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Using Distinctive Student Engagement Elements in a Technical Elective Course

Dr. Rambod Rayegan, Prairie View A&M University

Rambod Rayegan is an Assistant Professor in Mechanical Engineering Department at Prairie view A & M University. He has a strong background in conducting research in building energy efficiency and renewable power generation for buildings. He served as a Visiting Assistant Professor in Department of Mechanical and Energy Engineering at University of North Texas before joining PVAMU. He oversaw the research in the Zero Energy Laboratory at UNT and worked as a researcher at UNT in the sustainable energy area. He has a Ph.D. in Mechanical Engineering from the Florida International University. He has been member with prestigious Honor Societies such as Tau Beta Pi, Phi Kappa Phi, Sigma Xi and Golden Key. He has published number of conference, Journal papers and book chapters in energy and sustainability area. He is a reviewer of several Journals in energy efficiency area. He is a member of the Editorial Board of ASME Early Career Technical Journal. Raised in Tehran, Iran, Dr. Rayegan now lives in Houston. He has served as an instructor at Semnan University, Iran for 5 years. He was selected as the best teacher of the Mechanical Engineering Department by students during 2002-2003 academic year and the best senior project supervisor in 2003-2004 academic year. He has served as a consultant in three companies in the field of air conditioning and hydraulic power plants.

Karla C. Lewis Ph.D., SERVE Center at UNCG

Dr. Karla C. Lewis has been with SERVE Center for over fourteen years and served as a Project Director with SERVE's Regional Educational Laboratory Southeast (2006 – 2011). In this role, she supervised the work of the SERVE Center State Liaisons (senior staff assigned to each southeast state) and worked collaboratively with them to understand and respond to state educational agency (SEA) needs. Currently, her work focuses on evaluations of Early College High School projects, student support services, and STEM initiatives. She also co-directs the Nonprofit Evaluation Support Program (NESP). She has a Ph.D. in Educational Policy Studies from The University of Illinois at Urbana-Champaign and completed Post- Doctoral work in family engagement at the Center for the Social Organization of Schools at Johns Hopkins University

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Abstract

A new software-assisted, project-based technical elective course and its associated laboratory (BEELab) in building energy efficiency and green building design has been developed and implemented. The primary goals of this project, funded by the National Science Foundation (NSF), are to engage mechanical engineering students in the learning process and to make them prepared for the workforce in building-related fields. Distinctive elements that differentiate this elective course from traditional elective courses are: (a) incorporating applied software training and (b) making the course experiential and project-based (c) enhancing students' interaction with the related industry through guest speaker and field trip.

The course was implemented for the first time in Fall 2016 in a minority serving university. The data to evaluate the success level of the project was collected via: (a) pre- and post-implementation interviews, (b) classroom observations, (c) student focus groups, and (d) pre- and post-implementation student surveys.

Student survey responses at the end of the semester indicated that the use of, and exposure to, the engineering software was the highest ranked class feature/activity in terms of the value added to the elective course. Furthermore, during the focus group, students mentioned that their work with the simulation software helped them make a connection to the energy efficiency concepts they had been learning. The feedback on the BEELab was overwhelmingly positive. According to the survey and focus group data, overall, students indicated that they were provided with an opportunity to work with modern, well-designed equipment that should increase their marketability and, ultimately, give them an advantage in their transition to the workforce. Students provided positive remarks about the field trip. Many students mentioned this as a "real-world connection." During the focus group, the students stated that they enjoyed the guest speaker and thought she imparted some "real-world" information. They were able to connect her work to what they were learning in the course and current issues like climate change. In three of the ten ABET-required domains, student responses suggest that their abilities improved significantly. Due to the fact that so many students in the class were seniors (and therefore, would be expected to demonstrate many of the technical and non-technical ABET foundational outcomes prior to graduation), it is not surprising that, overall, student reported significant pre- and post-change on only 3 out of 10 items regarding their skills/abilities.

