Implementation of a Low-Budget, First-Year Engineering Project Based Experience: The Design of a Mini-Golf Hole

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Dr. Meyers background is in Engineering Education with experience in assessment, specifically of programs that might influence an incoming student's experience, affect retention rates and the factors that determine the overall long term success of students entering an engineering program. She is the Director of the STEM College's First-Year Engineering Program, the entry point for all beginning engineering students designed to provide a smooth transition from high school to University. Having been in charge of this program at the University of Notre Dame for 7 years and now at YSU has made her deeply familiar with the requirements for a thorough undergraduate curriculum that successfully transfers an in-depth understanding of the core principles of math, science and engineering to the incoming students through innovative coursework, mentoring and team work, and the value of hands-on teaching and one to one interaction of faculty and students.

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Abstract

A First-Year Engineering Design Project-Based Experience was implemented at a medium-sized, Midwestern, urban, public institution in the fall of 2012 and 2013. Beginning in the fall of 2012, a common First-Year Engineering Program was introduced which included a two-semester course sequence (each course is 2 credits) which teaches students fundamental engineering concepts: EXCEL, MATLAB, technical communication, and statistics in the context of hands-on design projects. In the program's first year, a pilot project in which student teams of 3-5 students designed a mini-golf hole using shared materials which included piece of Astroturf which is 6 ft. x 25 ft. long and bricks to define a golf hole. In its second year, fall of 2013, the project was improved from an administration perspective and also modified to engage students in customer requirements. Specifically, student teams met with the owner and golf professional at a local miniature golf establishment, played and evaluated the 18 hole mini-golf course, and developed an original design concept with their team (utilizing SolidWorks for visualization and EXCEL for analysis). Finally, the customer (owner and golf-pro) came to campus to evaluate the team projects, and selected the best projects to be built permanently in the indoor mini-golf course they are in the process of developing.

The initial year of this project implementation was a pilot, with minimal formal assessment conducted but improvements were made based on feedback from students (through course evaluations) and informal discussions. During the second offering, there was a formal assessment process which was primarily quantitative in nature but also posed several open-ended qualitative questions. The assessment was in the form of surveys that each student completed in class, on-line using BlackBoard. Surveys were administered at 3 points during the semester: (1) prior to starting the project, (2) after playing the mini-golf course and meeting with the customer, and (3) upon conclusion of the project / semester. Results indicate that student participation in the project is beneficial to establishing a network of peers which is critical to student success in completing an engineering degree.

Introduction

Improving opportunities for higher education for low-income, minority, and urban students remains a critical issue in engineering education[1], increasing the access to engineering educational opportunities of these key populations will have a significant impact on balancing the shortage of qualified engineers in the U.S. which is important for global competitiveness. Further, engineering educators are tasked with changing traditional ways of educating engineers and broadening the exposure of K-12 students to engineering careers, requirements, and opportunities [2]. With the wide range of research citing the need to transform traditional lecture courses into more interactive and responsive environments[3,4,5,6], many colleges and universities have begun transforming their engineering curricula. Youngstown State University (YSU) has also begun this transition by increasing faculty staffing and undergraduate teaching assistants in support of smaller class sizes focused on project-based learning experiences.

Background of Youngstown State University

Youngstown State University is an urban, public, research university in Northeast Ohio with a wide variety of higher education programs and majors serving ~13,000 undergraduate students, 86% of which come from within the state of Ohio. It is a very accessible school for students of diverse academic preparations and socioeconomic status. Specifically, it guarantees admission to any student earning a high-school degree or GED equivalent (although some programs, including engineering, do have restricted admissions). The STEM College is 72% male and 28% female and ~12% minority student population (5% Hispanic, 3% African American, 2% International, 1% Multi-Racial, and 1% Asian). Most students in the STEM College are of traditional college age (80% less than 25 years old), are full time students (85%), and live off campus and commute (90% commute). The STEM College had a total enrollment in the fall of 2013 of 2,833 students.

