Introduction to Engineering Design Graphics Project Supporting Problem-Based Learning for Students At-Risk

Jeremy V. Ernst
Virginia Tech

Aaron C. Clark
North Carolina State University

Daniel P. Kelly
North Carolina State University

Abstract

All engineering schools in the United States are currently teaching some version of a design graphics course, since it is required by ABET. This project will explore the factors that affect program persistence, in order to create a curricular approach that will improve the student experience, particularly for at-risk, females, underrepresented minority, and first-generation college students. Our overall goal is to refine a transferable Problem-Based Learning framework to promote engineering persistence, academic success, and engagement. The authors feel that such efforts will support the retention of STEM students by addressing shortcomings of introductory STEM courses (i.e. Engineering Graphics).

Introduction

In response to the nation's need to increase the number of STEM graduates from institutions of higher education (Holdren & Lander, 2012), further exploration and expansion of instructional approaches that have shown promising results in increasing the academic successes of students. To that end, in this project, we are studying the development, implementation, and effectiveness of active problem-based learning modules in a required engineering course at North Carolina State University (NCSU). The engineering design graphics course is critical for the development of engineering communication and visualization abilities, and the "techniques, skills, and modern engineering tools necessary for engineering practice" (ABET, Standard 3K) vital for success in later engineering coursework (Busby, Ernst, & Clark, 2013) . In previous studies, standard lecture-based instruction in the engineering design graphics course did not sufficiently increase academic success or improve the low retention rates of engineering students (National Science Board, 2016). Therefore, use of the active problem-based learning framework in delivery of this foundational engineering course is hypothesized to improve educational outcomes and retention rates for students already enrolled in college engineering programs

The Problem

Engineering programs have the problem of low persistence rates for undergraduate students with only about 53% of first-year engineering students will graduate in engineering (Ohland et al., 2011), with 35% of the original engineering majors actually entering engineering careers (National Science Board, 2016). These persistence rates are lower than the overall completion rate of 60% for all bachelor's degrees (*16*). At most institutions, underrepresented minorities (Ohland et al., 2011) and first-generation college students (Honken & Ralston, 2013) had lower engineering persistence rates than other student groups. Females already make up a minority of first-year engineering students (20-25%), and a smaller proportion of females than males persisted to the eighth-semester mark (Ohland et al., 2011). The largest proportion of non-persisting engineering students leaves the program during their third semester (Turns et al., 2007); the cause of non-persistence appears to occur early in the engineering program.

The causes of the low retention and persistence rates in engineering fall into three main categories: self-efficacy, academic success, and engagement (Bandura, 1989). Self-efficacy refers to a person's confidence in his or her ability to complete successfully a specific task (Stajkovic, & Luthans, 1998). In engineering education, engineering self-efficacy is a significant predictor of core engineering GPA (Mamaril, Usher, Economy, & Kennedy, 2016); engineering design self-efficacy is generally lower for female students than for male students (Godwin et al., 2016). The second factor affecting persistence of engineering students is academic success. Although GPA is the typical measure of academic success, spatial visualization ability is also a significant predictor of future academic success in engineering (Ernst, Williams, Clark, & Kelly, 2016). Mean mental rotation abilities are lower for female engineering students than for male students (Sorby, 2007).

Finally, student engagement also affects retention and persistence in engineering programs. The multi-faceted construct of engagement encompasses behavior, emotional, and cognitive process, involving such concepts as self-regulation, interest, and enjoyment (Wang & Eccles, 2013).

The Proposed Solution

In this study, we build on past successes of the NCSU program to create systemic changes that accelerate improvements in the quality and effectiveness of undergraduate education. In the Problem-Based Learning Modules (PBLM) framework, we will supplement course content within an online learning management system (LMS). The LMS will contain content modules, tutorials, sample exercises, self-check features, and active problem-based challenges, which allow students to self-regulate their learning of the content. This will make class time available for more in-depth discussion of content and concepts, where the instructor serves in a support role rather than as lecturer. Topics to be covered by the PBLM include:

1. Sketching
2. Engineering Geometry
3. Orthographic Projection
4. Pictorial Projection
5. Working Drawings
6. Dimensioning – Standards
7. Dimensioning –Annotation
8. Assemblies
9. Section Views
10. Auxiliary Views

The greatest distinction between the PBLM framework and traditional approaches involves the types of tasks and problems the students are challenged to solve. The traditional approach to teaching engineering geometry relies heavily on mathematical figures and equations (Fig. 1A). The PBLM related to engineering geometry would place this same mathematical problem in an engineering context, challenging the student to apply knowledge to a relevant engineering problem (Fig. 1B). In both cases, the students must understand the mathematics associated with parabolas, but the PBLM exercise would also require students to research the properties and use of a parabolic satellite antenna in order to construct a graphic model applying their understanding of parabolic mathematics. Such direct and explicit links to engineering problems will help students see the importance and applicability of what they are learning.

