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Piloting Accessible Engineering Education Online

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Abstract

Making engineering education accessible to those without the ideal background has long been a challenge. Faculty are looking to admit students with demonstrated academic competence in order to set them up for success. How can we help potential students prove and/or gain competence in order to have the opportunity to access a high-quality engineering education? This session will walk through an experiment with a competency-based pilot that allows students to demonstrate competence to fill in gaps in their background. It will provide background on the evolution of this approach from a focus on 'gap' undergraduate courses to a modular, competency-based pilot.

Introduction

It is often difficult to find potential new students with the perfect background – 3.0 GPA or higher B.S. from an accredited university in the desired engineering discipline. They are out there but there is not enough supply to meet the demand. And, the demand for those skills in our innovation economy is likely to grow according to the President's Council of Advisors on Science and Technology[i]. They speculate that the U.S. will need 1 million additional STEM professionals than we will produce over the next 6-10 years. How can higher education help meet this demand if there's simply not enough supply? Does it all revolve around building the STEM pipeline or are there other ways we can add to the supply? Universities have been grappling with this issue for years. Not only is it difficult to find students with the right background, it is difficult to find ways to get others who want to become students the background they need within a reasonable timeframe. This whitepaper explores the pilot of a competency-based approach to demonstrating pre-requisite knowledge necessary for success in graduate engineering education.

Starting to Build a Pipeline

For decades, Worcester Polytechnic Institute (WPI) has offered interdisciplinary programs at the graduate and undergraduate level. While these programs provide unique opportunities for our students to gain skills in niche fields in demand, the background required to be successful in these programs presents a challenge. For example, the fire protection engineering graduate program is taken by students with mechanical, civil, chemical, and electrical engineering backgrounds. None of these traditional bachelor's degree programs provides students with all of the background necessary to be successful in fire protection engineering. As a result, students are burdened with filling their knowledge gaps before starting or during their graduate studies. Since many of these students are working professionals, this scenario can provide a significant barrier to entry.

In order to make programs like fire protection engineering more accessible, WPI began offering 'gap courses' in 2010. These courses were selected based on a study of the knowledge gaps seen during the recruitment process and through interviews with faculty regarding the most common challenges impacting student success. These courses were offered to allow the student to gain the knowledge they needed to be successful in their graduate program before they actually started taking graduate courses. In some cases, the diagnosis of their gaps was uncovered through conversations between the potential student and a staff or faculty member. In other cases, these gaps were uncovered when they applied to the program. These students received feedback from the faculty regarding competence they needed to demonstrate before starting graduate work. We tried to reduce the barrier to entry for these students and began to offer generic, self-paced online courses in calculus. We began with calculus because it was the common area of need identified by all programs. These courses were built in modules. They began with a pre-test that was graded by the faculty and helped the student determine focused areas for improvement. This program was developed to help students struggling to remember critical elements of calculus upon returning to engineering school after working in industry for some time. This program, while quite generic, has acted as great refresher for students. And, it has prevented them from becoming overwhelmed when re-entering higher education to participate in a graduate program, where the calculus knowledge is assumed.

Prior to 2010, our potential students had limited options. They could take classes of interest to them and see how they fared without the prerequisite knowledge, as we do not require matriculation into graduate programs before taking a course. They could also take courses on our campus or at another university. And, in some disciplines, they could take a test to demonstrate knowledge. At the time, most of the courses offered by WPI and other universities that would provide the appropriate knowledge were offered as part of the traditional undergraduate program. These courses took place face-to-face during the work day and would not be appropriate for a large percentage of our working professional population. To alleviate this barrier, traditional undergraduate courses were transported to an online environment. Beyond the calculus courses, pre-requisite courses were added in topics such as heat transfer and thermodynamics. These courses were delivered specifically for students looking to participate in a graduate engineering program that needed to fill knowledge gaps. They were offered once or twice per year and consisted of the same material covered in the undergraduate courses. To make them more accessible, the courses did not carry undergraduate credit, had a pass/fail grading system, and were offered at a significantly reduced rate when compared to the current undergraduate course tuition rate.

