PBL BRIEF #4

WPI

Project-Based Learning in Graduate Education

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Briefer Brief

- The National Academies of Sciences, Engineering, and Medicine (2018) recommended that graduate students ideally should be taught using team-based projects "as a means of developing transferable professional skills such as communication, collaboration, management, and entrepreneurship" (p. 3).
- Project-based learning (PBL) can be used to enhance research experiences by helping graduate students learn how to translate their content expertise into discipline-appropriate products for a variety of audiences (Mallinson, 2018; Sleeter, Schrum, Swan, & Broubalow 2019).
- As has been demonstrated in undergraduate education (Ahern, Dominguez, McNally, O'Sullivan, & Pedrosa, 2019; Hart, 2019; Stolk & Martello, 2015), graduate students who experience PBL learn an array of professional skills (Brundiers & Wiek, 2013; Wurdinger & Qureshi, 2015).
- Graduate students engage in more advanced levels of knowledge construction in online courses that use PBL than in online discussions during non-PBL competency building assignments (Koh, Herring, & Hew, 2010).
- While PBL and similar student-centered experiential pedagogies may be widely used in graduate programs, there is little high-quality research examining the quality of implementation or best practices for bringing PBL to scale in graduate programs.

Introduction

While frequently studied in the context of undergraduate studies, the suitability of PBL for the discipline-based training of graduate education has also been examined. This emerging literature extends two key benefits of PBL seen in undergraduate education: learning 21st century skills needed in the evolving workforce and engaging students to address gaps in retention. In 2018, the National Academies of Sciences, Engineering, and Medicine released a joint report about the future of graduate STEM education recommending that graduate students ideally should be taught using team-based projects "as a means of developing transferable professional skills such as communication, collaboration, management, and entrepreneurship" (p. 3). The rise of student-centered pedagogies like PBL in graduate school might be valuable beyond STEM programs. Discussions on how to improve humanities instruction has also suggested student-centered, inquiry-based teaching as a solution.[1]

PBL and similar experiential high-impact practices have become increasingly common because of the impact not only on 21st century skills, but on student engagement.[2] Nationwide, 50% to 60% of students who begin a PhD program do not obtain their doctoral degree.[3] Given the evidence base with undergraduates, the possibilities of using PBL to engage graduate students and increase retention hold promise.

This research brief begins with literature describing how PBL can enhance the learning that graduate students traditionally do through research experiences. The ways PBL has been found to support the development of professional skills expected of graduate level training are then explored. Finally, we summarize some critical gaps in the available empirical literature on PBL in graduate education to suggest further study.

Using PBL to Enhance Learning from Research Experiences

Graduate education is designed to train students to become experts in particular fields. For many degrees, this requires students to engage in demonstrations of professional quality scholarship. Learning how to engage in scholarship is naturally experiential and ideally achieved with authentic opportunities to practice. The research on how PBL might be used to scaffold that learning is largely case study in design, conducted with small samples of graduate students as faculty examine the impact of their curricular and pedagogical decisions.[4]

Perhaps the most direct relationships between PBL and graduate student learning is how it can be leveraged to strengthen students' mastery of the research process. Sleeter, Schrum, Swan, and Broubalow (2019) documented the benefits of having students in a graduate history program use their own scholarship to create virtual PBL lesson modules. Mallinson (2018) demonstrates how PBL can structure doctoral coursework to help students connect their academic expertise to tangible products of value to industry, nonprofits, and government. This ability to translate scholarly expertise and communicate with multiple audiences—regardless of discipline or subfield—can provide graduate students with skills demanded by employers.

A few studies have more broadly assessed the state of PBL implementation in graduate programs. Brundiers and Wiek (2013) analyzed six problem- and project-based learning courses in sustainability and found wide variety in PBL format (e.g., workshops, hybrid courses combining lectures with student-centered projects), amount of structure, scope of work, and number of projects per course. Using a framework for transformational sustainability research,[5] Brundiers and Wiek found that several key principles of PBL are not reliably implemented in graduate studies, including self-directed learning and advanced teamwork. These emergent findings suggest that, while a promising practice, PBL is not yet widely embraced with reliable fidelity in graduate classrooms.

