Innovation Sandbox: Engineers in a Multidisciplinary Playground

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Introduction

Innovation Sandbox is a physical and programmatic environment where students of all academic levels and majors across campus can come together to explore and develop their early-stage ideas. The goal is to stimulate creative play outside the traditional academic environment through a mix of formal and informal engagement. This space allows innovations to progress beyond a single classroom project or exercise, but decouples innovation from a particular course or department, making it a true separated space devoted to team based and individual ideation. Content is driven by participants and facilitated by Student Mentors who ensure that there is a low barrier to entry. The Mentors assist with simple fabrication, facilitate connections with faculty and other campus resources, and provide mentoring/coaching and design input to program participants.

Due to the technical nature of many of the innovations, the College of Engineering was an early and enthusiastic adopter of the program, serving as both a source of expertise (e.g. fabrication, coding) and as the largest pool of participants. Through involvement and sponsorship of the university-wide Cal Poly Center for Innovation & Entrepreneurship, the program is broadening and maturing. Engineering students are seeing significant benefits from working with diverse majors on designs that sometimes involve technology in only a minor supporting role. This type of problem solving develops abstract, innovative "soft" skills that complement the technical depth they develop in their traditional curriculum. These skills are critical to producing engineers that can thrive in a global environment. At Cal Poly, engineering students are provided many opportunities in the classroom to develop technology innovations through class projects, senior projects, and as part of their regular instruction. However, the environment is not optimized to facilitate the progression of student directed innovations beyond the engineering classroom, nor is it suited for truly interdisciplinary efforts. Innovation Sandbox is a promising solution.

Grassroots efforts over the past year have laid the foundation for a successful program. Current activities involve turning these early efforts into a durable program with appropriate assessment tools that is fully integrated into the broader institutional goal of increasing innovation campus wide. The overarching goal of Innovation Sandbox is to *change the culture of our students to embrace innovation*. Assessment of demonstrable outcomes covering innovation, creativity, design, communication, and multidisciplinary activities is a high priority, to formalize the value of the program and support ABET accreditation activities. This paper discusses our process of developing, implementing, and validating assessment methods that are appropriate not only for engineering, but other participating colleges. Specifically, we seek to establish and quantify a link between skills developed through play in a voluntary, extra-curricular program and the skills required to meet the global engineering challenges of the future.

Beyond a Makerspace?

Innovation Sandbox is focused on the "messy front end" of the innovation process, in which needs are explored in very qualitative ways with potential users and beneficiaries, brainstorming is heavily utilized, and simple prototypes evolve into more functional solutions. Although this

program shares some of the characteristics of a typical "Makerspace," it was established to go beyond serving as another student-centric shop to provide a targeted extra-curricular supplement to other key campus-wide innovation initiatives. Our impression was that Makerspaces often involve only the technology curious working on their own projects; our goal for the Innovation Sandbox was to involve a wide variety of students, of course centered around technology, but fostering the "creative collisions" that lead to taking innovations to the next step.[1] Infrastructure includes the requisite 3D Printers and similar tools for early physical ideation, but also "hackable" hardware which can link computer-controlled systems to users (e.g. Oculus Rift, a Myo Armband, a NeuroSky Brainwave Kit, Leap Motion Controller, Arduinos, Android & iOS-based hardware, etc). Fundamentally, Innovation Sandbox is a clubhouse where students across all majors and academic levels can meet to explore modern technology and apply it to extremely broad topics. Any development *beyond early exploration and play* is better served in other campus machine shops and laboratories and through the programs of the campus Center for Innovation & Entrepreneurship. Key additional characteristics of Innovation Sandbox include:

- The program is a major part of the growing entrepreneurship ecosystem at Cal Poly, driven by the formation four years ago of a university-wide Center for Innovation & Entrepreneurship (CIE). The CIE cuts across all colleges and programs to create an environment for interdisciplinary student-driven innovation and entrepreneurship activities. The Innovation Sandbox is the earliest and "lowest barrier" complement to the Elevator Pitch Competition, Hatchery (on-campus incubator), HotHouse (off campus incubator) and HotHouse Accelerator (intensive 12 week summer business acceleration program) as well as the Entrepreneurship Club (student entrepreneurship organization) and many other programs.

