Problem-based learning in advanced photonics manufacturing: Adapting to online delivery during a global pandemic

Nicholas Massa[*a], Aimee Dalenta[b]
[a] Optics and Photonics Technology Department; [b] Early Childhood Education Department
Springfield Technical Community College, 1 Armory Square, Springfield, MA, USA, 01105

Keywords: Problem-based learning, photonics, STEM, online, advanced manufacturing, pandemic, COVID-19

ABSTRACT

In 2018, Springfield Technical Community College (STCC) was awarded a $551K grant from the National Science Foundation Advanced Technological Education (NSF-ATE) program to create a new series of multimedia problem-based learning (PBL) instructional modules, referred to as PBL Challenges, in advanced photonics manufacturing in partnership with MIT's AIM Photonics Group and the photonics industry in the Northeast. Due to the COVID-19 pandemic, however, the project's professional development and classroom testing of the modules had to be adapted to an online format. A qualitative study was conducted in which participating STEM educators and photonics technician students were surveyed and interviewed to better understand (1) how and to what extent online delivery of PBL instructional materials impacted teacher and faculty adaptation, and (2) the impact of online PBL instruction on student learning outcomes. Results of the study are presented.

1. INTRODUCTION

The onset of the COVID-19 pandemic demanded online and hybrid coursework immediately become the norm in K-12 classrooms, as well as at most institutions of higher education. Responding to this need inspired innovation and creativity, and also brought about challenges and hurdles at all levels of teaching and learning. Among the most innovative of responses to ensure scholarship and engagement was the adaptation of PBL modules from an in-person to an online format. Educators at the high school and college level, working in partnership with faculty from Springfield Technical Community College, received professional development and training about best practices in delivering the photonics modules virtually. Educators across the country and world who were involved in this distinctive PBL initiative were asked to make changes to their delivery method, and to shepherd students through a new way of engaging with their learning.

The following report addresses the perspectives of both educators and students regarding their experiences with these PBL initiatives. It describes the perceptions of both students and faculty as they traversed through the uncertainty and newness of PBL in an online environment. Most educators and students shared experiences of triumph and success; some described frustrations and roadblocks. *All* described experiences of tremendous professional or academic growth.

2. PROJECT BACKGROUND

PBL is a student-centered instructional approach that encourages engagement in authentic, real-world problem solving[1]. PBL is an active and collaborative process that addresses widespread industry concern about the ability of STEM graduates to work effectively on teams[2]. In a PBL initiative, the instructor serves as a facilitator, shepherding students through the problem solving process and providing direction or re-direction only as needed. The objective of PBL is for the student to experience deep learning, rather than surface learning[3]. Since 2006, the PBL Projects team has created over two dozen PBL "Challenges" (multimedia case studies) and presented professional development in their use to hundreds of teachers through four NSF-ATE funded projects; PHOTON PBL, STEM PBL, Advanced Manufacturing PBL (AM-PBL), and Advanced Photonics Manufacturing PBL (APM-PBL). This work is detailed on the PBL Projects website (https://www.pblprojects.org).

*massa@stcc.edu; phone 1-413-755-4579; www.stcc.edu/laser; www.pblprojects.org

Optics Education and Outreach VII, edited by G. Groot Gregory,
Anne-Sophie Poulin-Girard, Proc. of SPIE Vol. 12213, 1221303
 · 0277-786X · doi: 10.1117/12.2633496

In each of these PBL projects, the PBL Projects team worked with partner companies, organizations and research institutions to capture real-world problems and the structured process by which they were solved in a multimedia format suitable for classroom delivery. Each PBL Challenge contains four main sections in which the problem-solving process is re-enacted: (1) A company or organization overview, (2) the problem statement as it was presented, (3) the brainstorming session engaged in by the team solving the problem, and (4) the company or organization's problem solution. The brainstorming and solution sections are password protected so that the instructor can control the timing of when certain information is presented to students. The PBL Challenges also contain a password protected teacher tutorial, multiple assessment tools, and other resources to aid in classroom delivery and evaluation of student performance. Prior to the COVID-19 pandemic, educators were provided with face-to-face training in the use of the PBL Challenges as well as ongoing support by the PBL Projects team as they transitioned from a traditional instructor-centered to a learner-centered PBL instructional modality. In this paper, we present the first-hand experiences reported by 6 STEM educators and 6 STEM students as they transitioned to and engaged in the online delivery of PBL during the fall 2021 and spring 2022 semesters.

2.1 Adapting modalities

During the earliest days of the COVID-19 pandemic, the PBL Projects team realized that they needed to modify their traditional face-to-face delivery of professional development to an online format. Prior to the pandemic, the project team were accustomed to offering the PBL professional development initiatives in-person only; therefore, the modules needed to be modified for virtual learning, and the facilitators needed to rethink how to best administer the PBL Challenges in an online classroom space.

The project team worked diligently to pivot their methodology for teaching PBL virtually, working closely with participants to assure their level of preparedness matched that of in-person training. The result was a newly imagined, innovative, 21st century approach to teaching and learning, and a group of educators equipped to deliver the modules online. Using a virtual Zoom® classroom and utilizing its breakout room feature, the project team was able to emulate the traditional PBL classroom "roundtable" experience in which multiple teams of 3-4 students would work together to solve a problems and the instructor would "float" from team to team offering guidance and direction.