Using PBL to Teach Graduate Students Professional Skills

One of the more compelling benefits of using PBL with students in colleges and universities is its effectiveness at developing a variety of professional skills while students master content.[6] Learning professional skills is often part of the hidden curriculum of graduate school, which can be supported through explicit attention.[7] Wurdinger and Qureshi (2015) used pre- and post-course surveys to assess changes in graduate students' life skills in a course using PBL and found statistically significant increases in responsibility, problem solving, self-direction, communication, and creativity. However, there were no measurable changes in students' time management, collaboration, or work ethic. Further research is needed to validate these findings and expand upon which professional skills are developed indirectly through PBL experiences and which require more direct scaffolding in graduate student populations.

Brownell and Jameson (2004) presented a model that integrates the cognitive, affective, and behavioral learning objectives of problem-based learning, akin to PBL in its experiential pedagogy. Using a historical case study of a graduate management program, Brownell and Jameson demonstrated how such integration leads to professional skills often touted by proponents of PBL. Their analyses of their PBL-based management program indicated that graduate students engage in both analytical learning processes as well as interpretive learning processes to learn how to implement plans, lead teams, resolve conflict, persuade others, and communicate with multiple constituencies during projects.

Graduate education positions students differently than undergraduate education; this calls into question how the existing rich body of research on PBL with undergraduate students might be extended to fully understand the potential of PBL. For example, graduate students are often positioned as instructors, in addition to contributing to original research. In their exploration of sustainability courses, Brundiers and Wiek (2013) point out that positioning doctoral students as PBL coaches with undergraduate students provides them with experience using PBL teaching techniques, as well as practicing principal investigator roles. Further research in understanding whether and how such positioning benefits graduate students in their professionalization would provide a more compelling argument of this contribution to graduate student experiences.

Using PBL in Online Graduate Courses

Much of the attention in the literature on PBL in graduate school has focused on how to use instructional technology to leverage its benefits with adult learners. Some of these

studies have revealed that issues that sometimes plague online learning more generally, such as the risk of low-quality discussion and uneven student participation, can still occur when using PBL online.[8] The majority of these studies are also limited to single case studies with varying degrees of attention to transferability to new contexts and constructing or validating theoretical frameworks. Even so, some trends have emerged across cases.

There is moderate evidence that students learn more online when participating in PBL, compared to other pedagogies. Koh, Herring, and Hew (2010) compared the depth of knowledge construction among 17 graduate students during non-PBL and PBL components of an elective course in a school of education. In the first part of the course, students were asked to demonstrate competency in a series of e-learning courseware technical skills while participating in online discussions of how to apply theoretical principles to these tasks. Students then completed individual projects to develop e-learning courseware to address the learning needs of a self-selected target audience. Using qualitative content analysis of students' posts, Koh and colleagues found that during PBL, students were significantly more likely to engage in advanced levels of knowledge construction instead of more superficial exchanges, compared to their exchanges during the non-PBL competency building assignments.

Based on these findings, Ching and Hsu (2013) studied the role of peer feedback in providing learning supports that boost knowledge construction among graduate students. Twenty-one students enrolled in an instructional design course engaged in peer feedback exchanges while completing group instructional design projects. An evaluation of the course found that students used the opportunity to provide and receive feedback to "validate ideas, identify issues, and revise drafts into a well thought-out project," improving students' learning beyond their own initial independent work. When prompted mid-course to focus more on assessment of their peers' demonstration of content knowledge, peer feedback increasingly involved problem identification and suggestions, which points to the importance of instructor guidance in the quality of peer feedback among graduate students. The study was limited by an exploratory, descriptive design, however; there is much to be further studied related to how peer feedback works and how to best leverage its power.

Another mechanism for structuring online communication that has been investigated is mob programming, which comes from professional problem-solving practices in industry. In this tactic, a group of programmers with varying types of expertise and perspectives works on a problem simultaneously to maximize synergy and creativity. Each "programmer" in the "mob" is assigned a particular role: most members of a team are "navigators" discussing the idea to be coded, while one person serves as the "driver" who translates the discussion into code and types it into the group's computer. Programmers take turns cycling through the different responsibilities. Hilton and Sankaranarayanan (2019) assessed the efficacy of mob programming with undergraduate and graduate students and found that the clear definition of roles and rotation across them affords graduate students opportunities to understand the value of multiple perspectives while building multiple competencies. As the research in online PBL continues to mature, we might anticipate evidence of additional mechanisms to emerge.

