AC 2012-5195: USING ONLINE OPEN-INNOVATION CHALLENGES TO INTRODUCE DESIGN IN FIRST-YEAR ENGINEERING COURSES

Dr. Andrew Trivett, University of Prince Edward Island
Prof. Stephen Champion, University of Prince Edward Island

Using Online Open-Innovation Challenges to introduce Design in First-Year engineering courses

Introduction

Project-based courses in first-year provide the first exposure to design in many engineering programs in North America, and around the world. The first project a student encounters can color their view of the profession for the rest of their academic career. The project course has also been shown to have an impact on the student's enthusiasm and self-confidence in their personal ability to succeed in engineering [1].

Typically, the topic or scenario for early project problems are created by the faculty. Viewed from a cynical point of view, problems may appear to students as “cooked-up” , perhaps a bit stale, and in some cases students expect that they are not “real” design projects... after all, they are just assignments in a university course, not design in the “Real World”. Unfortunately, even though the learning can be excellent, the experience of students can be influenced by their belief of whether or not the design project is “real”.

This paper describes an approach we have used for the past three years in the first semester engineering design and communication course at the University of Prince Edward Island, Canada. This course is a first chance for students to get a glimpse of their future careers. The first design project in our program has a 3-4 week duration and is introduced during the first six weeks of a student's university career. The students review and choose a design “Ideation” challenge from a public online challenge website . The challenges are real, they are available worldwide to anyone wishing to attempt a solution, and the seekers offer real monetary prizes for the best solution.

There are several online “Open Innovation” sites, but our course currently uses “Innocentive”. Since it was created in 2001, Innocentive claims to have paid out over 1050 prizes totalling 34M$ for over 28,500 submitted solutions [2]. One faculty member within the UPEI program has won cash prizes for challenge submissions, a fact which gives us the confidence that the website is credible, and to use it with students.

Each Innocentive challenge has a brief description from the “seeker” outlining the seeker's problem and their criteria for judging responses. The Innocentive model provides a brief standard proposal format which is analogous to a brief engineering conceptual design proposal. Students, either as individuals or teams, can proceed through the development of a solution and the preparation of a proposal. Everything from conceptual design, drawings, technical specifications, and intellectual property can be introduced through these real design challenges. Each step along the way, in the engineering design course, is mapped to steps in a design cycle and engineering report.

The Open innovation model enables students to experience “real” social and industrial challenges that are not at all “cooked up” by local faculty. The design challenges can be used to highlight the global nature of engineering, innovation, and the need for being competitive in design for a global market place. The paper will review experience acquired through running introductory challenges in first year design over three academic years.

The approach described has been used for 3 years of our program with class sizes of 45-55, a very small number and not sufficient to base a statistical sample. Hopefully, future work will enable a quantified measure of the effectiveness of these problems. This paper does not offer anything more than stories and anecdotes from using open innovation as the basis for student design projects.

The First Design Project

The authors have written in the past about approaches to designing a design project. In the past work, it was proposed that the selection of the particular design topic is the final stage of developing a design project. We stressed in the past work that the first essential step in the design of a design project is to determine the learning outcomes, and tailor the progression of the design tasks and faculty-student or student-student interaction to help achieve those learning outcomes[3]. The first course in engineering design at UPEI, and at any university engineering programs is primarily focussed on students learning communication, graphics and professionalism. With this as the key to our learning goals, the range of possible design tasks is limitless. The most difficult task for many faculty is to come up with believable, relevant, and potentially tractable design problems for students fresh out of high school.

Since first encountering Innocentive, we have used the seeker/solver model to introduce engineering students to the idea that there are REAL seekers out there who NEED solutions, and anyone, even a first-year student may have an important contribution. The first time this was introduced to a first-year class, one student came up at the end of the lecture to say "*Wow! I've never seen anything like this before! I just texted my friend who's not in this class, and he wants to get involved too!*" The challenges become a central component of teaching students how to develop technical ideas, how to evaluate alternatives, how to share technical information, and how to present ideas in a professional setting.

"Design Something" versus "Design Challenge"

The "design process" as depicted by Dym and Little[4], a popular text in first-year engineering, begins with identifying a problem to be solved. It is difficult, when planning an engineering course on design, to leave this step up to the student. There are so many possible problems to be solved that an 18 year old undergraduate can get lost in the choices. Recently, in a course within the engineering design stream at UPEI, we assigned the students a task to "Design something". They were asked to simply sketch their idea on a one-page hand-drawn sheet. The goal was to meet the four main criteria used in the evaluation of a patent[5] (the criteria are effectively the same in the US and Canada, but our Canadian students are familiar with the US Patent and Trademark office, being the largest database of patents in the world). The criteria was intentionally broad, and students commented that the assignment was extremely difficult, not because it was hard to sketch a simple design on one page, but because it was so difficult to decide upon a single useful idea.

