A reflection on the process of selecting, developing, and launching a new design project in a large-scale introduction to engineering design course

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Abstract

Providing first-year engineering majors with an opportunity to experience engineering through a project-based design course has become an important curricular element in many engineering degree programs. This paper provides a reflection on the process of selecting, developing, and launching a new design project by providing a practitioner’s account that details the successes, missteps, and lessons learned in transitioning to a new design project. The reflection is supported by a survey administered to the instructional team at the end of the first semester the course was taught, the authors’ reflection and assessment of teaching the new course, and student course evaluation responses.

Introduction

Providing first-year engineering majors with an opportunity to experience engineering through a project-based design course has become an important curricular element in many engineering degree programs. Research on novice and expert designers is also pointing to best practices for the instructional design of these first-year courses. One instructional need that has received hitherto less attention in this literature is on how to meet the challenge of creating novel semester-long projects for use in first-year design courses. These projects need to be ill-structured design problems, feasible for first-year students to achieve within the time constraints, engage students in the engineering design process, illustrate how engineering science knowledge plays a role in engineering design: all within the constraint of a first-year course when students might not have a rich base of college-level physics and math content to draw on. There are also often infrastructural costs associated with implementing these projects. What compounds the challenge, in our experience, is that even excellent projects have a finite shelf life. Over time, faculty might become too familiar with what works and what doesn’t and inadvertently steer students away from less conventional design ideas. Practical knowledge also builds up among the student body so that over the course of many semesters we might start seeing the same designs replicated by team after team. Many of these shortcomings could be alleviated by radically changing the project every few semesters. But that introduces new challenges.

A radical change in the design project of an already established first-year design course offers challenges different from those that arise when setting up such a course for the first time. New
projects are likely to challenge the established norms and practices within the course, which could lead to resistance from instructors and teaching assistants. For example, faculty might be resistant to changing what already works and what they are familiar with; they might be reluctant to invest the additional time and energy required to create new product specifications, new product assessments, and, at times, instructional materials on new content knowledge required for a new project. Second, no two projects are completely identical with respect to desired features: there are differences in relevant engineering-science knowledge, in construction techniques that are useful, and in parts of the design process that they may emphasize. There might also be concerns about losing the progress made during the fine-tuning of the previous project, or regressing on the gains made in student satisfaction, refinement of instructional strategies, etc. As such, switching to a new project might require a re-negotiation among the instructional staff for which trade-offs are acceptable, renewing hitherto settled differences and arguments among instructors. But the engineering education literature offers limited insight into how best to navigate this process of change, what instructors should be aware of before entering this process of change, and what pitfalls they should avoid during the process of change.

Towards contributing to this deficit in the engineering education literature, this paper provides a reflection on the process of selecting, developing, and launching a new design project within an already established first-year design course. We share details of the multi-year process of such a transition (in a large enrollment first year design course at the University of Maryland College Park) from project conception through pilot testing and development to full-scale development and implementation, and initial evaluation of the implementation. The new project, an autonomous Over Sand Vehicle (OSV), was carefully selected and developed over a two-year period. The OSV project was taught for the first time during the Fall 2014 semester to all students enrolled in the introduction to engineering design course at the University of Maryland. The initial OSV project development was completed by a faculty focus group tasked with selecting the next project concept and demonstrating a proof of concept. The following year, two teams of senior engineering majors were assigned the project concept as part of a project-based ‘research experiences’ course. Following the successful demonstration of two vehicles designed and built by senior engineering majors at the end of the Spring 2014 semester, the OSV project was launched in the first-year introduction to engineering design course in Fall 2015.

This paper provides a practitioners’ account that details the successes, missteps, and lessons learned in transitioning to a new design project in the first-year engineering design course. The reflection is supported by a survey administered to the instructional team at the end of the first semester the course was taught, the authors’ reflection and assessment of teaching the new course, and student course evaluation responses.
Institutional context and motivation for change

The Introduction to Engineering Design (ENES 100) course at the University of Maryland College Park, a large state-supported research university, has an annual enrollment of about 1200 students and is a required course for all freshmen engineering students. This project-based course was initiated in 1991 and developed through the NSF sponsored Engineering Coalition of Schools for Excellence in Education and Leadership (ECSEL) program. The main effort made under the ECSEL program was centered on creating a project-driven approach to teaching engineering design to incoming students¹. In 1992, seventeen students participated in the pilot section of ENES 100, which was anchored around the design and construction of a swing set. Afterwards, five design projects were developed to form a design project cycle. Those projects were based on the development of a wind mill, a solar desalination still, a weighing machine, a postal scale, and a human-powered water pump. The motivation was that the design project cycle would ensure that the projects remained fresh for both faculty and students involved with the course.