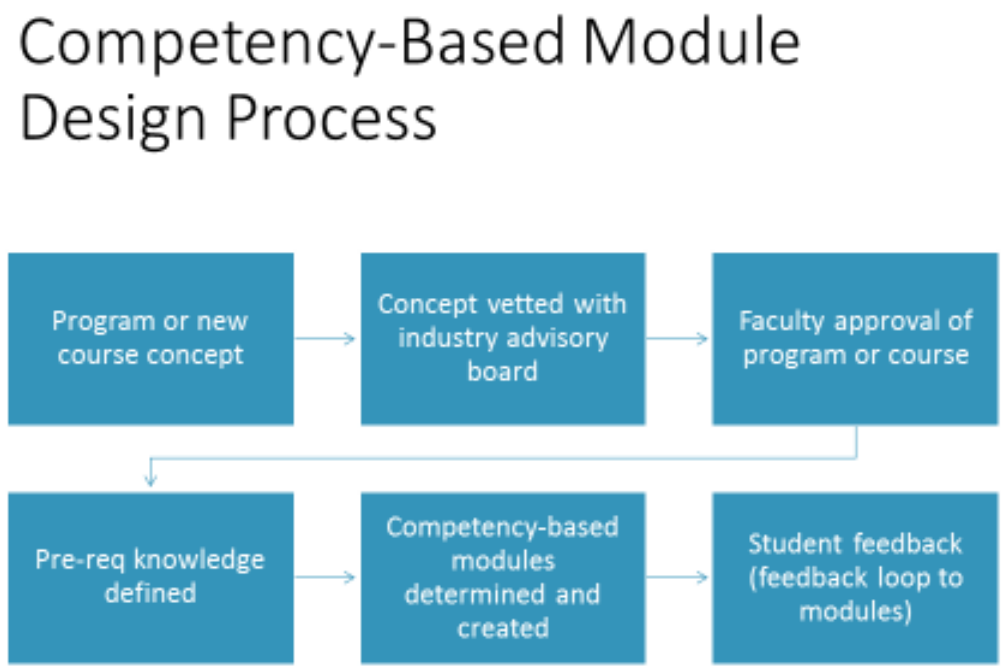
Tailoring competence to specific programs

An interim step along the journey to providing customized competency-based education to fill in knowledge gaps has been a pilot in which the gap courses and their applicability to the power systems engineering program was determined. While the full undergraduate gap courses were certainly comprehensive, they were not tailored in a way that allowed the student to focus on the competencies they needed to learn for the program given their current level of knowledge. This

process included groups of professors, those teaching the gap courses and those teaching the graduate courses, collaborating to identify those pre-requisite competencies that were needed by participants in order to be successful in the program courses. This is still in process but some of the components of the undergraduate courses were altered to address the gaps seen by the faculty teaching the graduate power systems engineering courses. The effort led to the development of a 'bootcamp' to help students develop competencies in math and electrical engineering that were directly relevant to program courses. The bootcamp has been successful in helping students in two ways. First, it has helped students acclimate to the work they will performing in a graduate program. These students have had an opportunity to regain knowledge they had lost or gain knowledge they did not have prior to starting their graduate degree. Second, it has assisted students who would likely not succeed in the program. It provides them with a mechanism to self-identify that they are not prepared for the program and should probably pursue an alternative path.

Students participating in the bootcamp have verbalized their appreciation for the courses and noted that they do not believe they would have been successful in the graduate program without the opportunity to gain this pre-requisite knowledge.

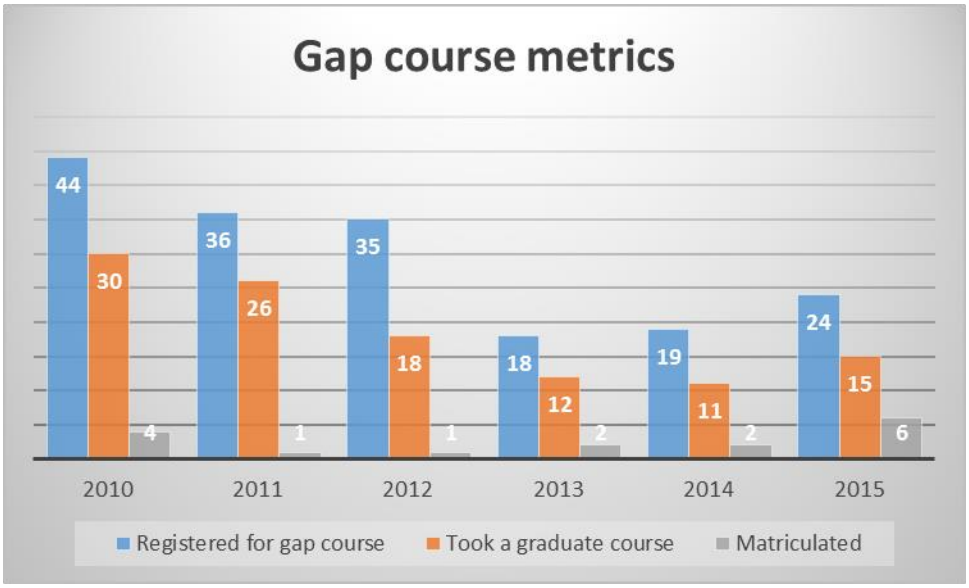
Process Design for Modules



The design process for new courses and programs consists of several steps to make sure the needs of industry and the potential students were being met. To date, the competency-based module development has been a by-product of this process.