This approach was successfully used in summer 2021 to train 24 STEM educators from across the U.S., Europe and Mexico in the use of the Advanced Photonics Manufacturing PBL Challenges. The training involved teams of 3-4 STEM educators working through four PBL Challenges just as their students would so that they could experience firsthand the challenges their own students would face in an online team-based PBL activity.

2.2 Creating successful student teams

The PBL Challenges, pre-pandemic, were not only mission-based, but also based on rapport between educators and students[4]. In addition, collaboration and collegiality between students in a given PBL group was emphasized by most educators at the onset of a new challenge. As PBL leaders transformed the delivery modality into the virtual space, many PBL educators were left wondering if they would be able to build camaraderie in the online learning environment that mirrored the successful collaboration that their students typically experienced in person.

The data uncovered by this study reveals that the majority of teachers and professors, both at the high school and college level, felt that they were able to successfully transition the collaborative component of PBL into the online learning modality. Teachers and professors immediately began to utilize strategies to create groups, most using the alphabetical or randomized selection that they had commonly used pre-pandemic. Some facilitators surveyed their students before the challenge began, administering questionnaires about learning styles and lifestyle/schedule restraints and grouping students accordingly. Still yet, other educators allowed students to choose at least one familiar groupmate to help ease the transition into the online learning platform. Most educators encouraged students to connect personally, outside of the confines of the PBL challenge, to speak more informally and set meeting times. All of these strategies helped to create fully functioning, successful teams as PBL challenges were administered in their new format.

The deliberations that occur organically during in- person PBL challenges do not occur the same way in the online format; therefore, students relied on digital communication tools to assure strong communication within groups in the online

learning space. Students reported using modern technology and applications to bolster communication between groupmates, and indicated a high level of comfort in using these tools. The primary purpose for these communications was to discuss and organize tasks, check in regarding progress, and debrief after confusion. Among the most popular communication tools were Google Meet®, Zoom®, and Discord®, as well as traditional text messaging. Students reported that they didn't form personal bonds with groupmates; rather, that they had formed strong professional and academic rapport based on a process-oriented project. According to the data gathered, this is what they expected, as there was not an initial expectation of creating personal friendships during the course. In fact, the majority of students surveyed most often relied on a pre-set, formal meeting with their groupmates and did not reach out beyond the confines of a scheduled meeting. Given this, students still reported feeling comfortable with their partner or group.

Students reported feeling successful during their PBL challenges in regards to peer collaboration. Most believed that their success during the challenges was primarily individual, yet not hindered by their groupmates. The vast majority of students surveyed felt either moderately or highly successful in their group, with one student reporting that their group didn't function as highly as they'd hoped. Overall, students understood the mission of the PBL challenges, and valued the collaborative nature of them.

2.3 Student engagement

Authentic student engagement is a primary mission of PBL. As PBL modules shifted to a completely online environment, facilitators were tasked with maintaining the same high levels of student engagement as they did when delivering the challenges in person. Educators reported that at the onset, the notion of maintaining high levels of student engagement online seemed overwhelming; most reported that after beginning the projects, high levels of communication between students and facilitators helped student engagement sustain its levels compared to in-person learning. Several educators even believed that student engagement in the virtual space increased from in-person learning, citing the students' autonomy or self-motivation as potential causes.

Facilitators reported that other factors may have led to positive student engagement during the PBL cycles, such as offering virtual office hours, being specific with expectations and due dates, and differentiating the amount of support or autonomy given to each group, depending on specific needs. Students reported that they felt engaged with the PBL process, noting that it required them to prioritize group communication and stay up-to-date on responsibilities among their group. The majority of students cited personal responsibility and accountability to their partner or group as a central reason that they were able to maintain high levels of engagement with PBL work. This is consistent with current research in the field regarding student engagement in an online PBL environment[5].

There were several outliers in this data set, which included the belief that student engagement on the whole had sharply decreased both before, during, and after the pandemic. This speaks to an overarching concern shared by teachers at all levels of education. Overall, the data supported the notion that although there were some challenges, student engagement in the online PBL environment mirrored the high-level of engagement in the in-person classroom. Current research studies have found similar results, acknowledging both the benefits and challenges of student engagement in online PBL settings[6].

2.4 PBL and self-motivation

Among the most remarkable data gathered during this study was student perceptions of their self-motivation and self-efficacy regarding the PBL challenges, and how this juxtaposed instructor perceptions of student motivation. Students overwhelmingly reported that their motivation, excitement, and determination during the PBL modules were high or very high, and that they didn't believe participating in the PBL challenges online hindered their ability to successfully complete the expectations of the modules. Students reported a high satisfaction level with the work, as well as a high confidence in their ability to complete it successfully, aligning with research in the field[7]. They believed themselves to be highly motivated intrinsically, driven primarily by their determination to complete the task well and work effectively with a group. Overwhelmingly, students believed that their experience online would be just as effective or impactful versus on in-person learning experience. Nearly half of the participants indicated a preference for learning online as opposed to on-ground.