In planning a course, we, as instructors, need to have some details worked out in order to deliver a useful experience to the students over a 14-week semester. Leaving such major decisions as the topic of a central design project to chance is risky. From teaching first-year design at UPEI and other Canadian engineering programs, the student design ideas are either so vague as to be unmanageable (“ a way to produce energy”). Or so specific as to be trivial (“a better mousetrap”). While the design process is the same regardless of the specific topic of the design, the experience students may have is governed by the appropriateness of the project topic.

A growing trend that we have noticed in our student population is a lack of “practical” knowledge of technology. In a University with a mix of rural/urban/suburban communities from which the majority of new students are drawn, we now see engineering students who come without the childhood experience of having tinkered with technology. The loss of this tinkering background seems to have the effect of delivering students to our first year classes who lack knowledge of how things work, or of the parts that make up complex systems. Ask a class of first year engineering students in 2012 how many of them have rebuilt an engine, or even changed the oil on an engine and the answer is surprisingly low. This is a “skill” that we might have considered commonplace to an engineering class from 20 years ago. (Notably, a small number of students from farming or fishing families still come to class with the tinkering skills on which to build their technology wisdom). Without hands-on knowledge acquired as teens, the majority of our incoming class is poorly equipped for even identifying a topic for their first design problem.

A Project Using “Open Innovation”

We teach students of engineering that the profession is about solving problems for people. Those fictional “people” can be embodied by corporations, or governments, or individuals. Rarely, in the practice of engineering, do we have a chance to start a project with a clean sheet of paper and no client or intended customer for the design. Rather, a problem is delivered to us by the client, the marketing director, or the head office. The first engineering problem in a project-based design course should mimic the “client need”. The best introductory task cannot be “design something” , but rather “design something for client X”.

We have chosen to use, at least for a first experience, clients who are real, but who are faceless. The Open Innovation model allows real problems to be published widely in a way that makes it clear what the problem is that needs a solution, but masks the identity of the client (the “seeker”). It is publicly available to anyone choosing to register on a website and attempt to solve the design problem (“the solver”). While there are a number of levels of project competitions, the easiest to adapt or use in a first engineering course is the “Ideation” challenge. These competitions ask solvers to simply produce a 3-5 page description of their proposed solution, but leave the details ultimately to the seeker.

Identifying Appropriate Challenges to Match Student Skills

Since all of the challenges are available publicly, instructors in our design program visit the Innocentive site a few weeks before start of term, and verify that there are a few challenges which may be suitable for our student's level of knowledge. Many of the design challenges are clearly inappropriate for first-year students in an engineering course, some requiring chemical, pharmaceutical or molecular biology knowledge beyond what we expect of new students. In past years, we have found between 5-10 design challenges at any time which would be suitable for a first-year class.

The first time that we delivered a project using this approach was in September of 2009. At that time, students were asked to go to the Innocentive website, register and review the available challenges. They each were required to prepare a summary of two challenges as a first writing assignment. The intention was to have them read more than one challenge in detail. From these reviews, we collected the list of different challenges that attracted their interest. The example list generated from student interest is shown in Table 1. It was clear that most students chose problems that could reasonably be expected to rely upon common background knowledge. Some students selected projects that were too far from any background knowledge they might possess, such as protein extractions or chemical formulations. Based on their reviews, the projects chosen by students were short-listed on the course management site (Moodle), and students were asked to choose their challenge.

Challenge Title	**IC #**	**Suitability for First-Year Projects**				**Overall Suitability**
		Science	**Scope**	**Complexity**	**Social**	
Laser Bonding	8662885	N	Y	Y	Y	**Y**
Control of Bubble Size	8651427	Y	Y	Y	Y	**Y**
Olefin to Ketone	8628624	N	Y	N	N	**N**
Biocide Formulation	8742612	N	N	Y	Y	**N**
Self Cleaning Handle	8690025	Y	Y	Y	Y	**Y**
Extraction of Proteins	8652318	N	N	N	N	**N**
Cutting Method	8658323	Y	Y	Y	N	**Y**
New Decoration Tech	8753619	Y	Y	Y	Y	**Y**
Leaf Sampling	8585178	Y	Y	N	Y	**Y**
Browning in Juice	8629801	Y	Y	N	Y	**Y**
ALS Biomarker	8305421	N	N	N	Y	**N**

The IC# column in Table 1 refers to the identification number assigned to each challenge by Innocentive. The specifics of each challenge can be found from the Innocentive website [2]. The project descriptions are proprietary, and users must register with the site and agree to a non-disclosure clause before the details of the challenge are revealed.