Introduction

Students' disconnectedness to the presented contents in engineering courses is a challenging issue in engineering education. Even in technical elective classes which students should experience practical aspects of their core classes, they cannot make a connection between theoretical materials presented during lectures and real world projects. Wlodkowski's model of effective instruction [1] listed expertise of the presenters/instructors, relevance of content, choice in application, practice and reflection, and group work as motivating factors for adult learners. The Accreditation Board for Engineering and Technology (ABET) adopted a new set of standards in 1996 and shifted the basis for accreditation from quality of inputs to quality of outputs. In other words, what is learned should be assessed instead of what is taught [2]. The Center for the Study of Higher Education at the Pennsylvania State University, investigated the effect of output-based accreditation. In this study, the curricula change through applying active learning methods in order to follow output-based ABET criteria was assessed. Based on faculty reports, the highest compatibility with new ABET standards, were increasing computer simulations, application exercises, case studies, open-ended problems, design projects, and use of groups in class [2].

The design of this course is grounded in educational literatures on inductive teaching and active learning [3, 4] that found to be effective in enhancing students' motivation, engagement, and learning. This project has taken an innovative approach in designing a technical elective course in building energy and green building design through incorporating a variety of best practices and instructional activities for student engagement with an emphasis on providing rich work-related experience for students. The distinctive features of the course includes (1) **applied software training**, (2) **lab experiments**, (3) **fieldtrip to local Heating, Ventilation and Air Conditioning (HVAC) industry facilities**, (4) **invited guest speaker from building industry**, and (5) **real-world open-ended design projects** which are implemented in teams. To the best of authors' knowledge, there is no similar combination of aforementioned active learning features for a technical elective course in engineering. To be more specific, all previous efforts on the topic of energy and energy efficiency were mainly focused on renewable energy and suitability concept education with a focus on increasing awareness [5-8].

The course was implemented for the first time in Fall 2016. SERVE Center at the University of North Carolina at Greensboro serves as the external evaluator of the project. SERVE staff collected data via: (a) pre- and post-implementation interviews with the PI, (b) review of course documentation, (c) pre- and post-implementation student surveys (d) classroom observations, and (e) student focus groups. The pre survey link was shared with all students during the first few weeks of the course, while the post survey link was sent to the students a week before final exam. A total of three classroom observations were conducted during the semester by a volunteer Mechanical Engineering Department faculty member including one laboratory session and one focusing specifically on software use. SERVE staff also developed a focus group protocol to gather students' perspective regarding their experiences in the newly developed course. Students were asked about various components of the new course a week before the final exam.

The main accomplishments of the distinctive features of the newly developed course were qualitatively described in the previous article of this research group [9]. The highlights of the achievements can be listed as follows:

- Based on student post-survey responses, the use and exposure to the engineering **software** was ranked the highest among the five class features/activities in terms of the value added to the elective course. More specifically, during the focus group, the students stated that their work with the simulation software helped them make a connection to the energy efficiency concepts they had been learning.
- During the focus group, students stated that they liked the **lab** because it was "very clean" and "refreshing to have everything function like it should." They were not only happy to work with new, modern equipment, but felt that the experience would increase their marketability as they entered the workforce.

- On the post-survey, one-third of the students selected the **field trip** to the HVAC industry facilities as a feature that contributed most significantly to their learning in the course. Many students mentioned it as a "real-world connection."
- During the focus group, the students stated that they enjoyed the **guest speaker** and thought she imparted some "real-world" information. They were able to connect her work to what they were learning in the course and current issues like climate change.
- Students stated that the **real-world projects** lead to their engagement and the instructor should keep focusing on the projects for future implementation of the course.

In this paper, the extent to which participation in the course improved their ABET-related skills/abilities in Table 1 will be discussed. The self-assessment survey data were processed in two separate stages: (a) data import and cleaning, and (b) data analysis.

Table 1. ABET-related skills/abilities

Use basic engineering and scientific principles to analyze the performance of processes and systems
Analyze data and interpret results from an experiment
Use evidence to draw conclusions or make recommendations
Identify essential aspects of the engineering design process
Apply systematic design procedures to open-ended problems
Design solutions to meet desired needs
Test potential solutions to an engineering problem
Apply engineering skills and tools (e.g., software, experimentation, measurement devices) in engineering practice
Integrate engineering skills and tools to solve real-world problems
Consider contemporary issues (economic, environmental, technical, etc.) at the local, national, and world levels

Data Import and Cleaning

Pre- and post-survey responses were downloaded in comma delimited format (CSV) as both character and numeric data. The primary difference between the two formats are the transformation of Likert-type scales (i.e. No ability, Some ability, Adequate ability, More than adequate ability, High ability) to numeric scales (i.e. 1, 2, 3, 4, 5) in order to facilitate quantitative analysis. The data were then read into the R statistical computing environment (version 3.3.2), and data cleaning was undertaken.