After the highly successful ECSEL program ended in 2002, the leadership role and responsibility of teaching ENES 100 was assumed by the Dean’s Office. Several new design projects were developed in an attempt to introduce microprocessor controls using the LEGO RCX brick. The first few years following ECSEL support brought mixed reviews of the course, both from the students enrolled and the instructors tasked with developing projects and teaching the course. As a response to these less-than-enthusiastic evaluations, the Dean’s office conducted a comprehensive review of ENES 100 in 2005 to identify areas where continuous improvement and significant changes were needed. The areas identified for improvement were in the development of new design projects with system integration requirements, applications of new technologies, and enhanced communication skills through teamwork.

At the beginning of 2006, the Dean’s office established the Clark School Keystone Academy of Distinguished Professors to recognize those educators who have made significant contributions to the undergraduate education in engineering, and to provide these faculty members with the support necessary to continue to make contributions to the undergraduate curriculum. The mission was clear: to revive the infrastructure of freshman and sophomore engineering courses with a focus on engineering design. To ensure the success of this new initiative, the Keystone program encouraged the school's best faculty members to teach the most fundamental courses in the engineering curriculum. In Fall 2006, ENES 100 became the first “Keystone Course” and the newly appointed Keystone professors were tasked with developing a new approach to revitalize the teaching and learning process.
The project developed by the Keystone faculty was for the design, construction, and testing of an autonomous hovercraft. The level of complexity of the hovercraft project far exceeded any project attempted previously. In order to be successful, each member of a team of 10-12 students spent on average 75 or more hours over the semester (inside and outside of the regular class time) designing, building, testing, and analyzing their vehicle and generating design reports and presentations. The hovercraft project was taught to all engineering majors during the academic years from Fall 2006 through Spring 2014.

The hovercraft project was selected because it exhibited a number of essential features sought in a design project. First, the complexity of the project was deemed appropriate as preparation for the types of real-life, multidisciplinary design challenges students would face later in their careers. Next, the project was sufficiently complex to require student attention over an extended duration and substantive cognitive activity. The project allowed for students to experience the product development process beginning with a product specification and ending with the testing of an alpha prototype. Projects that only require conceptual design activities were rejected from further consideration because of the learning that would be lost if students were not required to construct, test, and evaluate a physical prototype. The prototyping process is also very rewarding for students to experience. Last, the project was selected as a good fit at the authors’ institution because it required content knowledge valued by many of the largest engineering departments in the college (e.g., mechanical engineering, electrical and computer engineering, aerospace engineering). A weakness of the project was that it did not directly address content relevant to some other engineering departments in the college (e.g., fire protection engineering, bioengineering), but the faculty in these departments supported the course concept and regularly taught sections of the course.

In a typical year, 15 different faculty members teach one or more of the 30 sections of the course offered. Eight years into this project, most faculty members had been teaching this course for multiple years and over time had become very familiar with the design project, the instructional materials developed, and, likely to a fault, which student design concepts worked in the past and which failed. While the product specifications had been changed each semester to require unique student designs, the course model in place for the last eight years required all students to design, build, and test a similar product. As could and should be expected, both the faculty and the students grew somewhat tired of a design project that had only changed in small ways each semester. Anecdotally, the faculty had observed less student motivation and enthusiasm to make their projects work and a convergence towards fairly standard design decisions (e.g., the use of Styrofoam for the structure of the vehicle cut in the shape of a bullet). Additionally, the conceptions of faculty members on what could and could not work had also narrowed. Many design concepts were no longer being assessed on their technical merit but instead were being assessed against the success or failure past teams had experienced when attempting a similar
design. Typical feedback on an otherwise good idea might have resembled “You should rethink
that decision – I’ve never seen a team able to actually pull it off.” Needless to say, continuing to
teach the well developed, carefully selected, and positively received hovercraft project
indefinitely was not an option. This points to a major concern with teaching design -- all projects
have a finite shelf life. At the authors’ institution, signs that the autonomous hovercraft design
project had exceeded its useful life were growing in number with each passing semester.

