academy Press, 1996.
26 Scarmdamalia, M. and Bereiter, C., Process and product in problem-based learning research. In D.H. Evensen and C. Hmelo (Eds.), *Problem-Based Learning, A Research Perspective on Learning Interactions*. Mahwah, NJ: Lawrence Erlbaum Associates, 2000.
27 Palinscar, A. and Brown, A., Guided, cooperative learning and individual knowledge acquisition. In R. Glaser and L. Resnick (Eds). *Knowing, Learning, and Instruction: Essays in Honor of Robert Glaser*. Lawrence Erlbaum Associates. 393-444. 1989.
28 Piaget, J., *The language and thought of the child*. New York: Harcout, Brace, Jovanovich Publishing.Scarmdamalia, M. and Bereiter, C. (2000). Process and product in problem-based learning research. In D.H. Evensen and C. Hmelo (Eds.), *Problem-Based Learning, A Research Perspective on Learning Interactions*. Mahwah, NJ: Lawrence Erlbaum Associates, 1926.
29 Vygostky, L., Interaction between learning and development. In Gauvain & Cole, *Readings on the development of children* (pp. 34-40). New York: Scientific American Books, 1978.
30 Hanson, J. and Sinclair, K., Social constructivist teaching methods in Australian universities- reported uptake and perceived learning effects: A survey of lecturers. *Higher Education Research & Development, 27*(3), 169-186, 2008.
31 Talley, A., Schmidt, K., Wood, K., and Crawford, R., "Understanding the Effects of Active Learning in Action: What Happens When the "New" Wears Off in Teacher Training", Proceedings of the ASEE Annual Conference, June 2008.
32 Jensen, D. J., Weaver, J., Wood, K. L., Linsey, J., and Wood, J., "Techniques to Enhance Concept Generation and Develop Creativity," *ASEE Annual Conference*, Austin, TX, June, 2009, AC 2009-2369, pp. 1-25.
33 Linsey, J., Wood, K., and Markman, A., 2008, "Increasing Innovation: Presentation and Evaluation of the WordTree Design-by-Analogy Method," *Proceedings of the ASME Design Theory and Methodology Conference*, New York, NY, 2008.
34 Wood, K.L., Jensen, D., and Singh, V., "Innovations in Design Through Transformation: A Fundamental Study of tRaNsFoRmAtIoN Principles," *ASME Journal of Mechanical Design*, 2009, Vol. 131, No. 8, pp. 081010-1 thru 081010-18.
35 Jensen, D., Weaver, J., Wood, K., Linsey, J., and Wood J., "Techniques to Enhance Concept Generation and Develop Creativity", Proceedings of the ASEE Annual Conference, June 2009.

Appendix A – UGS 302 Course Rubric

Poster+ UGS 302 Final Project Presentation

Name: Project:	Novice	Apprentice	Practitioner	Expert
Mission Statement	• States the problem but it is unclear. • Show minimal understanding of the problem. • Identifies how the concept will address the problem in relation to the customer needs.	• States the problem. • Shows some understanding the problem. • Identifies how the concept will address the problem in relation to the customer needs.	• States the problem well. • Understands the problem. • Clearly identifies how the concept will address the problem in relation to the customer needs.	• States the problem well. • Shows understanding of the problem on multiple levels. • Clearly identifies how the concept will address the problem in relation to the customer needs.
Concept Development	• Uses activity journal to log ideas about a few daily challenges that spark concepts. • Unable to articulate how a problem can be solved with an engineering concept.	• Uses activity journal to log ideas about daily challenges that spark concepts. • Somewhat able to articulate how a problem can be solved with an engineering concept.	• Uses activity journal to log ideas about daily challenges that spark multiple concepts. • Able to articulate how a problem can be solved with an engineering concept and includes technical vocabulary.	• Uses activity journal to log ideas about daily challenges that spark many novel concepts. • Able to articulate how a problem can be solved with an engineering concept and includes technical vocabulary.
Concept Realization	• Considers none or one of the following: feasibility, ingenuity, & practicality needed for concept design & prototyping.	• Shows some consideration of the feasibility, ingenuity, & practicality needed for concept design & prototyping.	• Considers the feasibility, ingenuity, & practicality needed for concept design & prototyping.	• Considers the feasibility, ingenuity, & practicality needed for concept design & prototyping and articulates each one specifically.
Black Box	• Identifies none or a few of the system inputs & outputs.	• Identifies about half of the system inputs & outputs &/or diagrams incorrectly.	• Identifies almost all of the system inputs & outputs & diagrams them correctly.	• Identifies all possible system inputs & outputs & diagrams them correctly.
Customer Needs	• Asks questions to parse out some user requirements.	• Asks questions to parse out specific user requirements & some desires for product.	• Asks meaningful & appropriate questions to parse out specific user requirements & desires for product.	• Asks meaningful & appropriate questions to parse out specific user requirements & diverse desires for product.
Activity Diagram	• Creates partial or inaccurate path from product birth to product death.	• Creates path from product birth to product death.	• Creates path from product birth to product death with more than one perspective.	• Creates path from product birth to product death with unique & multiple perspectives included.
Top 5 Functions	• Imagines & specifies none or some of the main 5 functions in the product.	• Lists the main 5 functions in the product.	• Imagines & specifies in detail the main 5 functions in the product.	• Imagines & specifies in detail that includes engineering vocabulary the main 5 functions in the product.
Historical Innovator	• Provides a biography of a historical innovator.	• Provides a biography of a historical innovator. • Aligns principle with research of a historical innovator.	• Provides a biography of a historical innovator& images that help create understanding of her/his important work. • Aligns principles & applications with research of a historical innovator.	• Provides a biography of a historical innovator& images that help create understanding of her/his important work. • Aligns multiple principles & applications with research of a historical innovator.
Concept Generation Techniques	• Engages in one strategy that facilitates concept generation and partially attempts other strategies.	• Engages in a few strategies that facilitate concept generation.	• Engages in multiple strategies that facilitate concept generation.	• Engages in strategies that facilitate concept generation and shows close connections to those strategies throughout the design process.