We had decided in that first effort to let the students pick their own challenges, and were forced to stick with that rule. The first experience led to a number of students interested in attempting solutions to challenges that were inappropriate for them, despite faculty attempts to discourage them from doing so. After the first experience using these challenges, it was clear that some challenges simply did not fit the students or the course. Table 1 shows a set of reflection rankings by faculty of those first projects. The criteria shown are:

- **Science:** is the background science knowledge within the expected knowledge base of the students and faculty

- **Scope:** is the level of detail of the challenge reasonable with a 3-4 week exercise
- **Complexity:** will the anticipated solution have too many components or aspects for students to make reasonable headway in drawing and explaining the solution,
- **Social:** are the social or market aspects of the challenge reasonably within the knowledge or experience of the students.

Table 1 indicates which of the challenges might have been appropriate for students based on these four criteria. In hindsight, the students who had actually attempted the inappropriate challenges in the first version of this project did not achieve the same learning outcomes as those who chose the simpler, more appropriate ones.

Since the first experience in 2009, we have struggled with ways to ensure the challenges match student ability and background. Two alternative approaches are either to prescribe or to coach. In the former, faculty would short-listed the projects prior to the students viewing the Innocentive challenges. Only the acceptable challenges could be chosen. In this model, students would select a challenge that attracts their interest from the short-list. In the "coach" model, students are asked to review several challenges as part of a warm-up assignment and evaluate the suitability of the challenge. Individuals would then be coached to rank the challenges to decide which one is best. The latter model has been the most successful so far in a small class. For classes larger than 50, this model may be impractical for faculty to manage.

Regardless of the method for pre-selecting the challenges, students must make a choice based on their level of interest in the alternatives. Once they have chosen a challenge, they must register on the Innocentive website in order to read the complete details of each challenge, and in so doing, open what is known by Innocentive as a "project room".

The Assignment: Background Research

Once they have chosen a challenge, we require that students spend the first week of a 3 or 4 week project carrying out background research. For first-year students, we ask them to submit a summary of their research that must include references to material from no fewer than 4 articles. The assignment at this stage is supported by library staff and classroom lecture on proper sources of information. With the help and support of library and academic writing staff, we insist upon sources beyond the Wikipedia or simple web resources. Through the nature of Innocentive challenges, students quickly find that none of the familiar simple Googling searches are effective to provide high quality detailed information. This stage of the project opens up an opportunity to show the value and depth of really good quality academic review papers or engineering journals.

The Assignment: Ideation

Once students have submitted their reports on background research into the problem, we meet during class and the class is broken into groups of students according to their chosen design challenge. Depending upon the preference of the instructor, some groups are already formed, or formed in pairs around a common choice of design challenge. Students understand that the group discussion is intended as an idea generation (Ideation) exercise to try and develop novel solutions to the challenge problems.

Throughout the one-hour discussion class, the students in each group are instructed to ask questions of each other, and to keep notes of the discussion. Prior to the conversation between students, faculty give a brief introduction on the concept of intellectual property. One key issue that is brought to their attention is the risk of “giving away” their good ideas to the other students versus the potential reward of getting good suggestions for improvement. The experience provides a touch-point for all students when, at some future date, we discuss intellectual property in a subsequent design course.

The Assignment: Intellectual Property

Through the first group discussion, as well as subsequent ones, the students explain to each other their solution ideas. This sharing helps to develop those composite ideas that often become the best solutions, and the students start to grapple with the intellectual property from a pragmatic, and perhaps urgent viewpoint. Since the challenges are real, and there is potentially thousands of dollars at stake for a winning solution, they again come face to face with negotiating ownership of ideas. These dynamics take place naturally with little to no input from the instructor, aside from clarification of concepts in response to student questions.

Over the next few weeks of the course, preparing the Innocentive challenge submission becomes the central focus. In order to explain their solutions, students sketch their concepts using both hand drawing and Computer Aided Design tools, and try to write a clear explanation for the solution submission.