In the absence of identifying information, such as first and last names and student ID numbers, the first step in the data cleaning process was to generate an identification code for each response. This step is important for two reasons: first, identification codes allow multiple submissions from a single respondent to be flagged; second, identification codes allow to match pre and post samples. Identification codes were generated by concatenating the numeric codes for gender, ethnic background, month of birth, and day of birth. A male student who identifies as European American/White and whose birthday is July 4 would be coded as 1-4-7-4, whereas a female student who identifies as African American/Black and whose birthday is November 28 would be coded as 2-1-11-28.

In the next step of the data cleaning process, incomplete submissions were removed. Incomplete submissions were defined as entries that did not have entries for at least eight of the ten ABET-related items skills/abilities.

Data Analysis

33 respondents completed the pre survey, a nonequivalent sample of 33 respondents completed the post survey, and 25 completed both the pre and post surveys. Table 2 shows the proportion of responses by gender, ethnic background, first-generation status and major. Figure 1 shows the graphical representation of the percentages for combined responses.

Table 2. Proportion of responses by gender, ethnic background, first-generation status and major (pre, post, combined)

Factor	Level	Completed Pre (N = 33)		Completed Post (N = 33)		Completed Both (N = 25)	
Gender	Female	5	15.2%	4	12.5%	2	8.0%
	Male	28	84.8%	29	87.5%	23	92.0%
Ethnic Background	African American/Black	15	45.5%	15	45.5%	12	48.0%
	American Indian/Alaska Native	1	3.0%	6	18.2%		
	Asian	6	18.2%	3	9.1%	4	16.0%
	European American/White	4	12.1%	6	18.2%	3	12.0%
	Hispanic/Latino	6	18.2%	3	9.1%	5	20.0%
	Other	1	3.0%	0	0%	1	4.0%
First Generation	Yes	-	-	17	52.0%	13	52%
	No	-	-	16	48.0%	12	48%
Major	Mechanical Engineering	32	96.9%	32	96.9%	24	96.0%
	Other	1	3.1%	1	3.1%	1	4.0%