In the fall of 2012, the STEM College established a formal First-Year Engineering Program. A curricular restructuring such that all First-Year Students take the same two semester course sequence (2 credits each): Engineering Concepts (ENGR 1550) and Engineering Computing (ENGR 1560) in addition to a one credit Engineering Orientation course (ENGR 1500). This structure requires Pre-Calculus as a prerequisite for ENGR 1550 (rather than Calculus I), which removes an administrative gate for students[7,8]. This increases accessibility for entering students drawn from disadvantaged socioeconomic schools that may not have had the same levels of mathematics and science preparation in high school[8,9,10]. Additionally, there are devoted First-Year Advisors that transition students to their selected engineering departments during the second course in the sequence, Engineering Computing. This delay in decision making optimizes informed choice in selecting an engineering major[11,12].

As shown in Figure 1, the previous course structure involved lecture once per week (50 minutes) and lab once per week (2 hrs. 50 min). The lecture took place in a large lecture hall (200+ students in a single section with 1 instructor) in a learning environment indicative of traditional approach that is not only passive[13] but is also incompatible with the project-based learning approach; which is recognized as one of the best educational practices[13,14] for heightened students engagement[15,16]. Active learning strategies have been reported to improve the long term retention of average students in engineering[17]. Further, cooperative, project-based learning experiences grounded in a broader societal context (i.e. projects having a clear, positive benefit for society) have been recognized as positive influences for all students, including underrepresented groups such as women and minorities[18,19,20]. A change to an active learning environment was implemented during the spring and fall of 2013, wherein students met twice each week (75 min) in a hybrid lab/lecture setting in a class of 55 students with one instructor and two undergraduate teaching assistants (sophomores). The longer term goal is to further enhance the experience for students by reducing the class sizes from 55 students down to 40.

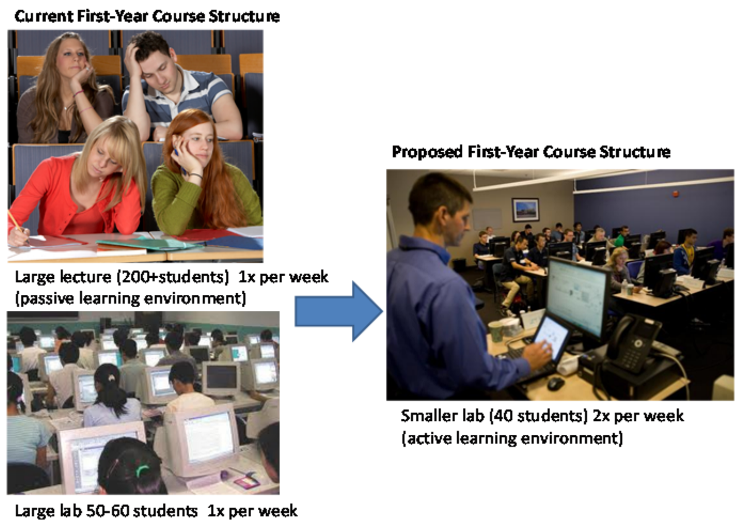

Figure 1. Previous vs. New Structure for First-Year Engineering Course Sequence

At the end of the course sequence, the students understand key foundations of engineering computing and analysis. The student will have experience with: spreadsheets, visualization, statistics, computer programming, and technical communication. In the fall semester, the predominant content area is learning to use Excel as an engineering tool. The students then use Excel in two project experiences including the design of (1) an Edible Car and (2) a Mini-Golf hole wherein Excel is the analysis tool used (calculations, statistics, plotting, and error analysis). In the spring semester, MATLAB is used as the primary engineering tool (computer programming, plotting, data analysis, and modeling) in the context of designing an engineering exhibit for OH Wow! The Roger & Gloria Jones Children's Center for Science & Technology, the local children's science center located in Youngstown, Ohio (OH Wow!, 2011). The Mini-Golf Project is the primary focus of this study, wherein student teams of 3-5 students designed, built, and tested a Mini-Golf hole given a piece of turf that is 6ft wide by 25 ft. long in which removable bricks were used to line the course. The students were required to create a design that included: an elevation change, a bend, obstruction(s), and some form of theme. An example of a student project is shown in Figure 1 in which the project team created a Wizard of Oz themed mini-golf hole.

