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Ready, Set, Go: Fostering Student Success in an Introductory Biomedical Engineering Technology Course

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Hi, I am Dalynn Park, a sophomore at Penn State University, New Kensington Campus. I am studying Biomedical Engineering Technology and Biobehavioral Health in hopes to continue further for a graduate degree. In the future, I hope to obtain a master's degree in prosthetics and orthopedic sciences to one day work as a pediatric prosthetic practitioner. I want to use my degrees and knowledge to help children and other individuals in the rehabilitation process after amputations and/or have been the recipient of a prosthetic limb. In addition to my studies at Penn State New Kensington, I maintain an active student status. I am involved in numerous clubs such as Biomedical Engineering club, Biobehavioral Health club, THON, and Campus Activities Board. I also had the opportunity to be a 2019 orientation leader for the campus. I am a member of the Tau Alpha Pi - National Honor Society of Engineering. Along with my studies and participation on campus, I am also conducting undergraduate research for the CTL scholars program. I work alongside Penn State faculty members to look at interactive teaching techniques within my preferred course of study of engineering.

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Full Paper: Ready, Set, Go: Fostering Student Success in an Introductory BMET course

I. Abstract

This mixed-methods research study follows the progress of an incoming cohort of biomedical engineering technology (BMET) students as they engage in a re-designed introductory course and navigate problem-based learning (PBL) activities with a career focus. Taken collectively, our findings affirm previous studies of PBL as an effective strategy for fostering engineering habits of mind; and they further underscore how PBL can serve as a vehicle for enhancing onboarding and persistence through career-oriented degrees in engineering, with particular salience for transitioning returning or non-traditional students to the workforce

II. Introduction/ Literature Review

A primary focus of research in engineering education has been student success, with an increasing emphasis on the various pathways through which students enter the field, persist to their degree, and obtain relevant employment after graduation. That being said, these studies have most commonly been conducted with traditional four-year engineering degree programs. Unlike these traditional programs, BMET is a relatively new, specialized major, with the preponderance of degrees awarded at the associate's level. BMET programs are specifically designed to train students to meet the rising demand for technicians with sufficient academic and vocational training to be able to work with the complex machines used in healthcare settings. Students who enroll in biomedical engineering technology programs are often strongly career-motivated, and populations typically include significant numbers of non-traditional students seeking second or even third careers, including relatively large numbers of military veterans [1]. To date, almost no research has been conducted on student success pathways in biomedical engineering technology [2], [3], a gap this study seeks to fill with a mixed-methods study of student engagement and persistence in an introductory biomedical engineering technology course.

Because BMET is directly career-oriented, the typical gateway course in the major focuses on career awareness, including an overview of skills, knowledge, and opportunities available. At the institution where the study was conducted, this one-credit course had been taught as a series of information sessions, focusing on topics such as ethical standards, required certifications, healthcare settings, and career paths. Despite rising career prospects in the region, the program had been struggling not only to attract, but also to retain majors, and the decision was made to rethink the introductory course in an effort to strengthen student motivation and persistence through the degree program and into the workforce. Four-year biomedical engineering degree programs typically have a different focus and larger enrollment, but comparable retention data are not readily available.

The instructor chose to redesign the course using problem-based learning (PBL). PBL is a student-centered approach where students learn about a subject by working, often in groups, to solve an open-ended problem [4]. Th problem is what drives the motivation and the learning. There are hundreds, if not thousands, of studies demonstrating the impact that PBL can have on significant learning outcomes in engineering, especially higher order skills such as analysis, evaluation, and design [5]–[11]. That being said, fewer studies have looked at the influence of PBL on the development of skills outside of primary engineering content [12]–[15].

The Accreditation Board for Engineering Technology (ABET), for example, has placed increasing emphasis on the development of "soft" or professional skills, such as communication and collaboration, in its accreditation standards [16]. Studies in other disciplines have suggested that PBL can positively influence similar outcomes [17]–[19], but the connection has not been extensively explored in engineering programs. The present study was intended to assess the degree to which a PBL approach can enhance the development not only of higher order thinking skills but also of those related to career efficacy, literacy, communication, and collaboration, within a BMET major.

Traditionally, PBL had been used (and studied) primarily as the basis of upper division courses in engineering. This redesigned course joined the growing ranks of other first and second engineering courses that have embraced PBL, a practice that has received increasing attention in the research literature [20]–[24]. Even with this growing interest, only a handful of those studies have focused on the integration of PBL strategies into introductory courses with a focus on career awareness and readiness [25], [26] and, somewhat surprisingly, no such studies exist for the entire field of BMET, a gap which this study seeks to address.

