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Active Learning Module Development for At-Risk Learners in Engineering Graphics

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Abstract

This paper describes the creation of an active learning framework and process of module development in efforts to build requisite knowledge and skills for at-risk learners enrolled in university introductory engineering design and technical graphics courses.
Specifically, the module sequence, strategy for building direct relevance for at-risk populations, and culminating performance-based learning tasks are identified and detailed. Student-oriented reference points of learning are leveraged through relevant imagery, examples, and objects in further building personalized meaning and deeper comprehension of processes.
Ten learning modules were initially developed within the Problem-Based Learning Modules (PBLM) framework and are currently being pilot tested under the Active Learning Modules to Support Problem-Based Learning: Effects on Engineering Retention and Academic Outcomes of At-Risk Students project funded through the National Science Foundation IUSE Program (Award # 1725874) to refine through evidence-based process outcomes.

Introduction

An engineering graphics course is important for the development of visualization abilities, communication in engineering settings, and provides foundational skill needed in subsequent engineering coursework [1], [2]. Like many introductory courses at the collegiate level, engineering graphics may be taught via a lecture-based format of instruction with students working on assigned work outside of the classroom or in a large laboratory setting [3]. This format may not be ideal for learners and particularly difficult for students categorized as at-risk [4], [5]. The at-risk student population is defined as including those with a GPA of less than 3.0 and unlikely to matriculate into an engineering related discipline, underrepresented minorities, first-generation college students, as well as female students in engineering [6] - [10].

In contrast, an Active Performance-Based Learning (APL) framework that incorporates Problem-Based Learning (PBL) has the potential to build students' self-efficacy, educational outcomes, mental rotation ability, and engagement all of which are factors that affect retention and persistence rates in engineering [11] - [15]. This project develops a set of online problem-based learning modules (PBLM) to supplement engineering graphics instruction serving to improve these important factors. These PBLM serve to deliver supplemental engineering graphics materials that students can attempt on their own, thus facilitating self-regulated learning, a predictor of future academic success [16].

In-line with the APL Framework calling for application of knowledge in the context of real-world engineering problems, the developed PBLM contain a variety of materials including engineering graphics content, self-checks features, and challenges drawing from relevant examples with corresponding imagery and multimedia. Previous research has demonstrated improved academic performance in at-risk populations when instructional methods incorporate media-rich exercises which are socially relevant and problem-based examples from real-world scenarios [4]. An underlying purpose, for this approach, is to help students recognize the importance and future application of the engineering graphics concepts presented and move to deeper levels of learning.

Additionally, the APL Framework in an online format may facilitate an increase in the time available for more in-depth discussions of content and concepts while devoting extra attention to struggling students during the in-person meeting time all while collecting a variety of metrics to track engagement. While the APL Framework is not a new pedagogical approach to instruction [17], it is often employed in small-class-size scenarios whereas this project shifts the use into practice in larger class sizes.

This paper details the development of these PBLM for use in a pilot study including the development of module sequence, how to boost relevance for at-risk students, and incorporation of the APL framework to build deeper understanding of concepts and applications to increase engagement while building student mastery and self-efficacy.

PBLM Topics

A specific set order does not exist for teaching engineering graphics; however, comparisons of introductory courses reveal commonalities in major topics included in the curricula [18]. Future distribution of these developed PBLM to two- and four-year institutions call for the alignment of the topics to parallel the common materials found in introductory engineering graphics courses. Meyers [18] determined that the areas of visualization, orthographic projection, pictorial projection, section views, dimensioning and working drawings were universally included, setting the foundation determining the focus of the main PBLM topics. These specific topics help with building proficiency in visualization, design techniques, industry standards, and mental rotation skills [3], [19], [20], all of which are identified as being crucial for success in engineering [21].