Figure 1. Student Design Project: Mini-Golf Hole Wizard of Oz Theme

Finally, the project took place over 6 weeks and is outlined in Table 1. It began with team formation and concluding with formal oral presentations given by project teams that discuss the results of their project design demonstrations. There was significant focus on error analysis (predicted values vs. measured) and technical communication.

Table 1. Timeline for Project

Date	Activity / Requirement
Week 1	Introduction to the Mini-Golf Project Form Project Teams Mini-Golf Field Trip to CreekSide Golf Dome
Week 2	Visualization Exercises using SolidWorks Tutorials
Week 3	Excel – Error Analysis Project Group Work / Testing Time
Week 4	Excel – Solving Systems of Equations Technical Communication Project Group Work
Week 5	Mini-Golf Project Demonstration Technical Communication
Week 6	Written Report for Mini-Golf Project Due Oral Presentations

Most of the materials for the Mini-Golf Project were reusable with a one-time cost of $850 as shown in Table 2. However, we did partner with a local golf establishment as the "customer" for this project such that students were able to go on a field trip to their facility and play 18 holes of mini-golf and hear directly from the golf professional the key elements of a design that they deem critical to incorporate into a final design. This field trip came at an additional cost of ~$1000 per year but was deemed critical by organizers to have a team building experience and to enable students to understand customer needs. In addition to meeting the design constraints set out from the class, the golf professional also served as the "judge" for the golf holes at the project demonstrations.

Table 2. Project Administrative Costs

Project Elements	Notes	Cost
Turf	4 turf set ups were purchased from a vendor. Reusable from year to year	$400
Golf Balls	1 bag of old range balls Reusable from year to year	$10
Putters	4 used or donated putters Reusable from year to year	$40
Pallet of Bricks	$400 for a pallet of bricks from Home Depot. Reusable from year to year	$400
Field Trip to Golf Dome	Transportation costs were low by using University Vehicles. ~$4/student to attend *250 students	$1000

Methods:

The First-Year Engineering Design Project in the fall of 2013 at YSU to design a Mini-Golf Hole was assessed by administering 3 on-line surveys to the students enrolled in the course. The surveys were anonymous and administered through BlackBoard such that students were given course credit for completing the survey, but the instructors could only see who completed the survey and not their individual responses. The collective responses of the 240 students enrolled in the course were analyzed for statistically significant differences, and further the open ended qualitative questions were reviewed to further understanding of the large scale quantitative results. Surveys were administered at 3 distinct points throughout the project: (1) prior to starting the project, (2) after playing the mini-golf course and meeting with the customer, and (3) upon conclusion of the project / semester. The number of responses for each survey is outlined in Table 3, note that the response rate for the third survey was lower than the other two likely because it took place at the conclusion of the semester (not during class time). The response rate for women was higher than men for all of the surveys which conforms to the expectations set by prior studies which showed that gender is the single greatest predictor for survey completion[21].

Table 3. Summary of Response Rates by Survey

	Number of Responses			Potential Number of Responses			Response Rate		
Survey #	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Overall**
1	193	42	235	198	42	240	97%	100%	98%
2	175	40	215				88%	95%	90%
3	138	38	176				70%	90%	73%
			626				85%	95%	87%

A few of the survey questions were common on all 3 surveys, such as asking the students to assess the learning objectives, their interest in the project, comfort level with their peers, and other perceptions as well as some background information such as their gender, what section they are enrolled in, intended engineering discipline, and the number of college credits they have completed. An outline of those questions is shown in Table 4.