Towards a new beginning

New design project concepts to replace the autonomous hovercraft project were being searched
for, starting as early as 2008, just two years after the hovercraft project launched. Many
excellent resources existed for searching for possible first-year design projects. However, very
few projects met the criteria the instructional team sought in a design project. These criteria
included (1) a sufficiently complex project that requires a multidisciplinary team effort requiring
significant cognitive effort over an extended time period, (2) the design of an autonomous or
semi-autonomous product that requires systems integration, (3) a project that permits both
conceptual/detailed design and prototype construction and testing, (4) a project that could be
administered effectively to over 1000 students each year, and (5) a project that exposes student to
rigorous technical content valued by many if not all of the engineering departments within the
college. In considering new project concepts, the faculty also sought to be opportunistic to help
mitigate some of the known limitations of the hovercraft project. This primarily included
seeking a project that genuinely interests students in all majors and a project that is a bit easier to
control than an autonomous hovercraft (controlling the linear and/or angular momentum of a
low-friction hovercraft is very unforgiving). Many projects that were considered were ultimately
rejected because they failed to offer one or more of the essential components so valued in the
hovercraft project.

In 2012 the idea of a Mars rover-like vehicle that had to explore unknown terrain and report back
findings gained traction among faculty as having relevance and potential interest to students.
However, the idea of designing an extraterrestrial exploration robot was discarded early on, as
the authentic design of a robot for a different planet would require gravitational considerations
that could not be implemented when testing student prototypes at the university. Instead, the
idea of developing an autonomous vehicle capable of exploring a sandy terrain on Earth’s
surface was selected. Despite the possible mess and logistical complications, sand was selected
because it offered a vehicle-ground interaction surface that would be much more forgiving than
that experienced by the hovercraft, but that would require a lot more thought and analysis than
designing a vehicle to travel over a hard surface.
During the Spring 2013 semester, an experienced ENES 100 Teaching Fellow with considerable robotics experience was hired and tasked with exploring and prototyping vehicle concepts for navigating in a sandy terrain. The prompt was left vague and wheeled, tracked, bipedal walkers, spoke wheel systems, etc. were fair game for implementation. This student met weekly with a small team of engineering faculty who reviewed the progress/findings and encouraged additional future work. At the end of this semester this student was able to demonstrate a first working proof of concept that a vehicle could be made to travel in sand under the control of an Arduino microcontroller. Of equal importance, the challenges the student experienced (e.g., sand stalling motors, designing wheels that do not slip, etc.) made it clear that this design challenge was on par with the autonomous hovercraft project. Two additional important ideas came out of this working group. First, the idea of providing students with the equivalent of localized GPS and magnetic compass data to aid their navigation algorithms was conceived of and plans to implement an overhead camera vision system to accomplish this were set in motion. Second, the student hired reflected on past design experiences he had in a upper level ‘projects in engineering’ course and encouraged that a course be created to invite senior engineering majors to attempt the project before launching it in ENES 100.

During the Fall 2013 semester, a recent graduate was hired as a program specialist to support the ENES 100 course. One task assigned to this individual, as time permitted, was to develop a vision system for the new design project concept. While the senior projects in engineering course was noted as an outstanding idea, faculty resources were not available during the Fall 2013 semester to offer the course. The course, ENES 499: Senior Projects in Engineering, was however offered during the Spring 2014 semester. By this time, reasonable progress had been made on a vision system to demonstrate the concept.