The order of these engineering graphics topics is not standardized permitting interchangeability of the developed PBLM. Consequently, the PBLM were designed as stand-alone units to fit with a wide variety of engineering graphics instructional sequences. Instructors can incorporate the developed PBLM at their discretion concerning placement to best supplement their specific engineering graphics curriculum. This approach to development does mean that portions of material may overlap between the individual module topics (e.g., line types in sketching & text and orthographic projection). Increased exposure to these concepts from different perspectives may help the material resonate more with students and help facilitate making connections between the various topics. The PBLM topics and original order for a pilot study were as follows:

1. Sketching and Text
2. Engineering Geometry
3. Orthographic Projection
4. Pictorial Projection
5. Working Drawings
6. Dimensioning - Standards
7. Dimensioning - Annotations
8. Assemblies

9. Section Views
10. Auxiliary Views

PBLM Instructional Content Development

A systematic approach was taken to determine the necessary instructional content to include to adequately introduce necessary concepts. Since the intent of the PBLM are to supplement instructional materials. This led to a careful examination of the curriculum details in an introductory engineering graphics course through the study of lecture slides, review of the detailed course syllabi, and parsing through established popular engineering graphics textbooks to create a comprehensive outline for subtopics to include in each PBLM. Next, the traditional course evaluation methods (in-class exercises, assignments, quizzes, and exams) were examined to determine the specific desired skill set students ought to develop over a semester timeline. These skills were further categorized to belonging to a specific PBLM. For example, students need to be able to identify different types of surfaces (normal, inclined, oblique) which best falls into the orthographic projection PBLM.

Combining the content lists and desired skills, the activities were preliminarily developed for all PBLM topics as well as self-checks to give formative feedback for these exercises. These activities allow students to self-assess and regulate their own learning while experiencing success needed to build mastery and self-efficacy. Students are given the opportunity to complete the self-checks as many times as they deem necessary for their learning. To illustrate the process, consider this instance where the preliminary list for content inclusion indicated that the alignment of top, front, and right side views based on third-angle projection was an essential sub-topic and then the assignment assessment showed that taking into account proper positioning of orthographic multiview projections was an important aspect in grading. This led to the development of an activity where students had the opportunity to practice identifying the top, front, and right side views of common objects from photographs like those seen in Figure 1 of the coffee mug. Taking this exercise further, students were able to then select the correct multiview orientation for third-angle projection.

Figure 1: Orthographic projection multiview layout of coffee mug images.

The arrangement of the material in the PBLM was determined using an iterative brainstorming process. Overall, PBLM length varies from topic-to-topic as the amount of relevant material differs, but there is a set target of 15- to 20-minutes for completion as these are intended to supplement–not replace–existing course materials. Each PBLM contains an introduction, an everyday uses section, and then the actual content portion interspersed with self-checks, exercises, and activities. The introduction framed the PBLM by providing a brief overview of concepts in the section, an abbreviated real-world example, and emphasized why learning the material in the PBLM was important for future engineering design work. The intent is to introduce the material in an easy to understand manner and connect immediately with the student leading to increased engagement.

PBLM Everyday Uses Discussion

The everyday uses section contained approximately three detailed examples illustrating the application of a specific PBLM topic in a real-world setting with emphasis on appropriate visual imagery. Brief text combined with a public domain image showing the actual dimension limits gives the students a concrete example of how the topic of dimensioning is applied in a real-world context. Subsequently, students may consider the importance of dimensioning in communication when designing a wide variety of spaces. An example includes a picture of NASA Skylab as a hand drawn sketch, technical sketch, and illustration in the Sketching and Text module. Students can see firsthand how these techniques each had a place in communicating an actual engineering design to a variety of audiences. Images from patent searches on childhood items such as a carousel and a playground slide help illustrate the use of pictorial projections in a real-world application with legal ramifications.

Modules were developed to include a wide variety of examples to appeal to a broad range of students with diverse backgrounds and focused on well-known engineering challenges. The driving intention of the everyday uses section was to help students connect previous exposure to these engineering graphics topics informally with respect to their everyday lives. This idea was reinforced with the integration of reflection questions interspersed within the everyday uses section where students are encouraged to elaborate on their personal experiences with a specific concept. Examining the topic of orthographic projection, the idea of using a glass box to contain a fragile sample for viewing in a museum environment like the bird nest in Figure 2, would likely be familiar to most students making it a relevant example to incorporate into the PBLM.

Figure 2: Everyday uses example: bird nest for observation.

A corresponding reflection question inquires about places the student may have seen something similar, such as sports memorabilia. This real-world example helps put into perspective the orthographic projection PBLM sub-topic of glass box theory that may have otherwise come across as a very abstract concept. By using well-known, relevant, engineering-related examples, the everyday uses section reflects previous research that demonstrated improved academic performance of at-risk students using media-rich exercises and examples [4].