This mixed-methods research study follows the progress of an incoming cohort of BMET students throughout the course of a 15-week semester as they engage in the re-designed course and navigate the problem-based learning activities with a career focus. Taken collectively, our findings affirm previous studies of PBL as an effective strategy for fostering engineering habits of mind; and they further underscore how PBL can serve as a vehicle for enhancing onboarding and persistence through career-oriented degrees in engineering, with particular salience for transitioning returning or non-traditional students to the workforce.

III. Methods

The study was conducted on students (n=5) in the course BMET 101 – Introduction to Medical Equipment Maintenance, which is a required one credit course, typically taken by first semester students, at a commuter campus that is part of a large, public, research-intensive university located in the northeastern region of the United States. The course serves and an introduction to the Biomedical Engineering Technology major. The five students enrolled in the course this year were all males (100%), two (40%) were adult learners, including one military veteran (20%) and three were traditional aged students (60%). These numbers reflect the typical students in this major. Over the past five years, graduates of the program (n=51) have been 92% male, 39% adult learners, and 14% military veterans.

We collected multiple sources of evidence for this study including pre- and post- survey data (scaled responses) using a career self-efficacy scale, student artifacts, and formative assessment questions. The career self-efficacy scale asked students to assess their confidence on a five-point scale, and these rating were tested for statistical significance. Student artifacts, including assignments and projects, were evaluated by two independent raters who used a 4-point scale (ranging from 0 (below) to 3 (exemplary)) across five desired outcomes: description, connection, integration, literacy, and recommendation. It should be noted that not all outcomes applied to all assignments. Formative assessment questions were offered periodically across the semester. Following each problem-based assignment, students were asked to answer two questions that pertained to knowledge of the topic, their understanding of the topic in relation to future career, and their ability to assess themselves. These qualitative data were coded using a structured coding method based on the five desired learning outcomes (listed above).

IV. Findings

We chose the widely-used career decision self-efficacy scale to measure gains in career literacy, motivation, awareness, and (perceived) skills [27], [28]. Based on the learner self-efficacy theories of Anthony Bandura (and others) [29], this 24-item instrument has been validated and applied to a variety of secondary and post-secondary contexts. At the beginning and end of the course, students indicated their level of confidence (using a 5-point Likert scale) in their abilities to perform tasks such as "make a plan of your goals for the next five years". Because of the small sample size, caution is encouraged when evaluating statistical results, but a comparison of the pre- and post-test scores indicates a marked increase in students' overall career self-efficacy, with six of the twenty-four scaled items registering significant differences from pre- to post (Figure 1). Variables in the figure correspond to the following items on the scale: find out the employment trends for an occupation over the next ten years; find out about the average yearly earnings of people in an occupation; identify employers, forms, institutions relevant to your career possibilities; accurately assess your abilities; choose a career that will fit your preferred lifestyle; and figure out what you are and are not ready to sacrifice to achieve your career goals.

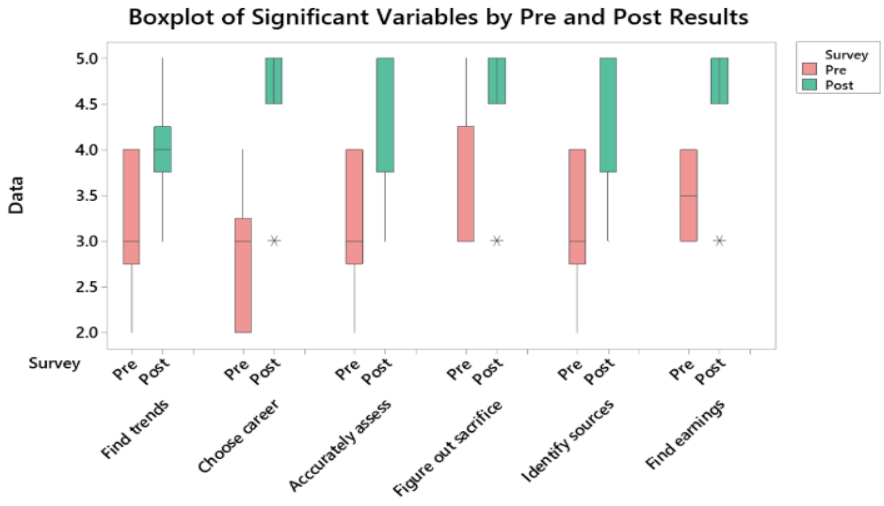

Figure 1: Significant Results, Career Self -Efficacy Scale (Pre- and Post).