- The program is consistent with and complementary to *but not part of* the academic curriculum. This allows innovations to progress beyond a single classroom project or exercise, and decouples innovation from a particular course or department.

- Programmatic content is *driven by participants* and facilitated by Student Mentors from across campus who ensure that there is a low barrier to entry by assisting with simple fabrication, facilitating connections with faculty and other campus resources, and providing mentoring/coaching/design input to program participants.

- The focus is on the process of innovation, with the goal of stimulating creative play outside of the traditional academic environment. Because the context of this play leans heavily on understanding the customer and the commercial potential of the technology, the program serves as a natural early-stage feeder to other campus entrepreneurship programs.

- The program has the capacity to support hundreds of participants across all Cal Poly colleges, with active interaction of 20-30 during any given formal program hour.

"Innovation Sandbox: Your ideas. Our playground. Together we can develop concepts, share knowledge, invest in ourselves, and turn impassioned ideas into tangible realities. Come and play."

Organic Growth Across Campus

Innovation Sandbox was prototyped during the 2012-2013 academic year. The development of this program is a mirror of the innovation process itself -- much of the development was organic and focused on the evolving needs of the constituents. A NCIIA Planning Grant[2] served as the catalyst for this effort; this grant was leveraged into a targeted donation from an alumnus, and supplemented by an additional match from the College of Engineering through an industrial partner. In addition, the Center for Innovation & Entrepreneurship contributed significant time through leadership and technical support to enable this as a university-wide program.

The early supporters of the program concept in the College of Engineering and the CIE recognized its potential as a critical complement to our institution's "learn-by-doing" tradition, providing a particular boost to invention-leading-to-entrepreneurship. Learn-by-doing is essential to the culture at Cal Poly, and students are provided many opportunities in the classroom to develop technology innovations through class projects, senior projects, internships, and as part of their regular instruction. However, the environment is not readily available to facilitate student, faculty and industry interaction focused on massaging student innovations to move them toward market-readiness, nor is it suited for truly interdisciplinary efforts. Innovation Sandbox seeks to capitalize on the growing interest of students, faculty, and administration across campus in technology entrepreneurship, as evidenced by the rapid growth of the CIE, to provide an environment to perform ideation and minimum viable prototyping.

Over the course of program prototyping, facilities were secured in space allocated by College of Engineering, the basic program infrastructure was developed, and a group of 40 "early adopter" participants was identified. Additionally, we recruited a core advocacy group of over 30 faculty members from across campus to help build connections with their students, colleagues, and academic activities. Mentors from the colleges of Engineering, Business, and Liberal Arts were initially hired as student assistants. We have found, however, that the strongest and most passionate mentors are unpaid volunteers, and have since moved to an overall student coordinator as the only paid position. Mentors develop all program content, with the goal of making Innovation Sandbox a place that students from across campus want to come and see what's happening. This group is also currently developing a strong online presence (through Facebook and team collaboration software), which will serve as an extension of the physical location, allowing continual sharing of ideas. A challenge to developing a truly interdisciplinary program like the Innovation Sandbox is to simultaneously provide opportunities for the more technically oriented members to dig deep into problems that interest them, while also maintaining a low barrier to entry for those without a strong technical background. While much of the Sandbox development was organic in nature, it was recognized that addressing this challenge required intentional programming from the Sandbox leadership team. This acknowledgment resulted in a spectrum of programs and activities that are central to the Sandbox operations, which address various needs of the diverse stakeholders.

At a high level, we summarize the activities and offerings of the Sandbox into the following:

- Technology resources and demos (Assets).
- Creative working space.
- Student initiated projects.