PBLM Content and Activities Discussion

The third section of each PBLM contains the actual course content including information for each of the previously outlined subtopics interspersed with self-checks and activities. Although each subtopic contains a moderate amount of text, it is specifically composed in an informal manner and reads as if an instructor is speaking directly to the student. To reinforce concepts public domain or researcher-created images and multimedia components were included with each subtopic with a wide variety of real-world examples to illustrate concepts. Figure 3 demonstrates the idea of how a full-section view is presented in the PBLM on sectioning. The apple (object) is sliced with a knife (cutting plane) to get the resultant half of apple (full-section). The follow-up activity asks students to select an object (suggestion: fruit) to cut in half so they can physically manipulate and explore how a full section is created.

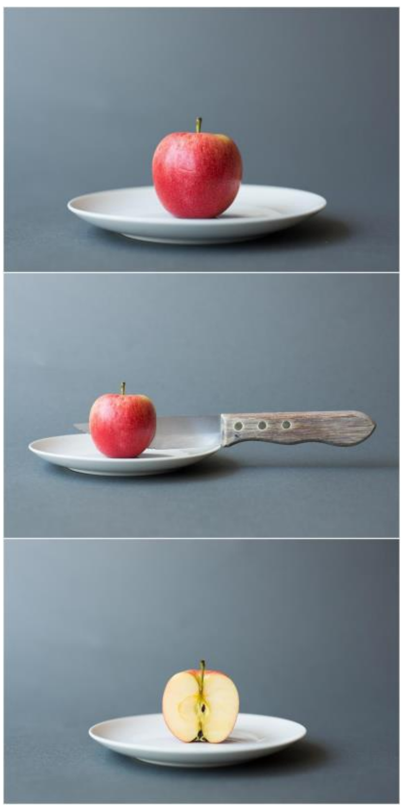

Figure 3: Demonstrating a full section view using a common object.

In line with the APL framework, the activities developed for the content portion of the PBLM topics focus on the application of knowledge to a relevant engineering problem. One common technique extensively employed in engineering design work is reverse engineering defined as analyzing an object and identifying the components along with interrelationships to be able to create a representation of the object in a different form [22]. Within engineering graphics, reverse engineering relies heavily on the ability to identify different geometric shapes and the Boolean operations to combine the shapes appropriately. Content to make this technique possible was included within the engineering geometry PBLM, so the developed activity has students practice reverse engineering a basic gumball machine with the intention of creating a CAD-based model. After devising their solution, students are provided with a sample solution along with CAD-parts for further exploration. Figure 4 shows the original object and a potential solution using basic geometric shapes. This type of process was used to develop interesting, relevant, real-world activities for each PBLM.

Figure 4: Reverse engineering exercise in engineering geometry PBLM.

Conclusions

Currently, the developed PBLM are being piloted across multiple sections of an engineering graphics course reaching roughly 320 students to gain baseline data related to self-efficacy, unit and course grades, mental rotation skills, self-regulated learning, engineering program persistence, and engagement as well as feedback on the modules themselves. Future work includes using protocols to identify how students perceive and interact with real-world examples as compared to theoretical examples traditionally employed in introductory engineering graphics courses.

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References

[1] J. V. Ernst, T.O. Williams, A. C. Clark, and D. P. Kelly, "Psychometric properties of the PSVT:R Outcome Measure: A preliminary study of introductory engineering design graphics," in *70th EDGD Midyear Conference Proceedings, Daytona, FL, USA, January 24-26, 2016.*

[2] S. A. Sorby and B. J. Baartmans, “The Development and Assessment of a Course for Enhancing the 3-D Spatial Visualization Skills of First Year Engineering Students,” *Journal of Engineering Education*, vol. 89, no. 3, pp. 301–307, 2000.

[3] R. V. Pucha and T. T. Utschig, “Learning-centered instruction of engineering graphics for freshman engineering students,” *Journal of STEM Education: Innovations and Research*, vol. 13, no. 4, pp. 24, 2012.

[4] C. Baillie and G. Fitzgerald, "Motivation and attrition in engineering students," *European Journal of Engineering Education*, vol. 25, no. 2, pp. 145-155, 2000.