The Assignment: Drawings

Through the process, Students are provided with samples of several unsuccessful solutions provided by faculty. All of the examples incorporate text with graphics using Innocentive's own submission format. The examples are chosen so that students get a sense of the range of ways to provide support for explaining their ideas, and for convincing the seeker that the ideas are feasible. One difficulty with the teaching model is that it is not possible to show students examples of winning solutions. Under the terms of all Innocentive challenges, the seeker owns the intellectual property of the winning solution in exchange for payment of prize money. All the unsuccessful solutions are property of the author, so these become the only source of examples for students.

Since drawing and sketching are important components of our first course in engineering design, these aspects are highlighted in the examples, and they form a key aspect of the student's design solutions. The intermediate drafts of solutions are typically scans of hand-drawn designs from the students hard-cover course logbook. It is expected that key drawings will be reproduced using CAD before the final documents are complete, but the hand-sketching is emphasized in early design discussion.

The Assignment: Drafts and Critique

By the end of the third week, students will have completed a draft of their challenge submission, including sketches to make the concepts clear, and their research references. Part of the evaluation of Innocentive challenges is to convince the seeker that a proposed solution is in fact feasible. The background research provides students with potentially solid research evidence to use in defending their ideas. Clear hand sketches help to make the ideas clear, and the integration of graphics, text, and technical content helps to motivate the improvement of these skills for students throughout their engineering education. Draft solution ideas are submitted to the course Moodle site for grading and feedback prior to the final submissions.

In the drafts, some hand sketches are expected, and the link is to be made between the text and images. In our experience, students frequently attempt to use images clipped from web sources, sometimes without any citation of the source. In these challenges, we completely discourage the use of imported graphics, stressing the value of citing references rather than copying from them, and the importance of custom made original sketches for illustrating the student's solution idea. The draft submission of the Innocentive solution submission is our opportunity to comment on the relevance of graphical components of the submission, even if those graphics are only in draft sketch form.

Draft documents can be reviewed for technical content, but our focus in the first year course has been on format, process and communication. There is very little comment from instructors on our opinion of the effectiveness of the proposed solution, and certainly faculty refrain from commenting on whether or not we believe the proposed solution will meet the seeker's requirements.

The assignment: Grading, rubrics

At the end of four weeks, students submit their completed solutions for grading. It is not required that they actually submit the solutions to Innocentive, but most do so as well. A rubric used to grade the submitted assignments is shown in Table 2. The rubric clearly is oriented towards the graphics and communication aspects of the design project, reflecting the intended learning outcomes of the introductory course.

Discussion

The Engineering program at UPEI is very small, and currently only serves the first two years towards a degree program that is ultimately completed at Dalhousie University through a long-standing transfer relationship. Students have historically had an excellent track record for being practical, and able to excel in capstone design projects after transfer. With a first-year intake of only 55 students, our student numbers are far too small for good statistical data on the learning outcomes from specific projects. Student comment is one of the only means we have to judge the effectiveness.

An invited blog entry on the Innocentive website in May of 2011 was posted by one of the authors. The response to that from recent students helped to put the Innocentive design exercise in context. One student wrote:

> *Through Innocentive, we researched firsthand real-world problems. This gave the then new engineering students a great perspective as to some of the real work available out there, and gave us an idea of what we may be doing for the rest of*

our careers. Although there was a major learning curve, there was no beating around the bush and the first few weeks was probably the single most important development stage for me as an engineering student. [6]

Another student who also participated in the first introduction of the Innocentive design exercise wrote in the blog:

> *...it became immediately clear that problems like this weren't solved by some genius in a lab somewhere, but rather through researching weighing options and designing solutions. I can personally recall a eureka where I realized I didn't need to wait for someone to solve the problem I was capable of doing it myself. The fact that I was capable of independently solving real world problems gave me a sense of true independence and I believe was the defining moment I realized I needed to become a Engineer.* [7]

The use of online open-innovation challenges can be a significant motivating tool for students' study of engineering. We have found that since the introduction of these design challenges has helped to support the learning objectives in our introductory engineering course.

In three years of student submissions to Innocentive, we have not had any students who have won cash prizes. However, there have been students who have been contacted with questions by the seeker. Even this level of notice was exciting to the students involved, and helped to encourage them to enter more challenges. None of the students that were asked months, or years after their first encounter with the challenges have commented that the experience lessened their enthusiasm for the profession, and all have expressed their intent to enter more challenges in the future.

