AC 2009-1906: INCREASING THE INNOVATION ABILITY AND APTITUDE OF TECHNOLOGY AND ENGINEERING STUDENTS THROUGH FOCUSED COLLABORATIVE, CROSSDISCIPLINARY DESIGN-THINKING BOOT CAMPS

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Innovation Boot Camps: a Collaborative, Cross-Discipline, Technology Enhanced Approach to Enhancing Student Innovation Aptitude and Ability

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Abstract: We believe students need to possess an understanding of innovation and related skills (i.e., creativity, problem finding and forming, ability to generate and develop new ideas into practical and helpful products, etc.) to keep pace and stay ahead of the rapid development and implementation of new science and technology in the 21st century. This research focuses on the methods and efforts developed and being implemented to advance a culture of innovation within our college of technology and engineering. The primary method we have developed to help our students be innovative involves emerging them in an Innovation Boot Camp. The purpose of this paper is to describe the purpose, learning outcomes, curriculum, methods of instruction, and the relative impact the Boot Camp is having on student understanding of and skills associated to innovation, and how the experience is impacting our college initiative to create a culture of innovation.

Introduction

The *Innovation Boot Camp* is an intensive hands-on, collaborative experiential learning workshop focused on educating students on the principles and processes of innovation. The structure of the initial Innovation Boot Camp was a two-day experience, blending students and faculty from six different programs/departments (i.e., Technology Engineering Education, Manufacturing Engineering, Industrial Design, Information Technology, and Construction and Facilities Management).

The purpose of this paper is to describe what we did, how we did it, and why it is important. The "What" section will include a description of the Innovation Boot Camp: it's purpose, development, curriculum, theoretical underpinnings, learning outcomes, and associated literature. The "How" section will discuss the implementation stages of the Boot Camp, its organization and logistics, activities developed and engaged in, and methods of instruction. Finally, the "Why" section will outline the findings and data analysis aggregated thus far, and provide a discussion of the impact the Boot Camp is having on student understanding of and skills associated to innovation, restructuring issues, how the experience is impacting our college initiative to create a culture of innovation, and why we believe other universities/schools would be interested in this effort.

Innovation Boot Camp: What We Did

Background

Ever since the late 1700s to modern day, "a major source of technological advancement has been the result of individual inventors [and] innovations" (Kleppe, 2001, p. 16); surprisingly, most technology and engineering programs around the U.S. do not explicitly teach innovation (Smoot, 2006). With the increasingly complex and competitive global market, and with new interest and concern over environmental issues, biotechnologies, and so forth, many companies (American and foreign) are reforming how and in what they do business. Additionally many academic institutions are calling for a "radical restructuring of the theoretical knowledge taught in academic education programs… in order to create competencies of professional value in today's business situations" (McAloone, 2007, p. 770). In order to address the many challenges involved in the new global industrial arena, many technology educators believe the theoretical restructuring that needs to take place must involve and center on innovation. If we want to better prepare technology and engineering students to be globally competitive, we must expand and center our current curriculum on innovation (Kleppe, 2001).

A study done by the Southern Technology Council found that there are very few universities supportive of innovation, despite the need to include it as a key component of technology and engineering curriculum (Kleppe, 2001). The lack of support and inclusion of innovation in technology and engineering related programs seems to stem from archaic mathematic and science curriculum standards, and immature technology and engineering curriculum standards. Although engineering programs have existed and been taught for well over sixty years at the university level, most of the courses and degrees have focused on traditional engineering concepts (i.e., hard math and sciences) and have not bridged into the areas of creativity and innovation. It has only been recently that universities have started to recognize creativity as a key component of engineering (Courter, 2006). In light of the need to ensure our students are ready for the challenges in our global economy, we as technology and engineering educators, need to ensure we are continuing to evolve our practices and curriculum – which at present time, demands the need to include innovation as a key component of technology and engineering curriculum.

Statement of Problem

Dating from the foundation of the United States, one of its defining characteristics has been its ability to encourage and accept innovation. However, with the economic need and acceptance of outsourcing, and competition in global product development, among other things, many American engineering and technology companies and institutions are re-thinking and re-structuring the content and instruction of engineering and technology curriculum (McAloone, 2007). In an effort to address this issue, our college has established several school wide technology and engineering initiatives, one of which specifically focuses on enhancing and promoting innovation.