- Student led governance.
- Cross-campus technology outreach and advocacy to classes, clubs, CIE events, and through Sandbox open office hours.

For the technically oriented (typically STEM students) we provide resources to cutting edge technology, and also provide an environment and support materials and supplies for student initiated projects. While not limited to projects that are purely technical in nature, at this stage, the projects tend to be teams of engineers and scientists that are working to prototype new technologies that are outside the scope of their formal curriculum. In addition, students use the working space to discuss new ideas, study, and as an on-campus place to "hang-out."

For those from traditionally non-technical fields (typically non-STEM), the Sandbox leadership team does technology outreach to classrooms, participates in non-STEM seminars, hosts and publicizes speakers, provides access to creative materials, and also provides expectation-free space for these students to engage in creative discussion with those outside their discipline. These advocacy efforts beyond the College of Engineering have been in wide ranging disciplines including journalism, graphic communication, education, and business. The goal of these efforts is to expose students to ways that technology may influence their chosen discipline in the future, and to provide motivation for those students to come visit the Sandbox.

While these efforts are still in their infancy, the Sandbox has begun monitoring program participation and is installing tools to analyze the efficacy of the outreach efforts (Figure 1). The early adopters to the program typically participate in some form of programming for ~5 hours/week, and have worked to include and train new volunteers that have enabled the Sandbox to expand its formal open hours from less than 10/week at launch, to currently ~50/week. Participation in weekly informational meetings is recorded with the educational major of each participant tracked, and a manual sign-in sheet is located at the entrance to monitor weekly "drop-ins" from students who are hearing about the program and want to see/use the technology. We are in the process of migrating to an electronic system for automated data capture which will more thoroughly track the response rate of students. While the limited data set is understandable given the relative infancy of the program, we believe it's important to be maintaining records on participation and impact across disciplines, as there is very little data available in the literature that quantifies the impact of such interdisciplinary programs, particularly those that are technology-centric, as a function of the discipline of the participant.

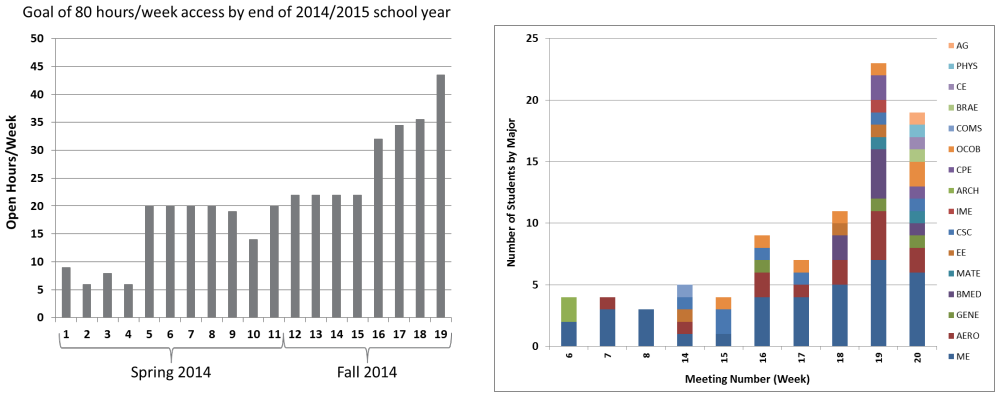

Figure 1. Early data on program participation.

Soft Skills, Hard Problems

Qualitative observation and anecdotal evidence clearly point to the value of this environment to engineering students. The greatest value is in areas underserved in the curriculum: truly interdisciplinary opportunities, experiences with highly abstract problems, and communication of technology solutions to a wide audience.[3] As an example, one important role engineers are developing as Innovation Sandbox matures is that of *technology ambassador* – delivering short "show & tell" presentations to a broad, non-technical audience in classes across all majors and levels explaining current technological innovations in the context of societal changes.