In opposition to this data, many instructors reported that they perceived their students to be less intrinsically motivated as compared to motivation levels before COVID-19. Instructors reported that some students appeared to be disengaged and

apathetic during some aspects of the PBL challenges, some even believing that motivation was more instructor-driven, rather than intrinsically driven by the student. Overall, this information exposes a glaring disconnect between student experience and instructor perception during PBL challenges.

2.5 Instructor feedback

A key indicator in student success with virtual PBL challenges was their accessibility to their instructor, and the quality and timeliness of the feedback the instructor provided to groups. The majority of students reported that they felt supported by their teacher or professor, and knew several different modalities in which to reach him or her, including email, office hours, or even by cell phone. Students reported a high level of comfort in making contact with their instructor, and felt that they would receive help or clarification as needed by making this contact. Furthermore, students also felt confident that their instructors would provide timely feedback on assignments or modules within the constructs of PBL. Students reported that specific feedback and conversations with their professors helped them during difficult stages of a PBL challenge, paralleling many years of research on this topic. Conversely, instructors cited specific and timely feedback as a core component to their approach with the online learning modules. The research on feedback aligns with this data[8], underscoring the importance of strong communication between instructor and student, and highlighting the importance of providing timely, detailed, student feedback, especially in a completely online learning environment.

3. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this project was to create a series of new multimedia PBL instructional modules in advanced photonics manufacturing. Due to the COVID-19 pandemic, these modules were later adapted to be delivered in a fully online format. The data gathered during this research project highlights the overall success of this initiative, and reveals several areas for improving online delivery of PBL. The ingenuity and adaptability of students and instructors alike cultivated a prime teaching and learning environment for PBL to occur. Instructors adjusted to the changing times, but didn't lose sight of their overall values and objectives. Students maintained their motivation and adapted to online group work exceptionally well. The experience was overall positive for all participants.

3.1 Program highlights

Students

- Felt prepared for the virtual learning environment
- Felt engaged, motivated, and supported by their instructors
- Experienced high levels of satisfaction pertaining to peer collaboration
- Believed their instructors were responsive and provided timely and specific feedback

Instructors

- Felt prepared to teach the modules online
- Believed the integrity of the PBL challenges was maintained in the online format
- Enjoyed the teaching experience

3.2 Recommendations for future implementation:

- Provide additional training for instructors regarding best practices for online teaching
- Hold 2-3 synchronous, whole-group sessions during PBL challenge implementation
- Expand strategies for selecting student groups or teams

REFERENCES

[1] Hmelo-Silver, C.E., "Problem-Based Learning: What and How Do Students Learn?" Educational Psychology Review 16, 235–266 (2004). https://doi.org/10.1023/B:EDPR.0000034022.16470.f3.

[2] Massa, N., “Problem-Based Learning (PBL): A Real-World Antidote to the Standards and Testing Regime,” New England Journal of Higher Education, v22 n4 p19-20 Win 2008.
[3] Massa N., Donnelly, J., Mullett, G., “Problem-based learning in advanced photonics manufacturing bringing real-world applications to the classroom,” (2019), SPIEDigitalLibrary.org/conference-proceedings-of-spie.
[4] Torp, L., & Sage, S. (2002). Problems as possibilities: Problem-based learning for K-16 education (2nd Ed.). Alexandria, VA: Association for Supervision and Curriculum Development.
[5] Randazzo, M., Priefer, R., & Khamis-Dakwar, R. “Project-Based Learning and Traditional Online Teaching of Research Methods During COVID-19: An Investigation of Research Self-Efficacy and Student Satisfaction,” Frontiers in Education, 6 (2021), https://doi.org/10.3389/feduc.2021.662850.
[6] Chao, C. T., Tsai, C. L., Lin, M. W., Yang, C. W., Ho, C. C., Chen, H. L., Hsu, C., & Sheu, B. C., “Fully digital problem-based learning for undergraduate medical students during the COVID-19 period: Practical considerations,” Journal of the Formosan Medical Association (2021), https://doi.org/10.1016/j.jfma.2021.11.011.
[7] Harun, N. F., Yusof, K. M., Jamaludin, M. Z., & Hassan, S. A. H. S., Motivation in Problem-based Learning Implementation. *Procedia - Social and Behavioral Sciences*, *56*, 233–242 (2012), https://doi.org/10.1016/j.sbspro.2012.09.650.
[8] Danielson, A., & Stevenson, F. T., “Virtual PBL: Online Student Interaction to Enhance Learning, Interest, and Peer Feedback,” Medical Science Educator, 21(3), 203–205 (2011), https://doi.org/10.1007/bf0334170.

ACKNOWLEDGEMENTS

The Problem-Based Learning in Advanced Photonics Manufacturing Project is funded in part by the Advanced Technological Education program of the National Science Foundation (NSF-ATE # 1801115). Principal Investigator, Nicholas Massa, Springfield Technical Community College; Co-Principal Investigators Judith Donnelly, New England Board of Higher Education, Gary Mullett, Springfield Technical Community College, Kelli-Marie Vallieres, Sound Manufacturing.