An instrumental stage of the new project development was offering the ENES 499 course to a group of 15 juniors and senior engineering majors. While the students in this course knew the project concept was being considered as a hovercraft project replacement (this motivated many of the students), the course experience was clearly defined as being separate from any future ENES 100 plans. What was expected of each student was to critically analyze, design, and build a terrestrial vehicle capable of navigating a sandy surface, using guidance from a central command with input from an overhead camera, using RF communication channels, measuring various physical and navigational parameters, and picking up payloads and depositing them at various points. For the first half of the semester students were split up into three separate functional teams -- mechanical systems, guidance systems, and sensing systems. Each team was required to consider what subsystems their functional area must consider and each student was required to submit an individual proposal describing how he or she would gain expert knowledge of the sub-system under consideration. About halfway through the semester functional design reports were turned in and the class was split into two cross-functional teams. Each team was
tasked with coming up with a set of product requirements and specifications, and then with designing, building, and testing a prototype that met those criteria.

The two design concepts the students in ENES 499 conceived of were a beach litter robot capable of finding, sorting, and delivering litter appropriately (e.g., distinguishing between glass, metal, and plastic bottles) and a fire suppression team whose robot was capable of detecting and extinguishing fire by two methods and “sniffing” for potentially flammable chemicals. An important feature of this course experience was the level of autonomy given to students to select their own project and develop their own solutions. For example, two additional vision systems were developed during this course. One utilized Labview and permitted three-dimensional mapping by tracing the path of a sphere in space and the other utilized Matlab and filtering techniques to allow red objects to be identified and communicated to the vehicle. Many students’ individual contributions to the team project more than fulfilled what is typically accomplished in an independent research study course. This course also permitted the waters to be tested with a small student population. Students were given freedom to select design problems they found interesting (e.g., a fire protection engineering major wanted to see a robot that could fight a fire and another team thought a robot that could clean up litter would be valuable) and to permit the ENES 100 faculty to better assess the boundaries of this project concept. At the conclusion of ENES 499, the ENES 100 faculty were invited to listen to the final team design presentations and to witness the prototype demonstrations. The vehicles looked and functioned in a similar way as typical ENES 100 student projects at the end of the semester, despite the significant technological advances made by most students to better inform our understanding of what can and what cannot easily be accomplished.

As the Spring 2014 semester drew to a close, the ENES 100 faculty met one final time to discuss plans for the Fall 2014 semester. The group was split on what should be done -- stick with the hovercraft project another year, offer up pilot sections of the new sand vehicle project, or switch entirely to the new project. Compelling arguments against switching to the new project included the notion that the program wouldn’t be ready for this major course transformation with just one summer to prepare and that it would be safer to learn the ropes on a smaller subset of students. However, most faculty when asked indicated they would be interested in teaching the new project concept. Not unlike the decision to launch the hovercraft project eight years prior, somewhat by fiat it was decided that the time was now to switch projects and that (1) having more minds on the transition would mean a better launch, (2) resources would not be divided between two projects during this instrumental semester, (3) we recognized that we would never be “ready” to switch, and (4) there was an understanding that things would not go entirely smoothly the first time through, but we would learn quickly and revise as needed to make the project a success. The decision was somewhat heated, but the Associate Dean of Undergraduate Studies compelled the transition -- with general acceptance and support of the decision by the
group. As was made clear, we had more time than we did when launching the hovercraft and had much more knowledge about how to run the course than we did back then. Following the meeting, a new direction was set and plans were made to transition to the new project effective immediately.

**Preparing to launch and project launch**

The summer before the Fall 2014 semester was used to develop the new Over Sand Vehicle project concept. This required (1) generating new instructional resources for teaching the course, (2) retooling the labs to support the new project, and (3) developing the overhead vision system. The process for generating new instructional materials was divided up among the group. A recent change to the course replaced weekly anchor lectures with short, instructional videos covering the same content (flipped classroom pedagogical approach). Pairs of faculty were assigned a topic in their general expertise area and were requested to film videos on the material, propose instructional materials to support teaching during discussions led by the section instructor, and create homework and quiz problems on the material. This generally equated to pairs of faculty members being responsible for generating one week of content. The filming went fairly smoothly with about half of the content from the hovercraft project being able to be recycled for the new project.

It is worth noting that features of the hovercraft project that had become institutionalized were revisited during the planning process for the new project and changes were made that previously had met too much resistance when suggested. Two notable changes include beginning the course with a broader discussion of engineering design instead of focusing immediately on technical content related to the project and reducing the amount of content that all students require from six weeks of common material down to four. The overall course calendar did not change much, but the final two weeks of material for the OSV project allow students a mechanism to specialize in a topic they find most interesting or that will support their work on the project (e.g., protecting electronic circuits or advanced 3D printing techniques). A handful of specialization modules were created with the intention to continue to add to this library over time.