The program or new course concept is identified through a variety of mechanisms including market research, a review of competing programs, and expressed demands by a customer. The concept is then vetted by the appropriate industry advisory board to ensure that there is a need for the concept in the industry and to determine the value of adding this course or program to our portfolio. Once vetted by industry, a proposal is put together for faculty approval, as defined by the governance system. The pre-requisite knowledge for the program is defined and necessary modules are identified. If there are modules that don't exist, market research is performed to determine the availability of these modules elsewhere. Once that research has been performed, a decision is made regarding investing in module creation. As students participate in modules, feedback is solicited and serves as a feedback loop for the module creators when determining necessary modifications.

Results to Date



Since 2010, 176 potential students have participated in the gap courses and bootcamp. Of those 176 potential students, 112 or 64% have converted to active student status and 16 or 14% of those converted have become matriculated students. This conversion rate to matriculated students was expected given the rigor of the graduate engineering programs. Our typical retention rate from course 1 to course 2 in the engineering graduate programs is 65%+. It was expected that this rate would decrease for students in need of acquiring pre-requisite knowledge prior to participating in their desired graduate engineering program. There has been an increased conversion rate from a low of 4% to a high of 40% as courses and retention processes have improved. For those who have become matriculated students, the average GPA is 3.6 and the students have been successful at progressing through their program at the same rate as their peers. The students have matriculated into programs including fire protection engineering, environmental engineering, robotics engineering and power systems engineering. In addition to the challenge working professionals tend to have with the calculus work after being out of school

for some time, all of the programs our students have matriculated into are interdisciplinary. These programs require pre-requisite knowledge that is not typically required at a bachelor's level in more traditional engineering disciplines. Without these gap courses, we had captured very few of these potential students because we provided them with no opportunities to gain the background they needed for success. With these gap courses, we provided a path to success that several took advantage of with a small percentage completing their studies. Prior to offering these courses, we saw little to no matriculation of these seemingly less qualified students into our graduate programs. These offerings have allowed the potential students an opportunity to demonstrate their readiness to succeed.

Future Pilot

As technology has improved and our understanding of the needs of non-traditional students increases, there have been significant efforts underway to improve the quality of our online courses and retention of qualified students. While these quality efforts have been focused on enhancing the quality of our graduate engineering programs, this knowledge is also being applied to gap courses. As part of the WPI's new strategic plan, one of the elevate impact initiatives is focused on pioneering competency-based online education with a focus on engineering education at the graduate level. This focus and investment has allowed us to reexamine the gap courses and identify areas for enhancement. Efforts are currently underway to transition those courses from traditional lecture-based courses to competency-based courses. While we expect the move to competency-based graduate courses to be a large undertaking, we expect the gap course effort to be minimal since the courses had already been modularized and graded in a pass/fail mode. Current efforts include working with an instructional designer to transition the gap courses from our existing learning management system to a learning management system designed for competency-based education. The faculty have been working to define the set of competencies necessary for success in the graduate programs. This new system will allow competencies to be defined as success criteria for participating in specific graduate programs. It will allow a tailored approach to learning that provides the student with the knowledge they need to be successful in a particular program rather than being provided with the knowledge generally contained in an undergraduate course on a topic such as heat transfer. In addition to determining basic competencies, the faculty will be collaborating to understand the specific competencies and levels of proficiency needed to be successful in a specific program. For example, there may be specific knowledge necessary in a thermodynamics course in order to be successful in a fire protection engineering program. That knowledge of thermodynamics may differ for the environmental engineering program. A new system will allow us to tailor the competencies needed by each student for their program without the need to manually provide that level of assistance and coaching. It will also allow the students to easily test out of competencies that they already have and focus on those they need to develop. Without such a system, the labor involved in tailoring these efforts would be cost prohibitive.

In addition to technology, efforts have been underway to provide training, coaching, and mentoring for faculty participating in online teaching. These efforts have included internal and

external resources, as well as a commitment by the administrative leadership. Collaboration between instructional design experts and faculty have been the key to success in these efforts. Continued development of internal expertise and institutional training are planned to continue to further our progress.

Increased retention efforts have been underway since 2014. These include utilization of new IT systems for better tracking of students and a greater focus on the first-year experience for part-time graduate students. Students entering the prospective student funnel without the necessary pre-requisite knowledge now have more opportunities to gain that knowledge and have a coach tracking their progress. This coach helps them navigate through our system, including identifying their knowledge gaps, and provides assistance as they progress through the gap courses and convert to becoming graduate students.

Conclusion

With these efforts underway, there is an opportunity to broaden the potential pool of candidates looking to advance their careers in engineering. These pilots have surfaced a need among a population that might not otherwise have the opportunity to gain additional credentials and necessary knowledge to pursue their passion for engineering. Some challenges include acceptance of these methods as demonstration of competence and preparedness for a rigorous engineering program. While we have not experienced this resistance to date, the population size has been small. As it continues to grow, we expect there to be healthy debate about this approach.

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[i] President's Council of Advisors on Science and Technology, *Engage to excel: producing one million additional college graduates with degrees in science, technology, engineering, and mathematics* (Executive Office of the President of the United States, 2012).