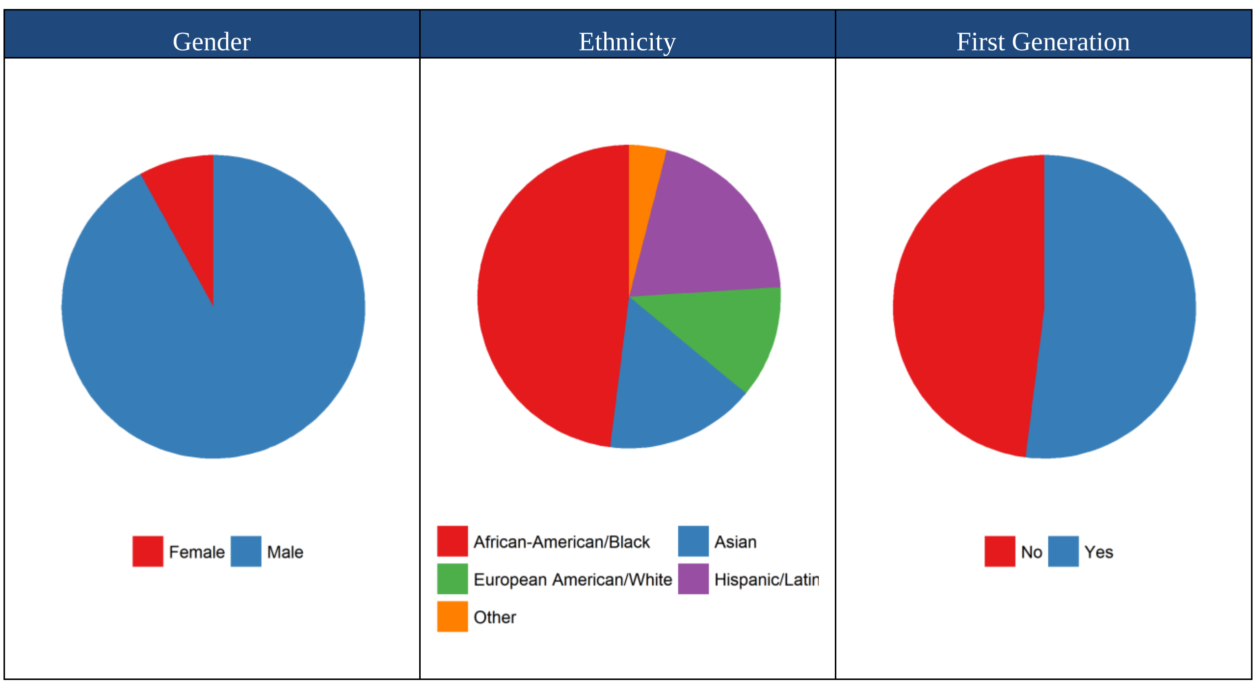

Figure 1. Proportion of combined Pre and Post responses by Gender, Ethnicity and First Generation status

Respondents were asked to assess their ability in ten ABET-required domains on a five-point Likert-type scale ranging from "no ability" (1) to "high ability" (5). Means of the scale responses were calculated for each of the ten items on the pre and post surveys and presented in Table 3.

Table 3. Student Pre-/Post-Survey Response Summary

Item	Mean (Pre)	N	Mean (Post)	N	Change	Significance (*p*-value)
Use basic engineering and scientific principles to analyze the performance of processes and systems	3.79	33	3.97	33	+0.18	0.379
Analyze data and interpret results from an experiment	4.12	33	4.15	33	+0.03	0.866
Use evidence to draw conclusions or make recommendations	3.91	33	4.21	33	+0.30	0.107
Identify essential aspects of the engineering design process	3.64	33	4.12	33	+0.48	0.031*
Apply systematic design procedures to open-ended problems	3.48	33	3.97	33	+0.48	0.048*
Design solutions to meet desired needs	3.66	32	3.88	33	+0.22	0.401
Test potential solutions to an engineering problem	3.81	32	4.03	33	+0.22	0.307
Apply engineering skills and tools (e.g., software, experimentation, measurement devices) in engineering practice	3.88	33	4.09	33	+0.21	0.293
Integrate engineering skills and tools to solve real-world problems	3.76	33	4.03	33	+0.27	0.268
Consider contemporary issues (economic, environmental, technical, etc.) at the local, national, and world levels	3.39	33	3.97	33	+0.58	0.016*
Total	37.28	-	40.42	-	+3.14	0.089

* The difference is significant ($p < 0.05$)

Note: The scale on the survey reads as follows: No ability (1), Some ability (2), Adequate ability (3), More than adequate ability (4), High ability (5)

To compare pre- and post-means, a statistical test of the change in central tendency must be employed. A paired-sample *t*-test offers more statistical power, though it requires the pairing of respondents from pre to post in order to support the assumption of equal variances. In this study the sample is small, and relying on only paired responses would reduce the sample by a further 20%. For this reason, Welch's *t*-test was used to determine the degree and significance of the change in central tendency (mean score) from the beginning of the semester to the end of the semester (e.g pre-survey to post-survey). Welch's *t*-test was selected specifically because the sample that responded to the pre survey is not the same as the sample that responded to the post survey, and therefore equal variances cannot be assumed.

In all cases, a *p*-value of 0.05 was used to distinguish between statistically significant and insignificant differences. That is, for all following comparisons of means, there must be a 5% (or lower) likelihood of a false positive change, where an apparent change from pre to post is misleading.

Across the board, students indicated that they had at least adequate ability across all ten categories before taking the class. By the end of the semester, there was no indication that students felt that their overall, aggregate abilities had changed in a significant way. Indeed, at the beginning of the semester students indicated they had, on average, "adequate ability" verging on "more than adequate ability" across all ten categories, with an aggregate scale score of 3.7/5.0.

By the end of the semester, across the board, students indicated that they still felt that they had, on average, “adequate” or “more than adequate” ability in all categories, with an aggregate scale score of 4.0/5.0 ($p > 0.05$).