A second major undertaking was re-purposing the laboratories that support the ENES 100 course to better reflect the new project. For example, hot wire cutters and a small wind tunnel that were used extensively for the hovercraft project were placed in storage and drill presses and mechanical fastening tools were purchased for the OSV project. Additional laboratory modifications included developing the vision system and building in-lab test beds (7 x 14 ft sand boxes). A notable shortcoming in the project transition was the lack of time and expertise to develop laboratory equipment to test the output of motors or the wheel-sand interactions and the
inability to port many of the good laboratory demonstrations that were utilized with the hovercraft project over to the new project during the first semester taught. These areas remain works in progress.

In critically thinking about the new project many assumptions tied to the hovercraft project were challenged and a number of significant changes were made. A notable change is that four mission requirement options were made available to students, allowing some degree of choice in the project that students attempt. Each team in the hovercraft project was required to meet the exact same product specification and mission requirements. Additionally, both base level and bonus objectives were included, thus providing a lower entry point for success while still permitting motivated students to attempt to solve ill-defined and challenging design problems. The four missions included in the Fall 2014 semester were water sampling, terrain mapping, metal collection, and vent detection. The vent detection mission was originally presented to students as smoke detection, with the intention being to release controlled smoke with a cinematic fog machine that could be detected with a chemical sensors. This mission was changed to the detection of an air vent about three weeks into the semester, leading many students and faculty to rightfully begroan the change. This example is somewhat indicative of the fact that much of the development simply could not be completed during the summer months, leading much of the development to continue throughout the entirety of the Fall 2014 semester. Along with the change to allow some degree of student choice in mission selection, it was decided that instead of having each team competing against all other teams that it might be productive to require sections to compete against other sections. The rationale for this decision was that teams within the section might support each other more fully, pay more attention when reviewing design presentations, etc. so that the overall section succeeds.

In the end, much of the structure and learning objectives associated with the hovercraft project were repurposed with minor revisions for the OSV project. For example, relatively minor changes were needed to the instruction of electronics and Arduino programming or to the overall flow of the course with the timing and requirements for design presentations, reports, and performance milestone demonstrations. Other areas required completely new material and was thus much cruder in how it was presented (e.g., OSV mechanics that dealt with motor selection, wheel-sand interactions, and motor-wheel matching). Figure 1 below provides a visual representation of the mission arena where students competed.
Unlike with the hovercraft project where teams needed to qualify to compete in the final design competition, all student teams had an opportunity to complete in the final OSV project competition. Student designs exhibited considerable variation in material selections, component selections, approaches to solving mission-specific problems, and the level of success achieved on competition day. Figure 2 provides an example of an OSV that a student team designed and constructed for the water sampling mission. Only minor changes are evident between the preliminary design concept rendering that was submitted at the midway point in the semester and the final prototype constructed. The designs of most other teams changed more substantially between these two points in time.
FIGURE 2: An example of a well-designed student project: preliminary design concept (left) and final prototype (right)

As compared to recent semesters, weekly course planning meetings were better attended and contained more excitement with the new project being launched. The faculty instructional team used these meetings to share their classroom experiences, to suggest what worked and what did not work, and to make recommendations for improvements that could be made to the course. Some of these improvements allowed for other faculty members to immediately benefit from the shared input. For example, a new 3D printing feature was added to the course this semester and each student was required to print one part during the course of the semester that they modeled using CAD software. One of the faculty members whose students began printing earliest in the semester shared with the rest of the team the scheduling system and lessons learned supporting this new course component. Other feedback received at these meetings were archived for future consideration. For example, the first week of technical content focused on the engineering design process. One of the civil engineering faculty members who taught the course provided a pointed critique of this material and the structured manner in which he expects civil engineering students to understand the engineering design process. This feedback was used to revise the lecture videos filmed on this material for use in future semesters to better reflect the expectations and needs of the diverse set of students and faculty associated with the course.