To address the innovation initiative, the college created a committee to investigate ideas of how to promote innovation. The committee, or Innovation Design Team as they were later titled,

travelled to several internationally recognized institutions known for their exemplary models of innovation (i.e., Stanford D-school, IDEO, and so forth), and performed a significant literature review and analysis of innovation, its principles, processes, techniques, implications, and so forth. One of the resulting ideas the Innovation Design Team developed and hoped would make a positive impact on student innovation ability and aptitude was to institute an intensive experiential multidisciplinary class focused on teaching innovation.

Statement of Solution: Innovation Boot Camp

The Innovation Design Team used the data they collected from their observations and visits of the various well-known innovation institutions, and the literature they read (i.e., *Handbook of Creativity, Six Thinking Hats, Lateral Thinking, Creative Toolbox*, various journal articles, and so forth) to formulate several ideas of how to create a culture of innovation in our college of engineering and technology. Various ideas were hypothesized, however, ultimately it was decided an intensive experiential workshop highlighting the key principles of innovation would be first tried; this workshop was titled the *Innovation Boot Camp*.

In short, the boot camp was an intensive workshop focused on innovation where students were immersed in an experiential collaborative learning environment, where they worked in teams with students from the various programs housed within the college (i.e., Industrial Design, Mechanical Engineering, Manufacturing, Technology Engineering Education, Information Technology, and Construction and Facilities Management), to identify and solve problems using processes of innovation.

Innovation Boot Camp: How We Did It

Boot Camp Architecture

Initially the Boot Camp's primary curriculum and instructional techniques were based on "Design Thinking." Design Thinking is a method that is *user centered*, has a tradition of *prototyping* (which includes visualization), and a *trust in the process* of: 1) Seeking inspiration for problem finding through the activities of Look, Do, and Ask; 2) Broad divergent ideation; 3) Implementation in the form of prototyping; and 4) Public Presentation using the activities of Show, Tell, and Act. This definition was culled from several sources including IDSA (Industrial Designers Society of America) National Conference presentations, site visits to the Stanford d.School (institute of design) and IDEO (top-rated innovative design firm), publications on creativity and innovation by the Rotman School of Business, and various other sources on creative problem solving and innovation.

The Boot Camp structure is currently organized as a two-day experience, where students from the various programs within the college collaborate to problem find and ideate solutions to various product, service, and or process issues. Thus far we have held six boot camp experiences, averaging 16 participants. The participants were split into small multidisciplinary groups of 4 – 6 students and 1 faculty member. In the initial iterations of the Boot Camp we placed the faculty in their own group because we wanted to give the students a chance to work independent of the faculty, and not be influenced by any figures of authority. We later realized both faculty and

students seemed to mutual benefit from collaborative interactions with each other, consequently in subsequent boot camp sessions we have mixed faculty with students.

A key attribute of the group organization and design was to create positive competition between the groups. To accomplish this, in the first activity of the day, prior to any introductions or instruction, each multidisciplinary group (or team as we called them), was to create a "team identity using only the supplies provided them on their tables (e.g. Play Dough, wire hangers, tape, card stock paper, etc.) For this activity they were provided 10 minutes, and were told their identity needed to be representative of the names and interests of each group/team member. At the end of the 10 minutes each group went to the front of the classroom and presented who they were and their identity creation (note: for the rest of the Boot Camp the teams were referred to only by their team name). Immediately following the team identity activity the students were provided an outline of the day's schedule, learner expectations, and a brief introduction to the need and purpose of the Innovation Boot Camp.

During day one we introduced the students to the need and idea of innovation, and helped the students establish a working definition of it by engaging them in various mini-activities highlighting the primary principles and processes of innovation. The activities ranged from "user-centered" activities such as *personamining and bug listing,* to "personal filter" exercises such as *metaphor and analogy creation and association, vuja de, association thinking, and so forth (each of the activities and others are explained in appendix A found in the full paper).* The purpose of the mini-activities was to: a) provide the boot camp participants with activities to help them semantically encode the primary principles of innovation, and b) to help them prepare for the final two innovation activities: a formative ideation project, and a summative capstone experience.

Both the formative ideation project, and the innovation capstone experience required the students to demonstrate how they came to their solutions as a result of using/engaging the principles and processes of innovation. The participants were assigned and completed the ideation project during the first day of instruction. It provided the participants with the opportunity to immediately put into action the principles and processes they had experienced in the innovation mini-activities. The ideation project required the participants to not only rapidly go through each of the processes of innovation, but to create a working prototype of the product, service, or process they created. Appendix B provides a brief description of several of these projects.