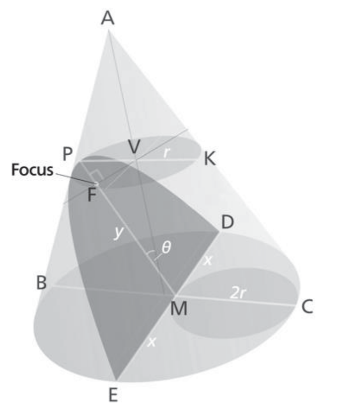
Student Solution A:	*Student Solution B:*
	

Figure 1. A traditional, mathematics-based engineering geometry assessment task (A) and a task assessing the same content knowledge in a problem-based engineering context (B) as would be used in the PBLM framework.

Methodology

At NCSU, engineering students are required to take a course in engineering design graphics. Each semester, approximately eight sections of this course are taught, and each section contains approximately 40 first- and second-year students. We will collect data from students enrolled in the course, but focus analyses on engineering students and the engineering program. We will also study Illinois State University (IL St.) students enrolled in TEC116: Introduction to Technical Drawing and Constraint-based Solid Modeling. This course is currently taught using lecture-based instruction, with weekly lab sections. Much of the course content is the same as in the NCSU course.

To quantify engineering self-efficacy students will complete an Engineering Design Self-Efficacy Instrument (Vogt, Hocevar, & Hagedorn, 2007),used to examine freshman engineering students determined to be at risk of not matriculating. To measure spatial visualization and mental rotation skills, students will complete the Purdue Spatial Visualization Test: Rotations (PSVT:R). Since much of the facilitative instructional approach relies on self-regulated learning outside of class time, students will also complete the Self-Regulated Learning subscale of the Motivated Strategies for Learning Questionnaire (MSLQ). Students will complete these three instruments pre- and post-course to allow us to quantify changes in the constructs over time.

References

Accreditation Board for Engineering and Technology, (ABET). (2016). Criteria for accrediting engineering programs, 2016-2017. http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/#outcomes

Bandura, A. (1989). Social cognitive theory. (pp. 1-60). Greenwich, CT: JAI Press.

Busby, J. R., Ernst, J. V., & Clark, A. C. (2013). Visualization ability and student outcomes in engineering design graphics. *International Journal of Vocational Education & Training*, *21*(2).

Ernst, J. V., Williams, T. O., Clark, A. C., & Kelly, D. P. (2016). Psychometric properties of the PSVT: R Outcome Measure: A preliminary study of introductory engineering design graphics. 70th EDGD Midyear Conference Proceedings.

Godwin, A., Potvin, G., Hazari, Z., & Lock, R. (2016). Identity, critical agency, and engineering: An affective model for predicting engineering as a career choice. *Journal of Engineering Education, 105*(2), 312-340.

Holdren, J. P., & Lander, E. (2012). Report to the President—Engage to excel: Producing one million additional college graduates with degrees in STEM. President's Council of Advisors on Science and Technology.

Honken, N., & Ralston, P. S. (2013). Freshman engineering retention: A holistic look. *Journal of STEM Education: Innovations & Research*, *14*(2), 29-37.

Mamaril, N. A., Usher, E. L., Li, C. R., Economy, D. R., & Kennedy, M. S. (2016). Measuring undergraduate students' engineering self-efficacy: A validation study. *Journal of Engineering Education, 105*(2), 366-395.

National Science Board. (2016). Science and engineering indicators. Arlington, VA: National Science Foundation

Ohland, M. W., Brawner, C. E., Camacho, M. M., Layton, R. A., Long, R. A., Lord, S. M., & Wasburn, M. H. (2011). Race, gender, and measures of success in engineering education. *Journal of Engineering Education*, *100*(2), 225.

Sorby, S. A. (2007). Developing 3D spatial skills for engineering students. *Australasian Journal of Engineering Education*, *13*(1), 1-11.

Stajkovic, A. D., & Luthans, F. (1998). Self-efficacy and work-related performance: A meta-analysis. *Psychological Bulletin, 124*(2), 240.

Turns, J., Cardella, M., Atman, C. J., Martin, J., Newman, J., & Adams, R. S. (2007).Tackling the research-to-teaching challenge in engineering design education: Making the invisible visible. *International Journal of Engineering Education*, *22*(3), 598.

Vogt, C. M., Hocevar, D., & Hagedorn, L. S. (2007). A social cognitive construct validation: Determining women's and men's success in engineering programs. *Journal of Higher Education*, 337-364.

Wang, M. T., & Eccles, J. S. (2013). School context, achievement motivation, and academic engagement: A longitudinal study of school engagement using a multidimensional perspective. *Learning and Instruction, 28*, 12-23.