In addition to sharing experiences at weekly meetings, many faculty members also shared their instructional materials with the rest of the team. This was managed through Canvas, the university’s electronic learning management software. Instructor-only pages were created that permit lesson plans and lecture notes to be posted and all members of the faculty to comment on the materials, how effective they were, and what if anything could be improved. Unfortunately, while a valuable resource, only a small number of faculty actually contributed to this material
bank. With details of the development and launching of the new OSV project specified, the remainder of this article provides a reflection on how the transition to the new project went.

**Evaluation and reflection**

A number of methods have been used to evaluate the success of the new design project and to establish areas where future improvements can be made. The data considered includes (1) a survey administered at the end of the semester to the ENES 100 instructional team of faculty, undergraduate teaching fellows, and undergraduate laboratory assistants, (2) end of the semester course evaluation results, and (3) the authors’ reflections on the project transition. Each of the three authors was intimately involved with the course transformation, taught one or more sections of the course in the Fall 2014 semester, and participated in most faculty planning meetings and one or more student focus groups. Despite a large number of students being invited to participate in these focus groups from each section, these were poorly attended and so a detailed analysis of the focus group results has been omitted. The discussions have informed the authors nonetheless.

**ENES 100 instructional team survey**

The instructional team expressed many positive comments about their experiences with the new project. One of the most commonly expressed sentiments was that it was re-invigorating to not have a set of known solutions for the new project. Instructors and students alike found this to be exciting and it provided the opportunity for genuine creativity. In addition, many on the instructional staff appreciated the introduction of 3D printers and a GPS-like navigation system, citing that this was representative of what students would experience in the real world. Next, many noted that the number of teams with successful vehicles increased from the number with the hovercraft project, making for a more satisfying experience for instructors and the student teams. Despite the many challenges that came with the new project, many on the instructional team called this a successful experience.

The survey also revealed many instructional team members’ discomfort with switching to a project with so many unknowns. Many responses included sentiments such as feeling scared, stressed, or intimidated. Not all of the course materials and details were ready on time, and this caused instructors to feel unprepared and caught off guard.

When asked to write about the weakest aspects of the new project, many of the instructional team’s comments reflected on the new project’s lack of testing prior to implementation at the start of the semester. Some of these time-related issues included running an RF communication system and overhead vision system with many technical glitches, offering student access to a
new 3D printing lab without knowing how best to manage such a powerful resource, and making changes to the mission details as the instructional team learned the limitations of the lab’s capabilities. Many of these concerns could have been mitigated with sufficient testing of all systems prior to the start of the semester.

Beyond these types of comments, the instructional team also supplied valuable feedback that likely could not have been prevented with more time. One reflection was that the instructional team did not know what concepts would be most important to highlight, and the result was an occasional emphasis on unimportant topics and not enough coverage of topics that would have been very useful to the project. Another comment was that one purpose of introducing four different missions was to appeal to a variety of majors, but the simplifications to the missions in the end did not authentically expose students to different disciplines. A third common response was that instructors frequently saw teams not effectively apply the content from the first part of semester to the design of their vehicles. This feedback was extremely useful for making changes to the course for the subsequent semester, and it will also be used to inform the generation of future new projects.

**Student course evaluations**

A second source of data that has been examined to evaluate the learning changes between the hovercraft and over sand vehicle projects was obtained through the online course evaluation system used for all engineering courses at the university. All students are provided an opportunity to complete the survey during the final two weeks of the semester. Data from the Fall 2013 (hovercraft project) and Fall 2014 (OSV project) semesters are compared. Fall semester data was selected because the student demographics and faculty teaching the course during this semester are more closely matched than in the Spring semester when many seats are provided to non-engineering majors. In total, 445 evaluations were submitted during the Fall 2013 semester (72.7% response rate) and 420 evaluations were submitted during the Fall 2014 semester (70.0% response rate). The evaluation uses a 5-point Likert scale ranging from 0 = Strongly disagree to 2 = Neutral to 4 = Strongly agree. Results for five campus-level administrator questions and 16 college-specific questions were analyzed by considering the mean score on each question by section. A comparison of survey means between groups was analyzed for statistical significance using the statistical analysis tools available in Microsoft Excel. Specifically, a two-tailed t-test was performed (using the T.TEST function), specifying a test for two samples with unequal variance. The critical threshold for a statistically significant difference in the means was taken to be \( p < 0.05 \).