In three of the ten ABET-required domains, student responses suggest that their abilities improved significantly ($p < 0.05$). Respondents indicate that their ability improved from “adequate” to “more than adequate” with regard to identifying essential aspects of the engineering design process ($p = 0.031$). Furthermore, responses suggest that students’ ability to apply systematic design procedures to open-ended problems improved over the course of the semester ($p = 0.048$). Finally, asked to indicate their ability to consider contemporary issues (e.g., economic, environmental, technical) at the local, national, and world levels, responses indicate that students believed they were significantly more able at the end of the semester than at the beginning ($p = 0.016$).

Outcome Data Limitations

Due to the fact that so many students in the class were seniors (and therefore, would be expected to demonstrate many of the technical and non-technical ABET foundational outcomes prior to graduation), it is not surprising that, overall, student reported significant pre- and post-change on only 3 out of 10 items regarding their skills/abilities.

Although self-reported abilities appear to improve across all ABET-related skills/abilities, the small sample size does not allow for a robust conclusion. That is, the observed difference between pre- and post-survey may be due to the chance or measurement error, rather than the new instructional design. The small sample sizes in this study have negative effects on the statistical power of any types of analysis that may be undertaken to compare means over time. Doubling the size of the sample is likely to yield more useful results. In the next step of the research, the results of the second implementation of the course in Fall 2017 will be added to the first year results which will make the statistical results more valid.

Conclusions

A new software-assisted, project-based technical elective course and its associated laboratory in building energy efficiency has been developed through integrating a variety of best practices and instructional activities with an emphasis on providing rich work-related experience for students. Applied software training, lab experiments, fieldtrip to local HVAC industry facilities, invited guest speaker from building industry, and real-world open-ended design projects are distinctive features of the course. The students’ feedback on all of these features were highly positive. The extent to which participation in the course improved the students’ ABET-related skills/abilities was investigated. Self-reported abilities appear to improve across all ABET-related skills/abilities. In three of the ten ABET-required domains, student responses suggest that their abilities improved significantly. Respondents indicate that their ability improved from “adequate” to “more than adequate” with regard to identifying essential aspects of the engineering design process. Furthermore, responses suggest that students’ ability to apply systematic design procedures to open-ended problems improved over the course of the semester. These two positive outcomes can be attributed to the fact that the curriculum was specifically designed to enhance students’ work-related experience in the area of building energy efficiency and green building design by focusing more than half of their time and effort on real-world open-ended design projects. Finally, the responses show that the students' ability to consider contemporary issues (e.g., economic, environmental, technical) at the local, national, and world levels were increased significantly throughout the semester. The latter positive outcome suggests that the course content and the topics addressed by the invited speaker, as were intended, successfully affected students understanding of contemporary issues in the area of building energy efficiency and green building design. The small sample sizes in this study have negative effects on the statistical power of any types of analysis that may be undertaken to compare means over time. In the next step of the research, the results of the second implementation of the course in Fall 2017 will be added to the first year results which will make the statistical results more valid.

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Reference
[1] Wlodkowski, R.J. and Ginsberg, M.B., 2017. Enhancing adult motivation to learn: A comprehensive guide for teaching all adults. John Wiley & Sons.
[2] Lattuca, L.R., Terenzini, P.T., and Volkwein J.f., 2006, Engineering Change, A Study of the Impact of EC2000, Executive Summary, Center for the Study of Higher Education, The Pennsylvania State University
[3] Prince, M. and Felder, R., 2007. The many faces of inductive teaching and learning. Journal of college science teaching, 36(5), p.14.
[4] Prince, M., 2004. Does active learning work? A review of the research. Journal of engineering education, 93(3), pp.223-231.
[5] Kandpal, T.C. and Broman, L., 2014. Renewable energy education: A global status review. Renewable and Sustainable Energy Reviews, 34, pp.300-324.
[6] Bojic, M., 2004. Education and training in renewable energy sources in Serbia and Montenegro. Renewable energy, 29(10), pp.1631-1642.
[7] Collins, A., Galli, A., Patrizi, N. and Pulselli, F.M., 2018. Learning and teaching sustainability: The contribution of Ecological Footprint calculators. Journal of Cleaner Production, 174, pp.1000-1010.
[8] Acikgoz, C., 2011. Renewable energy education in Turkey. Renewable Energy, 36(2), pp.608-611.
[9] Rayegan, R., " *Engaged Student Learning Project: Challenges and Lessons Learned*", American Society of Engineering Education (ASEE) Annual Conference, Columbus, Ohio, June 2017.