References

[1] Trivett, Kotys-Schwartz and Cyrus, Comparison of Engineering Student Self-Confidence at Two Universities, ASEE Annual Conference, Vancouver, BC, 2011

[2] Innocentive Inc., Facts and Statistics website, http://www.innocentive.com/about-innocentive/facts-stats. , accessed January 10, 2012.

[3] Trivett and Champion, How To Design a Design Project: Guidance for New Instructors in First and Second Year Engineering Courses , ASEE Annual Conference, Vancouver, BC, 2011

[4] Clive L.Dym and Patrick Little, Engineering Design: A Project-based Introduction, 2nd Ed, Wiley, 2004 .

[5] US patent and Trademark Office, Guide for Independent Inventors, http://www.uspto.gov/inventors/patents.jsp#heading-4, accessed January 10, 2012.

[6] John Thomas McKenna, UPEI engineering student, Facts and Statistics website, http://www.innocentive.com/about-innocentive/facts-stats. , accessed January 10, 2012.

[7] Phillip Curley, UPEI engineering student, Facts and Statistics website, http://www.innocentive.com/about-innocentive/facts-stats. , accessed January 10, 2012.

Table 2: Instructors Grading Rubric for Innocentive final submission

ENGN121 Report Rubric

	Amazing	Good	Poor	
	5	3	0	
Drawings & Figures	Drawings and data plots are clear, and in-text figures have captions. All drawings are properly drawn, look like what they are supposed to represent, and can be read given the size they are shown on the sheet. Everything is done to make the report clear and easy to understand	Most drawings are clear, and detailed, showing all of the essential aspects of the system or components. The data plots show the results.	Poor drawings, not clear, look sloppy, or don't resemble what they are supposed to show. The data plots are confusing, or axes poorly labelled, or otherwise not easy to understand.	5
Research	You have shown an ability and creativity in finding, reading, understanding and interpreting a variety of very credible sources of information. you have taken the trouble to really look "outside the box" for stuff. In the text, you have shown that you understand the difference between "OK" technical articles, and really outstanding ones that are important in the background to your report. There is absolutely nothing important in the paper that is not verified by excellent sources.	The author uses primarily sources that come from credible published information such as peer-reviewed journals, or government, NGO, corporate reports or patents. Nothing is used as a supporting reference that is unsigned by an author or authors. If corporate websites are used, they are used carefully, and appropriately, balanced with material from competing solutions or from peer-reviewed sources.	The author uses more than 10% of sources that are not suitable for Engineering science, such as wikipedia, blogs, websites, high school grade instructional material, or general-information flyers. The author may have blanket statements in their paper which are unsupported by reliable evidence, or they haven't even investigated key areas of the problem.	5
Analysis	The author has gone to the effort to break the design into appropriate sub-systems, and has identified technical and analytic tasks to be done before the design could be prototyped. If there are technical issues beyond the ability of the team to analyze, they have clearly stated this, and shown an honest effort to do some analysis. They have identified what remains to be done before a prototype is built.	Some of the essential sub-systems and foundations of the design have been examined closely, but there are gaps... the team recognizes there is more to do, and has some evidence that they understand what those detailed analysis tasks might be.	The report leaves many details open, not considering the reality of the solution, just relying on "hope" that the thing would work. It reads a bit like a cheesy infomercial.	5
Clear conclusion and recommendations	The conclusion wraps up the piece, giving memorable summation of the points, and helps the reader understand the impact of the solution, and the challenges left to overcome. All of the points mentioned in either intro or conclusion are somehow reflected in the body of the piece. The conclusion has some memorable ideas reiterated. Recommendations are clear, easy to find and follow, and are concrete. In addition, it is clear to the reader that the recommendations follow logically from the body of the work. The work is memorable and insightful.	The conclusions are clear and logical. Nothing is raised that wasn't discussed in the body of the report. The recommendations are also clear and logical. The work is good, but not memorable and insightful.	The conclusion is missing, or if present, is not very well connected to the remainder of the article, or brings up new ideas that are not covered in the body of the work. Recommendations are not stated clearly, or are absent, or are not supported by the body of the report.	5
Mechanics	There are NO spelling errors. There are NO grammatical or punctuation errors. Vocabulary and use of words helps the reader. All sentences are clear and structured in a way that supports the tone of the piece. Nothing detracts from the argument. Perfection...	There are fewer than three errors in spelling or grammar or word choice. The clarity isn't hindered by the errors, but the work is not quite mechanically perfect.	Spelling and grammar or word choice errors impact the clarity. Making the work difficult to understand, or fogging the author's meaning.	5
	25/25	15/25	0	