The majority of questions asked on the course evaluation found no statistical significance between the mean score before and after the project transformation. However, statistically
significant results were found for a handful of questions. Of the five administrator questions the only one found to be statistically significant was the question that prompts students with “This course was intellectually challenging.” The mean score for the OSV project was 3.27 and the mean score for the hovercraft project was 3.09. This result was significant at the p = 0.01 level and may indicate that students undertaking the OSV project found it more intellectually challenging than the students who had the hovercraft project. We speculate that this is because the students who had the new OSV project could not draw on the knowledge of teams from previous semesters who would have had the hovercraft project. Two notable places where no statistically significant change was found include the prompts “I learned a lot from this course” and “The instructor was well-prepared for class.” This is a positive result because one could reasonably hypothesize that instructors would be much less prepared when teaching a new design project for the first semester and students would learn less as a result. However, students did not indicate this to be a concern when providing feedback through the course evaluation system.

Six of the 16 college-specific evaluation questions were found to have statistical significance when comparing the mean scores across all sections. These questions – along with the Fall 2013 mean score, Fall 2014 mean score, and the significance level – are presented in Table 1. It is interesting to note that only one of the questions found to have a statistically significant change was a question the authors found inextricably linked with the desired learning outcomes of the course -- the ability to identify, formulate, and solve engineering problems. The results indicate that students who had the OSV project believed it has enhanced their ability to identify, formulate, and solve engineering problems more effectively than those who had the hovercraft project. Three other notable questions that showed no statistical change include “My ability to apply engineering principles has improved as a result of taking this class,” “My ability to design a component, system, or process to meet desired needs has improved as a result of taking this class,” and “My ability to function effectively as part of a team has improved as a result of taking this class.” The learning outcomes tied to these three questions are closely aligned with the authors desire to provide students with a multidisciplinary, team-based introduction to engineering design. We interpret no change in these categories to be a positive result.
TABLE 1: Course evaluation comparison results that indicate a statistically significant difference in mean evaluation scores across sections between the hovercraft and OSV projects

<table>
<thead>
<tr>
<th>Course Evaluation Question</th>
<th>Fall 2013 (Hovercraft) Mean Score</th>
<th>Fall 2014 (OSV) Mean Score</th>
<th>Significance Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>My ability to apply knowledge of basic science (chemistry, physics) has improved as a result of taking this class.</td>
<td>2.50</td>
<td>2.34</td>
<td>0.05</td>
</tr>
<tr>
<td>My ability to use computers to solve engineering problems has improved as a result of taking this class.</td>
<td>2.76</td>
<td>2.91</td>
<td>0.05</td>
</tr>
<tr>
<td>My ability to identify, formulate, and solve engineering problems has improved as a result of taking this class.</td>
<td>2.88</td>
<td>3.01</td>
<td>0.05</td>
</tr>
<tr>
<td>My ability to design and conduct experiments has improved as a result of taking this class.</td>
<td>2.53</td>
<td>2.67</td>
<td>0.05</td>
</tr>
<tr>
<td>My ability to use the techniques, skills, and modern engineering tools has improved as a result of taking this class.</td>
<td>2.92</td>
<td>3.06</td>
<td>0.05</td>
</tr>
<tr>
<td>Taking this class has increased my awareness of the need to continually upgrade my technical knowledge base and skills.</td>
<td>2.90</td>
<td>3.10</td>
<td>0.01</td>
</tr>
</tbody>
</table>

The only result found to indicate the OSV project performed worse than the hovercraft project is the ability to apply knowledge of basic science (chemistry, physics) as a result of taking this class. While scoring high in this category is desirable, a high score is only appropriate if it aids students in having an authentic engineering design experience. The authors posit that the removal of fluid mechanics from the course and the increased emphasis on the engineering design process that accompanied the project transition is related to the lower evaluation results. Three of the questions that show a statistically significant improvement are somewhat surprising to the authors. These questions are related to the ability to use computers to solve engineering problems, the ability to use techniques, skills, and modern engineering tools, and the awareness of the need to continually upgrade their technical knowledge base and skills. The authors hypothesize that these improvements are the result of adding consumer-grade 3D printers to the course during the Fall 2014 semester and requiring all students to print a part drawn in one of their CAD homework assignments.