As these soft skills are practiced through Innovation Sandbox by a growing number of engineering students, there is an increasing need to collect data that quantifies this exposure. Innovation Sandbox is *designed* to sit outside of the academic curriculum. We have found at Cal Poly that critical interdisciplinary work occurs outside of the classroom; clubs, for example, have historically played an important role in supplementing the curriculum. Key limitations of extra-curricular activities from an assessment perspective, however, are: 1) they are not mandatory, and thus are difficult to use in program assessment, 2) students have a wide range of exposure to an extra-curricular activity, from a casual one time drop-in to full, continued engagement, and 3) there is a lack of process and data that would formalize the scope and value of these activities. Because Innovation Sandbox has the potential to impact all engineering majors to some extent, it makes an ideal test case for assessment of an extra-curricular activity.[4]

Familiar Territory: Program Educational Objectives and Student Outcomes

ABET self study methodology provides a suitable model for initial Sandbox assessment activities (Figure 2), with modifications as necessary to make assessment efforts useful across *all* colleges, and to account for voluntary and varying levels of student participation. We developed Program Educational Objectives (Figure 3) through a series of brainstorming sessions among key constituents, including faculty advisors, student program leaders, and representatives from academic departments, college administration, and the Center for Innovation & Entrepreneurship. This was an illuminating process in itself, as it gave the team an opportunity to evaluate how the organic evolution of the program has in turn reshaped the expectations of the program founders.

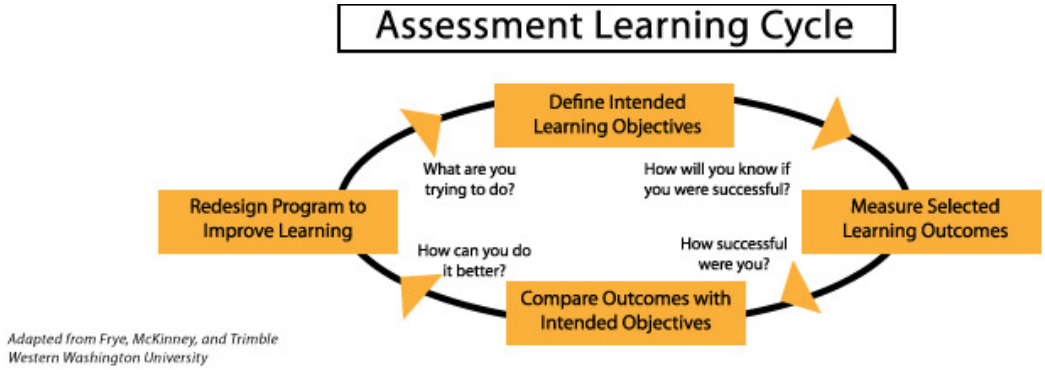

Figure 2. Assessment model.[5]

Program Educational Objectives

Innovation Sandbox Participants will:

I. Demonstrate a curiosity that leads to self-initiated creative and innovative problem solving.
II. Understand methods for communicating complex concepts that leads to a greater willingness to engage and lead in situations involving uncertainty.
III. Embrace interdisciplinary problem solving and communication with an appreciation for varied points of view, backgrounds, and skill sets.
IV. Demonstrate an appreciation and thirst for areas of technology innovation beyond those of the participants given discipline.

Figure 3. Innovation Sandbox Program Educational Objectives.

In a separate effort, the faculty most directly involved in program operations prepared a set of Sandbox Student Outcomes, analogous to, but completely independent of, ABET Outcomes (Figure 4). Once these Outcomes and Objectives had been agreed upon, a mapping helped us to quantify and communicate the high-level goals of the Innovation Sandbox (Figure 5).

Innovation Sandbox Student Outcomes

1. An ability to understand technology trends and the intersection with societal trends.
2. An ability to communicate to a wide audience using appropriate technical vocabulary.
3. An ability to articulate project goals and build an appropriate team.
4. An ability to physically realize early ideas through appropriate physical and digital prototypes.
5. An ability to apply discipline skills in highly interdisciplinary projects.
6. An ability to develop ideas and identify and communicate value creation.
7. A respect for diverse viewpoints.
8. A recognition of the need for, and an ability to engage in, learning and teaching complex concepts throughout ones career.