Table 4. Summary of Survey Questions

	Questions 1-4, to what extent do you feel the following learning objectives were met?	**Likert Scale Questions:**
1	To establish a solid working relationship with engineering class peers and work collaboratively on short and long term assignments.	Low 1: Strongly Disagree to High 5: Strongly Agree
2	To learn the fundamentals of spreadsheets (EXCEL) and how to use it as an engineering tool.	
3	To learn the fundamentals of statistics as an engineering tool.	
4	To gain experience and comfort with technical communication skills, both oral and written.	
	Perception of Experience Questions	
5	How interested in engineering are you in general?	Low 1: Disinterested to High 5: Very Interested
6	How would you rate your interest level in the mini-golf project?	
7	How relevant do you think this project will be to your education as an engineering student?	Low 1: Irrelevant to High 5: Very Relevant
8	How committed to engineering are you? (this does not mean you need to know which discipline of engineering you want to pursue yet)	Low 1: Not Committed to High 5: Highly Committed
9	At this point in the semester, how comfortable do you feel with your class peers in ENGR 1550?	Low 1: Uncomfortable (I don't know anyone) to High 5: Very Comfortable
10	Has this project had any influence on your selection of an engineering discipline?	Not really / Yes - it affirmed what I originally thought
11	Has this project influenced your commitment to continuing in engineering in general?	It has dissuaded me from continuing in engineering / Neutral - No influence positive or negative / Yes it has affirmed my plans to continue in engineering
12	How well do you feel your team has worked together on this project?	Low 1: Poorly to High 5: Very well
13	Please rate your level of enjoyment in working on this project.	Low 1: Not Enjoyable to High 5: Very Enjoyable
14	After completing the mini-golf project, which of the following best describes your viewpoint?	Low 1: Did not meet Expectations to High 3: Exceeded Expectations
15	Overall, I would rate this project as:	Low 1: Poor to High 5: Excellent
	Background Questions	
16	Gender	Male / Female
17	How many semesters have you completed at **XXX** (or another institution)?	0-6+
18	The section / course instructor of ENGR 1550 I am enrolled in is:	1 - 5

Only the students who completed the entire survey were included in the study. Incomplete survey responses were dropped from the analysis because it was believed that this was due to survey fatigue rather than due to data missing on a random basis. Some of the survey questions were open response. The quantitative analysis to the fixed-response survey questions was completed using the statistical software package STATA®. Responses were coded such that a more positive response was a higher value, and a less positive response was a lower number. The primary analysis methods were simple statistics of central tendency and variation as well as ttests (two group unpaired) to assess statistically significant differences. Paired ttests were not conducted since all responses were anonymous and not even the researcher knew the identity of specific respondents making pairing impossible.

Results:

The first four questions on each of the surveys related to the learning objectives for the course and the project and are summarized in Table 5. The questions were on a 5 point Likert scale, with a more positive response being coded as a higher number. Students indicated agreement that those objectives were met, with all objectives on all of the surveys having average ratings above 4 ("agree"). The means for each learning objective between survey 1 and survey 3 were compared through unpaired ttests. The largest difference was on learning objective 4 which relates to technical communication, and students indicated a much higher level of agreement on the third survey. This is not surprising since the majority of the technical communication takes place at the conclusion of the project when students are reporting on how their design performed. Finally, students indicated a higher level of agreement that students develop working relationships and work collaboratively.

Table 5. Summary of Student Responses to Questions Relating to Learning Objectives

Learning Objectives:	Mean Responses (out of 5)			ttest
	Survey 1	Survey 2	Survey 3	Survey 1 vs. 3
To establish a solid working relationship with engrclass peers and work collaboratively	4.29	4.35	4.43	-2.39*
To learn the fundamentals of spreadsheets (EXCEL) and how to use it as an engineering tool.	4.51	4.29	4.47	0.53
To learn the fundamentals of statistics as an engineering tool.	4.40	4.17	4.39	0.21
To gain experience and comfort with technical communication skills, both oral and written.	4.19	4.22	4.48	-4.09***

* denotes $p<0.05$, *** denotes $p<0.001$

To further corroborate the difference that students experienced with developing working relationships with their peers, there was another survey question: "How comfortable do you feel with your class peers?" The difference in means between survey 1 and 3 were compared using an unpaired ttest, and the difference was statistically significant to a 95% confidence interval indicating that students do feel more comfortable with their peers after working on a several week project. This is particularly meaningful given the recent attention to the need to establish a sense of belonging for students to improve retention / persistence within engineering programs. This is shown in Table 6, as well as mean comparisons between the first and third surveys for a few other key survey items, note that the project did not appear to alter (positively or negatively) student's interest or commitment to engineering. However, students did indicate a slightly lower interest and relevance level towards the project after the third survey, the differences were statistically significant but ratings were still very high, between a rating of a 4 and 5 on a 5 point Likert Scale. While this result is not positive, it is not entirely surprising that students start to lose a bit of interest / enthusiasm for a project over time, there is a steady degradation on both measures at survey 2 and still slightly lower at survey 3. It is important to consider that the third survey administration took place during the peak project workload (report, presentation, end of semester close out, finals). The optimistic view of these results is that all the ratings are above a 4 on a 5 point scale indicating high ratings of interest and relevance by students in general, while the pessimistic view would indicate that the project did not fully meet student expectations. This can be examined further by reviewing the qualitative responses, formally coding, and analyzing the results to offer meaning to the quantitative results.