In order to test the robustness of the above findings and to control for differences in faculty assigned to teach the course between the Fall 2013 and Fall 2014 semesters, we have run a similar set of statistical tests on the subset of faculty who taught ENES 100 during each of these semesters. When a faculty member taught two or more sections in a given semester their results were averaged across all sections taught. This reduced the sample from 14 and 15 sections in the
Fall 2013 and Fall 2014 semesters, respectively, to 8 sections each semester. With this level of control applied and the reduced sample size, only two tests reported statistically significant results. These results confirm the decline in students perceived ability to apply basic science knowledge and students perceived improvement in their awareness of the need to continually upgrade their technical knowledge base and skills. This test indicates that many of the findings noted above are not overly robust. Ultimately, we are relatively pleased that most changes related to student learning outcomes are insignificant. This indicates that little or no ground has been lost (with respect to students’ course experience) in transitioning to a new project concept.

**Reflections**

In this section we share some of our personal observations and reflections on our experiences as instructors and course-coordinators during this transition period.

We felt a renewed energy in our own experience of the course and also in our assessment of other instructors’ participation in the course. Regular instructors’ meetings for this course, we felt, were more frequent and better attended than in previous semesters. These thus provided a space for faculty to share particular instructional experiences which other people can draw on and also share what they value about the design process and their learning goals for the course. The meeting space was always intended to serve as a hub for the exchange of information, but over the years attendance and enthusiasm for the meetings was flagging. This semester that enthusiasm was restored. Discussions at some meetings have been instrumental in changing some of the content of the course. While this is good, we felt that it was not enough: meeting attendance was not 100% and some differences among faculty views remained unresolved. We hope that future semesters will offer further opportunities for establishing a more shared instructional vision. Additionally, not all faculty shared their instructional materials as freely as others did.

We certainly felt a sense of survival at the end of the semester. The semester was at times marked by last minute preparation, adapting to last minute changes, and at times just struggling to do our best to provide students with a smooth experience in a new project. Looking back, we are glad to have gone through the experience. We feel that any new project will require us to go through this period of turmoil during the pilot phase; it could not be avoided. We have learned about which parts of the curriculum require severe changes and what parts of the project require refinement. We have built on our pedagogical knowledge of what portions of the technical content is conceptually challenging for the students and can better orient the class to address these the next time around. We also feel that the experience has given us greater empathy for the students: ours was a journey of creating an instructional prototype alongside the students who were creating prototypes of their OSVs. Like them, we found ourselves responding to
unanticipated setbacks, time and resource constraints, and balancing tradeoffs in every choice that we made instructionally.

We think that transitioning to a new project allowed for a greater variety and innovation in the designs that student teams came up with. We saw much more diversity in the materials and construction techniques being employed. To some extent, we feel that not having access to the knowledge of how a variety of designs perform (as was the case for hovercraft, having taught it for multiple semesters) allowed us to really see the potential in students’ ideas rather than being drawn to potential difficulties (that might not have come to pass). Of course, this also means that over several semesters of the OSV, we will be ready for (and need to be ready for) another transition!

We have come out of the experience stronger and better prepared for a new semester, knowing where to target the first set of refinements.

**Conclusion**

This paper provides a reflection on the process of selecting, developing, and launching a new design project by providing a practitioners’ account that details the successes, missteps, and lessons learned in transitioning to a new design project. Unlike many traditional courses where the content does not change much from year to year, or even decade to decade for that matter, design-based courses require the inclusion of projects that have a relatively short shelf life. As such, these courses require regular renewal and revitalization in order to continue to meet the needs of students and faculty. This paper provides a unique contribution by describing our experiences at the precipice between two different design project offerings. In sharing these experiences, this paper provides other practitioners with signs that a project may be near the end of its useful life, a set of practices and procedures to consider for screening, selecting, and developing a new project offering, and an indication of areas where future curriculum developers should focus additional attention to avoid many of the potholes that could derail the successful delivery of a new project.

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References