Poster+ UGS 302 Final Project Presentation

Concept Selection	• Articulates how or why concept was chosen but some parts are unclear.	• Articulates how & why concept was chosen.	• Clearly articulates how & why concept was chosen.	• Clearly articulates how & why concept was chosen. • Shares decision-making process including communication strategies and overcoming challenges in choosing a concept.
Prototype/ Concept Model	• Physical model represents concept by addressing the problem. • Model is incomplete &/or not a robust design. • Materials are not carefully incorporated into design.	• Physical model represents concept by addressing the problem & customer needs. • Model is complete & robust. • Materials are carefully incorporated into design.	• Physical model represents concept by addressing the problem & customer needs. • Model is complete & robust. • Materials are carefully incorporated into design and used in unique ways to enhance function &/or aesthetics.	• Physical model represents concept by addressing the problem & customer needs. • Model is complete, robust, & meets multiple customer needs. • Materials are carefully incorporated into design and used in unique ways to enhance function &/or aesthetics.
Team Work & Participation	• Limited participation & communication with partner & others throughout the project phases.	• Actively participates & communicates with partner & others throughout the project phases.	• Actively participates & communicates with partner & others throughout the project phases. • Demonstrates leadership skills occasionally.	• Actively participates & communicates with partner & others throughout the project phases. • Demonstrates leadership skills throughout whole group, small group, and partner experiences.
Writing/Grammar/Mechanics	• Written product is limited or unclear in explaining the project processes. • Inaccurate sentence construction (including grammar, complexity, spelling, & punctuation).	• Written product explains the project processes. • Well-constructed sentences (including grammar, complexity, spelling, & punctuation).	• Written product explains the project processes. • Elegant sentence construction (including grammar, complexity, spelling, & punctuation).	• Written product explains the project processes. • Elegant sentence construction (including grammar, complexity, spelling, & punctuation). • An inclusion of alternative forms of written communication (e.g. poems, concept splashes, wordles).
Presentation	• Visual representation • Oral presentation: volume, eye contact, enthusiasm, knowledge of materials, timing, sequence of presentation, ability to answer questions	• Visual representation in multiple forms that are well constructed • Oral presentation: volume, eye contact, enthusiasm, knowledge of materials, timing, sequence of presentation, ability to answer questions	• Visual representation in multiple forms that are well constructed. Visuals include each facet of the design process. • Oral presentation: volume, eye contact, enthusiasm, knowledge of materials, timing, sequence of presentation, ability to answer questions • Finesse of storytelling to capture & maintain attentions and create clear journey of design process	• Visual representation in multiple forms that are well constructed. Visuals include each facet of the design process. Technology is incorporated in unique and enhancing ways. • Oral presentation: volume, eye contact, enthusiasm, knowledge of materials, timing, sequence of presentation, ability to answer questions • Finesse of storytelling to capture & maintain attentions and create vivid, clear, & provocative journey of design process