Great Ideas for Teaching Students (GIFTS): Developing Students Through a ”Design a Lab” Exercise

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abstract

In an effort to improve existing skills (and/or to develop new ones) of First Year Engineering students, student teams consisting of either three or four members were tasked with creating and designing a teaching experiment that demonstrated engineering principles for a target population of either high school or middle school students. The teams were presented with considerations of constraints such as: budgets for materials; classroom restrictions of space and time; quantity of class population served; ease of construction; and durability/ robustness of design. The First Year students navigated through the project using Guided Inquiry provided by an Instructional Team. The Instructional Team consisted of: a Teaching Professor; a STEM Education Specialist and two PhD Candidate Students.

Most students began the project with: ill-defined objectives; a lack of understanding of their target audience (and no consideration of the intellectual level of that audience); a lack of understanding of how to engage their target audience (relevancy, enthusiasm; fun); inhibited "free-thinking" conceptual/ ideation skills; no understanding of the creative process (including the use of the Engineering Design Process and decision matrices); limited understanding of the research component of a new idea (Does it exist already? If so, how do you make your idea novel, or improve on an existing idea that is not fully developed?); limited group interaction skills (and how to act as an equal member of the group including conflict resolution); and limited oral and written presentation skills. Students subsequently developed these skills (to various degrees) through the duration of the course. The Conceptualization-through-Implementation Phase of the Project followed an existing, recognized Product Development format developed by Karl Ullrich and Steven D. Eppinger of the University of Pennsylvania. Additionally, a Communications Professor was brought into the classroom to present a session on "Effective Oral Presentations" to help the students develop their presentation skills.

The results of the exercise were positive – with measured outcomes being encouraging. Additionally, the students commented in their end-of-term evaluations that they believed the greatest benefit to them was the "team teaching" by the members of the Instructional Team, who provided weekly monitoring and mentoring. This paper will also present the components of the course – which can be adapted by the reader for implementation in their own course.

introduction

In an effort to improve existing skills (and/or to develop new ones) of First Year Engineering students, teams consisting of either three or four members were tasked with creating and designing a teaching experiment that demonstrated engineering principles for a target population of either high school or middle school students. The teams followed a process in order to select the lessons they would design, and created lab manuals and teacher guides for their target populations. The students navigated through the project using Guided Inquiry by an Instructional Team. The Instructional Team consisting of: a Teaching Professor; a STEM Education Specialist and two PhD Candidate Students.

desired outcomes

Prior to the initiation of the course, the Instructional Team established a total of six (6) Desired Outcomes. The goal was for the students to achieve substantial growth in each of the six areas by the end of the term (10 week quarter). The focus of the six objectives were: 1. teamwork; 2. sketches, modeling and conceptual design; 3. exposure to engineering disciplines, 4. knowledge of the Engineering Design Process; 5. written and oral communication; and 6. the ability to obtain measurements and perform error calculations. For many of these skills, the Instructional Team was able to look for longitudinal growth by using a rubric graded pre-test and then comparing the results of the pre-test to the student performance at the end of the term (also using a rubric). For the rest, end-of-term assessments were made to determine final outcomes (however, obtaining initial data at the beginning of the term was not feasible). The results will be presented later in this paper.

incoming student skill set

Most students began the project with: ill-defined objectives; a lack of understanding of their target audience including prior knowledge and how to engage them with relevancy or excitement; inhibited "free-thinking" conceptual/ ideation skills; no understanding of the creative process (including the use of decision matrices); limited understanding of the research component of a new idea (Does it exist already? if so, how do you make your idea novel, or improve on an existing idea that is not fully developed?); limited group interaction skills (and how to act as an equal member of the group including conflict resolution); and limited oral and written presentation skills. Students subsequently developed these skills (to various degrees) through the duration of the course.

methodology

The Conceptualization-through-Implementation Phase of the Project followed an existing, recognized Product Development format developed by Karl Ullrich and Steven D. Eppinger of the University of Pennsylvania [1]. Additionally, a Communications Professor was brought into the classroom to present a session on "Effective Oral Presentations" to help the students develop their presentation skills.

project process for students

Students followed the following process through the course:

1. Ideate multiple objectives (content and process)
2. Ideate multiple 3-day lessons
3. Share with Peer Learning Communities (PLCs)
4. Develop design considerations, then receive instructor required considerations
   (Academic merit, safety, budget, population served, time…)
5. Design Decision Matrix with sensitivity analyses
6. Periodically evaluate essentials of lessons through giving ‘Elevator Pitches’ in PLCs
   (Prepare Reflection Papers, Additional emphasis of communication skills)

7. Final oral and written presentations including lab manual, teacher guide, expected outcomes for students, artifacts from testing of lessons/labs, built experimental prototype
8. Periodically evaluate

results

Students grew in all domains that were assessed. The greatest growth appeared to be in their ability to formalize decision making procedures, effect clear communication, collaboration, empathy with the audience/client and project management skills. Student growth was assessed by administering a pre-test (using a rubric) during the first week of the term, and an end-of-term assessment (also using a rubric), as well as the evaluation of both oral and written assignments. The outcomes that were assessed for longitudinal growth were: sketches, modeling and conceptual design; knowledge of an engineering design process, written/oral communication; and measurement and error calculations. The other outcomes were measured at the end of the term, but obtaining data at t_0 wasn't feasible, so the growth was not measured. The results are presented in Table 1 below:

TABLE 1
RESULTS COMPARING PERFORMANCE AND SHOWING GROWTH

Outcome	Average Pre-test Score (out of 4.0)	Standard Deviation	Average End of Term Score (out of 4.0)	Standard Deviation	Growth in Raw Points	% Attainable Growth Achieved
Knowledge of Engineering Design Process	1.06	0.62	3.75	0.49	2.69	91
Sketches, Modeling and Conceptual Design	1.04	0.97	3.65	0.62	2.61	88
Communication	1.02	0.74	3.53	0.52	2.51	84
Measurement and Error	1.96	1.27	3.49	0.54	1.52	74
Exposure to Engineering Disciplines			3.80	0.52		
Teamwork			3.76	0.43		

As can be seen in Table 1, Average End-of Term Scores were almost all above 3.5 out of 4 possible points. The area with the lowest amount of growth was in the use of measurements and error calculations. After reflection, it was realized that the Instructional Team did not invest much time on this area in class in favor of emphasizing other topics such as communication and reflective learning. More focus will be given to this subject area in future iterations of the course.

discussion and conclusion:

The students showed growth in all of the areas assessed. Additionally, Table 1 shows that the standard deviation values decreased at the end of the term – thereby suggesting that the scatter was more clustered at the end of the term. Whereas, the scatter was more varied at the begging of the term – suggesting that the incoming students had disparate skill sets.

end of term student comments

Student end-of-term comments in written evaluations were very positive - with the students indicating that the greatest benefit to them came from exposure to the Instructional Team Teaching effort, which provided effective, supportive weekly monitoring and mentoring.

references

[1] Ulrich, K. T., & Eppinger, S. D. (2008). "Product Design and Development". 2004. New York: McGraw-Hill.