Figure 4. Innovation Sandbox Student Outcomes.

Mapping Between Sandbox Outcomes and Sandbox PEOs		**Sandbox PEO**			
		I	II	III	IV
1	An ability to understand technology trends and the intersection with societal trends.				X
2	An ability to communicate to a wide audience using appropriate technical vocabulary.		X		
3	An ability to articulate project goals and build an appropriate team.		X	X	
4	An ability to physically realize early ideas through appropriate physical and digital prototypes.	X			
5	An ability to apply discipline skills in highly interdisciplinary projects.			X	
6	An ability to develop ideas and identify and communicate value creation.	X			X
7	A respect for diverse viewpoints.			X	
8	A recognition of the need for, and an ability to engage in, learning and teaching complex concepts throughout ones career.	X	X		X

Figure 5. Mapping between Outcomes and Objectives.

Figure 6 shows Sandbox Student Outcomes mapped to Outcomes important to the College of Engineering, as represented by specific ABET Outcomes.[6] Of particular interest in this exercise are the columns that have many checks (indicating that that a Sandbox Outcome is of particular interest to the College of Engineering), and the rows that have many checks (indicating that an ABET Outcome is well covered by the Innovation Sandbox Program). Using this simple analysis, Sandbox Outcomes (1), (4), and (5) have the closest relationship to ABET Outcomes, and ABET Outcomes (d) and (e) are the most supported by the Innovation Sandbox Program. While these results should be expected at the intersection of engineering and a program such as Innovation Sandbox, we find this table to be extremely useful in communicating the value of the program to the various engineering disciplines at our university.

Mapping Between ABET Outcomes and Sandbox Outcomes		**Sandbox Outcome**							
		1	2	3	4	5	6	7	8
(a)	Ability to apply knowledge of mathematics, science, and engineering				X	X			
(b)	Ability to design and conduct experiments, as well as to analyze and interpret data				X	X			
(c)	Ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	X				X			
(d)	Ability to function on multi-disciplinary teams		X	X		X		X	
(e)	Ability to identify, formulate, and solve engineering problems				X	X	X		
(f)	Understanding of professional and ethical responsibility					X			
(g)	Ability to communicate effectively		X	X	X		X		
(h)	Broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	X						X	
(i)	Recognition of the need for, and an ability to engage in life-long learning	X							X
(j)	Knowledge of contemporary issues	X							
(k)	Ability to use the techniques, skills and modern engineering tools necessary for engineering practice				X	X			

Figure 6. Mapping between Sandbox Outcomes and ABET Outcomes.

Expanding the Frontier: Mapping the Sandbox across the University.

Because the Innovation Sandbox is designed, funded and managed as an interdisciplinary, cross-college initiative, it is equally important to understand how the Sandbox serves the goals and objectives of its multiple academic constituents. The first effort here will be applied to the Orfalea College of Business, as this is the college initially most intertwined with Engineering. The Orfalea College of Business is accredited by AACSB and the Industrial Technology

Program is accredited by both the AACSB and the Association of Technology Management and Applied Engineering (ATMAE), maintaining a set of Learning Goals supported by Learning Objectives. The methodology applied above is thus directly transferrable to the Orfalea College of Business; the results, however, are expected to show a distinct difference in the value of the Innovation Sandbox to Orfalea College of Business students compared to College of Engineering students.

We intend then to work with the Colleges of Liberal Arts; Architecture and Environment Design; Agriculture, Food and Environmental Sciences; and Science and Math to conduct similar cross-mappings. The ultimate purpose of this is to insure that the Innovation Sandbox remains focused on meeting the needs of students across campus, that the Colleges increase their support of these activities and that Innovation Sandbox can be a valuable part of their assessment efforts. One challenge is the diversity of majors across many of these colleges – from Philosophy to Dance within Liberal Arts, from Physics to Kinesiology in Science and Math. We suspect that the focus of the Innovation Sandbox on innovation, on technology and on interdisciplinary practice will align well with the polytechnic mission of the University within all colleges.