The summative capstone experience was assigned at the end of the first day of the boot camp. The capstone experience required the students to engage the principles and processes of innovation over an extended period of time (1 – 3 days) in an effort to create an innovative product, system, or process. We believed the extended allotment of time would serve as a gestation period, helping the students further inculcate the principles of innovation. Additionally, we hoped the increased time allotment would provide the students with the requisite time to develop a more innovative product, service, or process. On the final day of the boot camp the participants were asked to present their innovation while discussing how they developed it. A panel of judges from local design and engineering companies were brought in to evaluate the student's projects. Awards were provided to the top three teams

We anticipated the students would present how they used the principles and processes of innovation to develop their capstone project. Although most of the groups did highlight how they used the innovation processes to develop their project, there were a few groups who reported they did not use the entire process.

There were additional findings we discovered in result of an exit survey, focus group interviews, and from analyzing the video documentary made about the boot camp, which will be discussed below.

Innovation Boot Camp: Why it is Important

Boot Camp Evaluation

Holistically we feel the adoption and commitment to explicitly teach and provide students with innovation training through efforts such as the boot camp is necessary and will prove beneficial. Thus far, the data points gathered from various surveys, exit interviews and discussions, and a video analysis of the boot camp suggest students are benefiting from the boot camp experience.

A dozen Innovation Boot Camps will have been held by the start of the ASEE2009 Conference. Currently we have held five Innovation Boot Camps and have gathered mostly qualitative data up to this point. However, as additional data points are aggregated in result of the subsequent forthcoming six boot camp experiences, a quantitative component will prove necessary and informative.

Formative and summative methods were used to evaluate the impact the Boot Camp experience had on the students and faculty. The formative evaluation method included two primary components: a film component, and an outsider evaluator component.

The film component consisted of filming a video documentary of the boot camp, which was used to critique and analyze the attentiveness and participation of each student. The instructors of the Boot Camp were also invited to watch the video to evaluate their instructional methods and the associated activities and content.

The outside observer component consisted of having two outside observers from the college attend the boot camp and take notes and make observations regarding what was done, how they perceived the instruction was being received, how the activities were helping the students understand the principles and concept of innovation, and how the students enjoyed or did not enjoy the experience and so forth.

The summative evaluation methods consisted of an exit survey, debriefing session, and a focus group interview session. The survey, debriefing, and focus group interview questions focus on issues relating to perceived innovation growth and understanding. The following list outlines a representative sample of the questions asked:

1. Define innovation (what does innovation mean to you?)
2. What re the parts/key components of the “design process”?

3. Rate your current level of innovation (understanding, skill set, and so forth) (Note: 1 = low, 10 = high).
4. Rate how willing you are to tolerate uncertainty and risk (1 = not willing, 4 = very willing).
5. What are the parts/key components of the "process of innovation?"
6. Rate how well you believe you can spot/draw links/relationships between things (1= not at all, 4 = above average).
7. Rate your current level of creativity (understanding, skill set, etc.) (Note: 1 = low, 10 = high).
8. Rate your level of creativity and how it stimulates creativity in others (Note: 1 = low, 10 = high).
9. Rate your willingness to tolerate ambiguity (the ability to perceive choices in a neutral and open way) (1 = not willing, 4 = very willing).
10. Rate how well you keep abreast of the new and best in your specific fields and related fields of study (1 = not at all, 5 = way above average).
11. Rate how well and willing you are to take risks that support innovation.(1 = not willing, 4 = very willing).
12. Rate your ability to think about problems in different ways (not to be constrained to a particular attack on a problem) (1 = not willing, 4 = very willing).
13. Rate your willingness to change as change is required (1 = not willing, 4 = very willing).
14. Rate you willingness and ability to work laterally (switching your thinking from one way or one direction to another) in contrast with vertical work (always driving forward to finish a project without deviation) (1 = not willing, 4 = very willing).
15. Rate how well you believe you can form association between distinctly different objects, careers, etc. (1 = not at all, 4 = above average).
16. Rate how adept you are at putting judgment on hold (1 = not willing, 4 = very willing).
17. Rate how well you incorporate innovative ideas into action (1 = not at all, 4 = above average).
18. Rate your willingness and ability to encourage and support innovation in yourself and others (1 = not at all, 4 = above average).
19. Rate how well you reframe failures positively and learn from them (1 = not at all, 4 = above average).
20. What are your general impressions of the Innovation Boot Camp (i.e., worth your time or not, suggestions re: content, curriculum, logistics, time, etc.)?
21. Did the Innovation Boot Camp influence your understanding of innovation (1 – 5 scale, 5 being highest influence)?
22. How do you think your skills related to innovation were influenced (1 – 5, 5 = significant amount)?
23. How do you think your propensity (interest and aptitude) for innovation was influenced (1 – 5, 5 = significant amount)?
24. Should the boot camp be offered on some scale (Yes/No)?
25. Give us some honest feedback regarding the boot camp (what did you like, dislike?) What would you add, subtract, etc.?