Case Studies of Project-Based Learning in Graduate Education

There are several case studies describing PBL implementation in graduate-level courses and programs (see Table 1). PBL at the graduate level is frequently employed as a pedagogical bridge to research and service-learning experiences, often in the context of studies that defy traditional disciplinary boundaries. We suggest these case studies as further reading. These articles provide details on how PBL has been deployed in particular graduate level courses and programs, which may be both inspiring and informative.

Table 1. Case Studies of Project-Based Learning in Graduation Education

Citation	Institutional Context	PBL Practices Studied
Ge, X., Huang, K., & Dong, Y. (2010). An investigation of an open-source software development environment in a software engineering graduate course. *Interdisciplinary Journal of Problem-Based Learning, 4*(2).	A major southwestern university	PBL in a graduate software engineering course, with authentic projects, a learning community, cognitive apprenticeships, and technology affordances
Ranger, B. J., & Mantzavinou, A. (2018). Design thinking in development engineering education: A case study on creating prosthetic and assistive technologies for the developing world. *Development Engineering, 3*, 166-174.	MIT, an elite private university in an urban setting	PBL pedagogy and industry partnerships in a human-centered design thinking approach to a design lab on creating low-cost prosthetic and assistive devices for the developing world.
Saleh, A., Cox, D., Fowler, T., & Duncan-Shemwell, B. (2010). Student and facilitator engagement to develop leadership competencies in a project-based learning environment. *Academic Leadership: The Online Journal, 8*(2), Article 38.	Data on the institutional context was not given	Redesign of a capstone portfolio to bring PBL to scale in an educational leadership program; focused on process evaluation with some assessment of impact for one cohort of doctoral students.
Sienko, K. H., Sarvestani, A. S., & Grafman, L. (2013). Medical device compendium for the developing world: A new approach in project and service-based learning for engineering graduate students. *Global Journal of Engineering Education, 15*(1), 1-8.	College of Engineering at the University of Michigan, a large urban public university	An evaluation of outcomes associated with a PBL service-based approach that transitioned from a course to a co-curricular activity on global health medical devices.
Sleeter, N., Schrum, K., Swan, A., & Broubalow, J. (2019). "Reflective of my best work": Promoting inquiry-based learning in a hybrid graduate history course. *Arts and Humanities in Higher Education*, DOI: 10.1177/1474022219833662	George Mason University, a large suburban public university	Curriculum, pedagogy, and outcomes associated with an inquiry-based hybrid graduate course in history education.
Wiek, A., Xiong, A., Brundiers, K., & van der Leeuw, S. (2013). Integrating problem- and project-based learning into sustainability programs: A case study on the School of Sustainability at Arizona State University. *International Journal of Sustainability in Higher Education, 15*(4), 431-449.	Arizona State University, a large public university	A program review of the problem- and project-based learning program in the School of Sustainability, highlighting the role of institutional structures that support implementation at scale.

Conclusions & Future Research

There are several effects of PBL that hold promise for graduate programs, yet have been under-examined in the existing empirical literature. Student-centered experiential learning experiences have been demonstrated to increase student retention as students transition from high school to community college,[9] persist through developmental coursework,[10] earn an associate's degree, and/or transfer to a 4-year institution.[11] However, there are no existing studies of whether this benefit extends through graduate degree attainment. Given that an estimated half of all doctoral students do not persist to degree[12] and findings that PBL can engage students early in degree pathways, such examination of persistence to graduate degrees may be warranted.

At the undergraduate level, PBL has been found to be an effective pedagogy for facilitating interdisciplinary learning.[13] Graduate programs are increasingly focused on emerging areas of expertise that require multi- and interdisciplinary training,[14] such as understanding the food, energy, water nexus, and developing effective human health systems. PBL may be particularly useful in such programs with its focus on authentic learning objectives and adaptability for multi-disciplinary teamwork.