[5] C. Hsieh and L. Knight, “Problem-Based Learning for Engineering Students: An Evidence-Based Comparative Study,” *The Journal of Academic Librarianship*, vol. 34, no. 1, pp. 25–30, 2008.

[6] J. V. Ernst and A. C. Clark., “At-risk visual performance and motivation in introductory engineering design graphics,” in *Published Proceedings of the American Society for Engineering Education Annual Conference and Exposition: ASEE 2012, San Antonio, TX, USA, June 10-13, 2012*. Session M209.

[7] J. V. Ernst and A. C. Clark., “Self-regulated learning of at-risk engineering design graphics students,” *Journal of Engineering Technology***,** vol. *31*, no. 2, pp. 26-31, 2014.

[8] J. Ernst, B. Bowen and T. Williams, "Freshman Engineering Students At-Risk Of Non-Matriculation: Self-Efficacy For Academic Learning," *American Journal of Engineering Education (AJEE)*, vol. 7, no. 1, pp. 9, 2016.

[9] N. Honken, P. S. Ralston, “Freshman engineering retention: A holistic look,” *Journal of STEM Education: Innovations & Research*, vol. 14, no. 2, pp 29-37, 2013.

[10] M. W. Ohland, C. E. Brawner, M. M. Camacho, R. A. Layton, R. A. Long, S. M. Lord, and M. H. Wasburn, “Race, gender, and measures of success in engineering education,” *Journal of Engineering Education*, vol. 100, no. 2, pp. 225, 2011.

[11] T. D. Fantz, T. J. Siller, and M. A. Demiranda, “Pre-Collegiate Factors Influencing the Self-Efficacy of Engineering Students,” *Journal of Engineering Education*, vol. 100, no. 3, pp. 604–623, 2011.

[12] S. Freeman, S. L. Eddy, M. Mcdonough, M. K. Smith, N. Okoroafor, H. Jordt, and M. P. Wenderoth, “Active learning increases student performance in science, engineering, and mathematics,” *Proceedings of the National Academy of Sciences*, vol. 111, no. 23, pp. 8410–8415, Dec. 2014.

[13] C. Loo and J. Choy, “Sources of Self-Efficacy Influencing Academic Performance of Engineering Students,” *American Journal of Educational Research*, vol. 1, no. 3, pp. 86–92, 2013.

[14] M. K. Ponton, J. H. Edmister, L. S. Ukeiley, and J. M. Seiner, “Understanding the Role of Self-Efficacy in Engineering Education,” *Journal of Engineering Education*, vol. 90, no. 2, pp. 247–251, 2001.

[15] M. Prince, “Does Active Learning Work? A Review of the Research,” *Journal of Engineering Education*, vol. 93, no. 3, pp. 223–231, 2004.

[16] K. G. Nelson, D. F. Shell, J. Husman, E. J. Fishman, and L.-K. Soh, “Motivational and Self-Regulated Learning Profiles of Students Taking a Foundational Engineering Course,” *Journal of Engineering Education*, vol. 104, no. 1, pp. 74–100, 2014.

[17] G. S. Mason, T. R. Shuman, and K. E. Cook, “Comparing the Effectiveness of an Inverted Classroom to a Traditional Classroom in an Upper-Division Engineering Course,” *IEEE Transactions on Education*, vol. 56, no. 4, pp. 430–435, 2013.

[18] F. D. Meyers, “First year engineering graphics curricula in major engineering colleges,” *Engineering Design Graphics Journal*, vol. 64, no. 2, pp. 23-28, 2009.

[19] J. Turns, M. Cardella, C. J. Atman, J. Martin, J. Newman, and R. S. Adams, “Tackling the research-to-teaching challenge in engineering design education: Making the invisible visible,” *International Journal of Engineering Education,* vol. 22, no. 3, pp. 598, 2007.

[20] G. Marunic and V. Glazar, “Spatial ability through engineering graphics education,” *International Journal of Technology and Design Education*, vol. 23, no. 3, pp. 703–715, 2012.

[21] S. A. Sorby, “Developing 3D spatial skills for engineering students,” *Australasian Journal of Engineering Education*, vol. 13, no. 1, pp. 1–11, 2007.

[22] T. Varady, R. R. Martin, and J. Cox, “Reverse engineering of geometric models - an introduction,” *Computer-aided design*, vol. 29, no. 4, pp. 255-268, 1997.