Cronbach's Alpha test was used to verify the consistency (some relate consistency to reliability) of the survey questions. The reliability statistics calculate Cronbach's Alpha to be .764. Thus we can conclude the survey seems to have a high internal consistency.

Overall survey and interviews results (n = 54) stated that 100% of the students reported they believed the Innovation Boot Camp should be continued. 71% of the students (n = 54) said they believed their time spent at the Boot Camp was *Effective*. When the students were asked to rate on a 1 – 5 scale (5 being high) how the Innovation Boot Camp influenced their understanding of innovation, the mean was 4.0, the variance was a 1, and the standard deviation was a 1, suggesting they believed the boot camp had a significant influence on the understanding of innovation. Additionally a pre post survey shows that students report they believed their innovative abilities increased in result of the boot camp (see table 1.1).

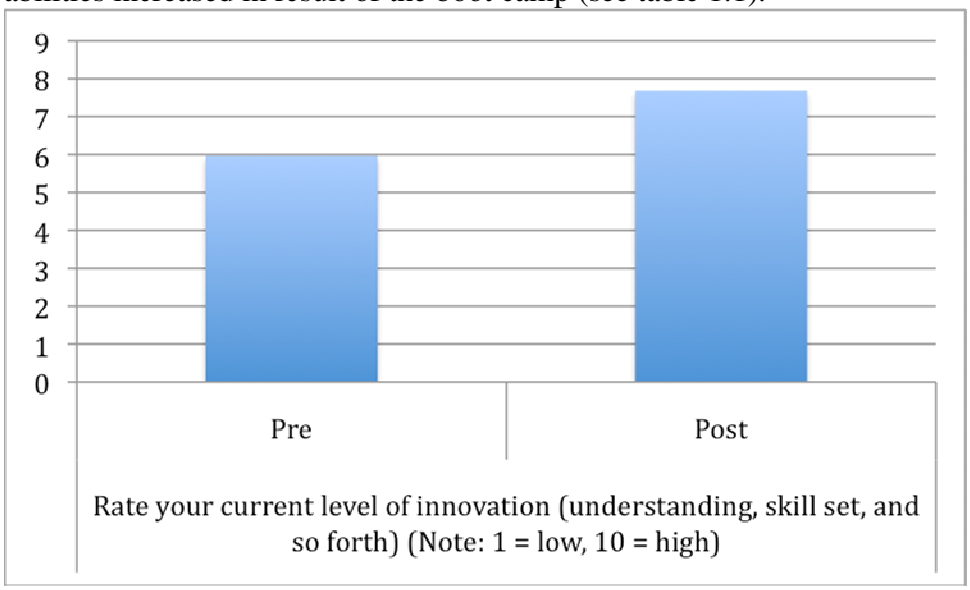

Table 1.1

In support of this several measures based on several creativity and innovation assessments were used to study how did student's innovative abilities increase. The following table (table 1.2) outlines a representative sample of these questions and student pre and post scores.

Question	**Pre Boot camp Score**	**Post Boot camp Score**
Rate how well you incorporate innovative ideas into action. (Based on a rating scale of 4).	3.5	3.8
Rate your willingness and ability to work laterally. (Based on a 4 point rating scale).	3	3.12
Rate how well you incorporate innovative ideas into action. (Based on a 4 point rating scale).	3.5	3.8
Rate your willingness and ability to encourage and support innovation in yourself	3.7	3.72

and others. (Based on a 4 point rating scale).		
Rate how willing you are to tolerate uncertainty and risk. (Based on a 4 point rating scale).	2.76	2.96
Rate how well you believe you can spot/draw links/relationships between things. (Based on a 4 point rating scale).	3.1	3.5
Rate your willingness to tolerate ambiguity. (Based on a 4 point rating scale).	3.36	3.52
Rate how willing you are to take risks that support innovation. (Based on a 4 point rating scale).	3.4	3.82
Rate how adept you are at putting judgment on hold. (Based on a 4 point rating scale).	2.9	2.97

Table 1.2

When the participants were asked to list the key principles and processes of innovation, 80% of the students were able to list the 5 key principles and processes. When the students were similarly asked to rate how they believe their propensity (interest and aptitude) for innovation was influence, 100% of the students said it made "more than a little" or "a significant amount". Then when the students were asked to rate how they believed their skills related to innovation were influence by the Boot Camp experience 86% reported they believe their skills were *significantly* influenced by the experience. Also, 85% of the students said they thought their time at the Innovation Boot Camp was spent either *effectively* or *very effectively*.