When the scaled items are grouped into larger categories, including awareness, literacy, skills and motivation, the students registered the highest gains in literacy and skills and the lowest in motivation and awareness. It should be noted

that the career decision self-efficacy assessment tool was originally developed for career counselors to work with students as they consider their post-graduation plans. This means that not all items on the survey are equally applicable to a disciplinary-based career readiness course that begins earlier in a student's academic career. For example, the course does not include attention to resume writing, but this skill does appear on the career decision instrument. Similarly, several of the motivational items, such as "change occupations if you are not satisfied with the one you enter," are not covered in the course, which focuses on specific career trajectories related to the major. Interestingly, one of the items "change majors if you did not like your first choice" registered individual gains from pre- to post-, and, indeed, two students in the course did choose to change majors, one before completing the course and another just after. In other words, an increase in career self-efficacy may register not as persistence within a given major, but in the ability to discern what majors (and related careers) do and do not fit with the student's overall abilities and aspirations.

Overall, the students did register significant gains in their career literacy, meaning that the course influenced their ability to get a sense of what careers are available, where to find these careers, and how to articulate the skills needed to successfully obtain a career in biomedical engineering technology. The introduction of career literacy skills such as these served as one of the primary motivations for the course redesign and the adoption of problem-based learning. The biotech industry evolves rapidly, so the instructor recognized the fact that successful graduates will need to be committed to on-going professional development of market-driven skills. For this reason, most of the problem-based learning scenarios used in the course involved a literacy component, which served to familiarize students with major sources of technical information, evidence-based practices, policies/procedures/guidelines, and emerging issues. Our findings affirm the effectiveness of this approach. Figure 2 indicates that, with the exception of assignment 5, the overall ability of students to engage effectively in finding sources of information increased over the course of the semester and the gains accrued were higher than any other cognitive outcomes evaluated by our raters.

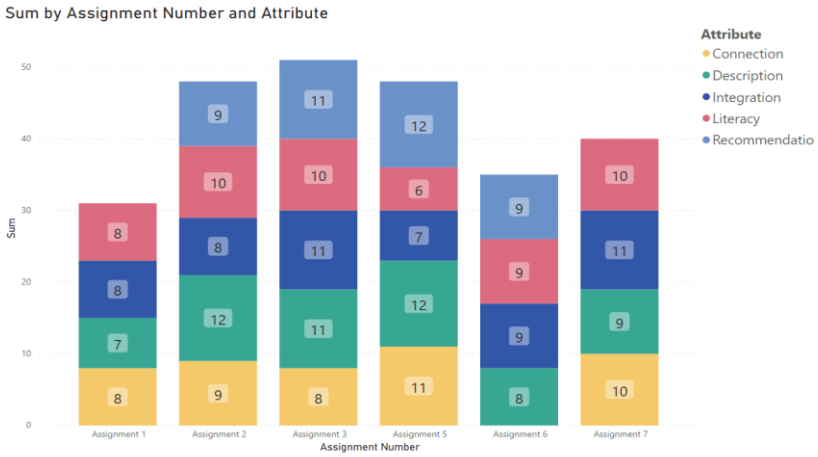

Figure 2: Summary of Ratings of Student Assignments by Outcome

Through the methods of formative assessments and outside exposure to the career, it was found that problem-based learning increased the students' ability to see themselves within the technical career. Through the PBL exercises, students gained exposure to components of everyday work-life, structures, and dynamics within this career path, and their responses to the formative assessment questions affirmed that they were able to make this connection. One student, for example, stated: *"sending professional emails and making spreadsheets of equipment is extremely important to learn early*

on… it's a task Biomed do often." After simulating a scenario where a fellow clinician is calling with a device problem, students were asked what they learned from this assignment. Another student explained: *"Sometimes the nurses won't exactly know exactly what's wrong or what the device is."* This student among many of the others gained the understanding that within a hospital environment, a biomedical engineer would be interacting with many other clinical personnel that would have different technical intelligence or communicational levels. In the formative assessments collected over the course of the semester, 80% of the students mentioned the importance of communication in various forms including reporting, professional emails, and non-verbal cues.