Table 6. Summary of Key Survey Questions Responses

Survey items	Mean Responses (out of 5)			ttest
	Survey 1	Survey 2	Survey 3	Survey 1 vs. 3
How comfortable do you feel with your class peers in ENGR 1550?	3.8	4.05	4.06	-2.68*
How interested in engineering are you in general?	4.8	4.77	4.74	1.06
How would you rate your interest level in the mini-golf project?	4.47	4.38	4.18	3.58**
How relevant do you think this project will be to your education as an engr student?	4.42	4.33	4.19	2.96**
How committed to engineering are you?	4.49	4.41	4.44	0.61

* denotes p<0.05, ** denotes p<0.01

While there was minimal analysis of differences between male and female students, it was found that student interest in the project was the same for both men and women as shown in Table 7. This is important to not select / develop a "gendered" project that would not appeal a significant group of students. There was also no difference in terms of how relevant male and female students felt the project was. And finally, men and women had similar experiences in terms how enjoyable the rated the project, how effectively their team worked together, and how they felt the project met / exceeded their expectations.

Table 7. Summary of Gender Differences

Survey items	Ttest Values		
	Survey 1	Survey 2	Survey 3
	Female vs. Male		
How would you rate your interest level in the mini-golf project?	-0.9	-0.37	0.16
How relevant do you think this project will be to your education as an engr student?	0.2	0.45	0.33
Please rate your level of enjoyment in working on this project.		-0.78	0.005
How well do you feel your team has worked together on this project?		-0.08	-0.25
After completing the mini-golf project, which of the following best describes your viewpoint?			1.31
Overall, I would rate this project as:			0.4

Conclusions:

The results of this study show that the Mini-Golf design project meets all of the learning objectives in the minds of students including collaboration with peers, Excel, statistics, and technical communication. It is noteworthy that there is a measureable difference in student's self-reported feelings of comfort with working with their peers. Specifically, two metrics showed statistically significant improvements related to peer relationships including: (1) the learning objective metric: To establish a solid relationship with engineering class peers and work collaboratively and (2) How comfortable to you feel with your class peers? And while a student's individual sense of belonging can be evaluated by other metrics as well, this is meaningful to the understanding of project-based learning; in addition to increased engagement and understanding it also helps students develop a sense of belonging within the engineering college – yet another benefit to active learning. According to Astin's seminal work, "What Matters in College," the peer-peer relationship is the single most important factor in a student's college experience[22].

While the measureable gains in peer relationships is clearly supported by the incremental improvements gained throughout the project administration, not all factors were measurable or positive, for example this appears to have made no difference in terms of student interest or commitment to engineering. The interest and perceived relevance of the project degraded overtime; however, the student ratings were all still very positive between a 4-5 (Very Interested / Very Relevant to Interested / Relevant). Finally, male and female students had similar interest levels in the project (no statistically significant differences) and they reported similar levels of enjoyment in participating in the project.

The most significant limitation of the current study is that it is based exclusively on self-reported data primarily based on large-scale quantitative survey responses, which offer less depth than open-response types of questions. And while the responses in terms of class demographics do support truthful responses (for example: the proportion of students reporting they are part of each of the five class sections is consistent with class enrollments) the anonymous nature of research design does not allow for verification. Future work includes doing additional data analysis. Additional statistically analysis is planned, to conduct step wise regression modeling to better understand the critical factors to the student's experience. Further, the open-ended, qualitative questions posed to students in the surveys will be formally coded and compared based on recurring themes to better understand the student perspective. The class project will continue in the fall of 2014 which is a further opportunity for assessment and corroboration of the initial results reported in this study.

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