The Final Frontier: Mapping Sandbox Educational Objectives to Broader University Learning Objectives

At the highest level, Innovation Sandbox assessment efforts must provide a link to the broader University Learning Objectives if the program is to achieve full recognition and support as a campus-wide asset. Questions to be answered include whether there are specific areas in which the Innovation Sandbox most reinforces these objectives, and whether there are any indicators of how student involvement in the Innovation Sandbox differentiates students along these objectives. Figure 7 lists our institution's University Learning Objectives, and Figure 8 illustrates a preliminary mapping between Sandbox Program Educational Objectives and these University Learning Objectives.

1. Think critically and creatively
2. Communicate effectively
3. Demonstrate expertise in a scholarly discipline and understand that discipline in relation to the larger world of the arts, sciences, and technology
4. Work productively as individuals and in groups
5. Use their knowledge and skills to make a positive contribution to society
6. Make reasoned decisions based on an understanding of ethics, a respect for diversity, and an awareness of issues related to sustainability
7. Engage in lifelong learning

Figure 7. University Learning Objectives.

Mapping Between Sandbox Objectives and University Learning Objectives		University Learning Objective						
		1	2	3	4	5	6	7
I	Demonstrate a curiosity that leads to self-initiated creative and innovative problem solving.	X				X		X
II	Understand methods for communicating complex concepts that leads to a greater willingness to engage and lead in situations involving uncertainty.		X		X			
III	Embrace interdisciplinary problem solving and communication with an appreciation for varied points of view, backgrounds, and skill sets.	X	X		X		X	
IV	Demonstrate an appreciation and thirst for areas of technology innovation beyond those of the participants given discipline.			X		X		X

Figure 8. Mapping between Sandbox Objectives and broader University Learning Objectives.

Measuring Sandbox Outcomes

The Outcomes and mappings presented in this paper represent the starting point for achieving buy-in from a broad constituent base across campus. Beyond the strategic value of this work, it is the foundation for a program of continuous improvement, again modeled on ABET. Figure 9 is a high-level example of our next steps: using both indirect and direct assessment tools to measure level of achievement in our stated Sandbox Outcomes. With support from the College of Engineering central assessment activities, we are currently developing a series of pre-and-post activity surveys, as well as forums for external evaluation (e.g. department advisory boards) and evaluation of Innovation Sandbox work products by faculty from the participant's home department. We are also working on ways to address the challenges associated with the voluntary and varying levels of student participation. While these efforts are in their most preliminary stages, the eventual goal is to provide data that multiple Colleges across campus will find useful in future assessment activities, and to provide a framework whereby the goals of a campus-wide program can be articulated, supported, monitored, and continuously improved.

The design of the Innovation Sandbox was intended to go beyond "another Makerspace" to provide an important facility and programmatics for students across campus to play outside the confines of their curriculum. In an era of extremely limited resources (especially at a state-supported school such as our institution), a broad extracurricular program requires broad support; the key to broad support is a strong definable, defendable link to reinforcement of traditional discipline skills at the department level. Seen this way, assessment is not only a tool for continuous improvement, but is the fundamental key to long-term program sustainability.

Mapping Between Sandbox Programs and Educational Objectives		Sandbox Educational Objectives			
		1	2	3	4
I	Student Initiated Projects	X		X	
II	Technology Resources and Demonstrations (Assets)	X			X
III	Creative Working Space (Property)	X		X	
IV	Cross-Campus Technology Outreach and Advocacy (Classes, Clubs, Sandbox Office Hours, CIE Events)		X	X	X
V	Student Led Governance		X		

Figure 9. Measurement and Continuous Improvement of Innovation Sandbox Programs.

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