In addition to enhancing soft skills like communication, the PBL methods applied in this course also impacted emotional intelligence. The need to improve their patience, for example, was mentioned by 40% of the students in their formative assessments. Over the course of the semester, students demonstrated increased confidence in their ability to integrate their emotional intelligence into navigating their career path, as indicated in questions 3,4, and 5, on the career self-efficacy scale (Figure 1). Part of that increased self-awareness included an understanding of their own learning, often referred to as metacognition. The students especially recognized the benefits of the experiential aspects of PBL. One student remarked: *"there is a lot of hands-on activities and that's how I learn the best. I think the strengths are that you have to be able to figure stuff out on your own."* Similarly, another student commented: *"We are learning from the ground up and hands-on",* while another explained: *"the hands-on, interactive portion of the course is extremely beneficial".* In fact, their feedback consistently emphasized providing even more open-ended, hands-on activities, especially those that would allow them more opportunities to interact with medical devices. One student even came up with a suggested activity *"...maybe do a matching assignment where different pieces of medical equipment are scattered around the desks and we have to match the device name and basic functions…"*

Finally, the redesigned course did enhance their problem-solving abilities. As one student commented, "*I would confront the issue similar to how we did in class but since I know what questions to ask, I would ask more specific questions to try to figure the problem out quicker*," Students also were able to visualize themselves doing this sort of problem-solving in their future careers. Another student described this well, saying "*I could see myself faced with these problems on the job in a hospital*" (about fixing a device). This study affirms prior studies about enhanced problem-solving skills in the context of an introductory biomedical engineering technology course [24].

V. Discussion and limitations

While we found PBL to be effective in many ways, including helping students to decide if the major is right for them, enhancing career literacy, aiding students in visualizing themselves in their career, getting students to take more responsibility for their learning, and improving soft-skills, we also found some notable limitations to this study and approach. The small sample size (n=5) likely limited our ability to find significant results. Because it was conducted with only one class on one campus, too, the replicability of the results is, as of yet, unproven.

The students struggled with one assignment, which asked them to use literature to provide recommendations for a hospital's policy dealing with cybersecurity, highlighting one of the

limitations of PBL in this type of class. We believe that students had the most trouble with this assignment because it was less tangible than the other problems that they were given, and it was more focused on the higher order of thinking, including evaluation and creation. Students seemed to better connect more concrete problems, such as taking inventory or fixing devices, with their careers than this exercise, which involve policy and recommendations. These are components of the BMET field but are less visible and less common aspects of the entry level job. Overall, students scored lower on most of the rubric metrics on this assignment compared to problems completed earlier in the class (Figure 2), and some students expressed their frustration with this problem. One student said, "*…it could be useful. Although we were never taught about it*" referring to integrating ideas from literature to form a recommendation. Another student stated, "*I don't really have an opinion on cybersecurity considering I know nothing about it*," indicating that at least some students were still seeking to be taught, rather than to learn on their own, the latter a desired outcome of sustained engagement with PBL. Providing students with more context on this assignment in the future might help them to better connect it with careers in the field and thus may improve learning and performance.

In addition, the next time this course is taught, we will take a closer look at areas where significant improvement was not seen on the career self-efficacy scale. These include items in the larger groupings related to motivation and awareness. Specifically, the career self-efficacy scale showed that including further exploration on various types of careers in the field, to allow students to determine their ideal career and steps needed to pursue that career, would be beneficial in future iterations of this course.

PBL also has limits to its utility based on the subject matter and type of course. We found that it worked quite well for this introductory level BMET course and believe it would also be effective in some upper level courses, for example, a course we teach in troubleshooting medical equipment. As this study was conducting by a student/faculty team, we were able to look at PBL from both perspectives. From a faculty perspective, PBL would be harder to implement in a class that is very fact based, such as those dealing with how devices work, preventative maintenance procedures, and electronics calculations. Of course, some elements of PBL could be applied in these courses. From a student perspective, incorporating PBL into a traditional lecture-based course could provide supplemental ways of learning. If a teacher preforms a conventional lecture, supplementing it with experiential learning, students can learn in a variety of ways and further their own knowledge. From observing the class, the students initially did want some type of traditional lecture but became more receptive to the PBL methods over time. In these cases, a mix of traditional teaching and PBL within the course, such as the method employed by Yadav et. al. [30] in an electrical engineering course, might be the most effective and efficient strategy to facilitate student learning.

VI. Conclusions

This study showed that PBL is effective in helping to connect first year BMET students with their future careers. By working through the problems in this class, they became more aware of career duties and requirements, were able to experience scenarios as they might see on the job, and were able to make informed decisions about whether this was the right major and career path for them. Other benefits of PBL in this course included students improving soft skills and taking more responsibility for their own learning.

We will continue to track the students who take this course as they move through the BMET program and start careers. While the study was conducted in an introductory BMET course, the potential connection between enhanced career self-efficacy and PBL suggested by our results could be applicable to any discipline seeking to integrate career orientation across their curriculum.

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