Thus far the qualitative findings seem to support the survey and interview results. Both of the outside evaluators reported that they believed the students to be engaged and learning, that important principles were being taught, and that effective instructional activities were being used. They did however, provide several suggestions. Their suggestions centered mostly on curriculum issues, and on possible related activities that would enhance the collaborative nature of the boot camp. We believe their feedback, coupled with the survey and interview results are essential to further development of the Boot Camp.

Boot Camp Costs

Although the primary purpose of this study is to understand the impact the Innovation Boot Camp is having on student innovation ability and aptitude, we feel it is imperative to discus the costs such an effort requires. There has been a definite cost of time, culture change, and money associated to the boot camp effort.

The cost of time has burdened both faculty and students. Faculty because it has required several faculty members to spend a significant amount of time preparing and teaching this class separate from and in addition to normal teaching and research loads. For students, the time cost has also been an issue. Many of the students have found it difficult to give up an entire day and a half to an extra curricular activity such as the boot camp. They have had to reschedule classes, make up missed classes, miss work, and so forth. Although both faculty and students have been willing to make this time sacrifice, it has been a definite cost, and we are currently investigating options where the cost might be reduced (i.e., develop a block or semester course focused on innovation).

The cost related to changing culture has to do mostly with developing college-wide buy-in among faculty. The plausibility of a college-wide buy in and adoption is difficult, due to a deeply traditional academic approach to teaching engineering and technology. In an effort to address this issue we have (and are) collecting data regarding perceived learning and skill development impact of the boot camp experience. We have presented several of the findings to the faculty at various meetings, and although we have tentative support, we realize additional positive data points from a longitudinal study are needed if we are to garner additional support from the college as a whole. In the meantime we have invited faculty from each of the various departments to attend a boot camp session, in hopes they would have curriculum and pedagogical feedback, and in hopes they would see the potential such a class would provide. Although we have had several faculty attend, who have reported they enjoyed the experience and feel it has great potential, we have yet to convince the naysayers of the college to attend a session. Finally, the effort required to change this culture related to the final cost encountered by the boot camp – money.

Although the college has been gracious to allocate a noteworthy amount of resources and monetary support to help us pilot test this innovation effort, we recognize the cost is significant. The college has allocated a separate lab for boot camp use, has provided funds for prototyping supplies and tools used during the boot camp (i.e., foam core, wood, metal, computers, printers, photo-paper, digital cameras, saws, markers, modeling clay, etc.). Additionally, the college has catered each of the boot camp sessions, and has awarded prizes to the most innovative projects developed in the boot camp.

Although the costs are real, and despite our limited data collection, we feel the results thus far seem to suggest that the boot camp is having a positive impact on our students' understanding of and abilities associated to innovation.

Boot Camp Restructure

We recognize we are still in the preliminary stages of our development and implementation of the Innovation Boot Camp, however, we believe the findings from the surveys, interviews, and qualitative observations have provided helpful insight to how we might re-structure and continue to develop the Boot Camp experience. The primary areas of restructuring we have thus far experienced center on curriculum issues. We have found there are two primary sets of innovation principles common in innovation related literature, and although the principles innately suggest

similar concepts, we feel it is important to solidify the language (i.e., vocabulary) being used. For example, in the first few Boot Camps we used the idea of "Design Thinking" and its associated principles of *"Think, Look, and DO"* (Welsh, 1993; Osborn, 1965; Sternberg, 1999; Kelly, 2005), while in the later Boot Camps we used the principles of: observing, questioning, idea networking, associated thinking, and experimenting (Dyer et al., 2001). We believe there is a need to continue to evaluate the Boot Camp experience, and anticipate continued restructuring of it, however, we also feel the results thus far provide great insight to how the seeds of a culture of innovation might be initially planted.

Conclusion

Although our data set is somewhat limited as yet (due to the Innovation Boot Camp's newness) we expect that the boot camp experience will continue to evolve. Additionally we anticipate a longitudinal commitment to this experience (among others) will help us develop a culture of innovation with our college of engineering and technology. Finally, we believe we are commencing on an important journey towards better preparing our students for a rapidly evolving and globally competitive world, where innovation is an essential and defining skill.

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