Finally, there is scant research examining how to bring PBL to scale in graduate programs. The majority of research at the graduate school level involves descriptive case studies of PBL in single courses. This makes it difficult to assess the cumulative benefits for graduate students who engage in PBL across multiple learning experiences. Without systematic examination, it is difficult to understand the best practices for transforming departments and academic fields in ways that balance pragmatic realities of higher education against the intended outcomes for the next generation of scholars.

Notes

[1] American Historical Association. (2016). AHA history tuning project: 2016 history discipline core. Accessed 4/13/20 at www.historicans.org/teaching-and-learning/tuning-the-history-discipline-2016-history-discipline-core; Association of American Colleges and Universities. (2017). LEAP principles of excellence. Accesse d 4/13/20 at https://aacu.org/leap/principles-of-excellence.

[2] Hart Research Associates. (2016). *Recent trends in general education design, learning outcomes, and teaching approaches*. Washington, DC: Association of American Colleges and Universities; Wurdinger, S., & Allison, P. (2017). Faculty perceptions and use of experiential learning in higher education. *Journal of e-Learning and Knowledge Society, 13*(1).

[3] Cassuto, L. (2013). PhD attrition: How much is too much? A disturbing 50 percent of doctoral students leave graduate school without finishing. The Chronicle of Higher Education, http://www.chronicle.com/article/PhD-Attrition-How-Much-Is/140045

[4] In this research brief, we focus on project-based learning, which is distinct from the problem-based learning model widely adopted in medical school and other practitioner-based graduate programs. If you are curious about the differences, Kolmos and colleagues (2009) present an overview of the multiple models in problem- and project-based learning in higher education. See Kolmos, A., De Graaff, E., & Du, X. (2009). Diversity of PBL-PBL learning principles and models. In Research on PBL practice in engineering education (pp. 9-21). Brill Sense. For an examination of how the McMaster PBL approach is used in graduate schooling in medicine, Neville's (2009) literature review and Hung and colleague's (2019) review of meta-analyses provide excellent syntheses and critiques. See Neville, A. J. (2009). Problem-based learning and medical education forty years on. *Medical Principles and Practice, 18*(1), 1-9; Hung, W., Dolmans, D. H., & Van Merriënboer, J. J. (2019). A review to identify key perspectives in PBL meta-analyses and reviews: trends, gaps and future research directions. *Advances in Health Sciences Education*, 1-15.

[5] Talwar, S., Wiek, A., & Robinson, J. (2011). User engagement in sustainability research. *Science Public Policy, 38*, 379-390; Wiek, A., & Lang, D. J. (2013). Transformational sustainability research. Working paper, School of Sustainability, Arizona State University: Tempe, AZ.

[6] Ahern, A., Dominguez, C., McNally, C., O'Sullivan, J. J., & Pedrosa, D. (2019). A literature review of critical thinking in engineering education. *Studies in Higher Education, 44*(5), 816-828; Hart, J. L. (2019). Interdisciplinary project-based learning as a means of developing employability skills in undergraduate science degree programs. *Journal of Teaching and Learning for Graduate Employability, 10*(2), 50-66; Stolk, J. D., & Martello, R. (2015). Can disciplinary integration promote students' lifelong learning attitudes and skills in project-based engineering courses. *International Journal of Engineering Education, 31*(1), 434-449.

[7] See Elliot, D. L., Bengtsen, S. S., Guccione, K., & Kobayashi, S. (2020). The Hidden Curriculum: Educational Pillars for Doctoral Researchers' Meaningful Experience and Successful Completion. In *The Hidden Curriculum in Doctoral Education* (pp. 113-127). Palgrave Pivot, Cham; Daniel, C. (2007). Outsiders-within: Critical race theory, graduate education and barriers to professionalization. *J. Soc. & Soc. Welfare, 34*, 25.

[8] See Akarasriworn, C., & Ku, H. Y. (2013). Graduate students' knowledge construction and attitudes toward online synchronous videoconferencing collaborative learning environments. *Quarterly Review of Distance Education, 14*(1).

[9] Schenk, T., Jr., Laanan, F. S., Starobin, S. S., Rethwisch, D., Moeller, D., & Chapman, M. (2012). An evaluation of Iowa Project Lead The Way on student outcomes: Summary report. Ames, IA: Office of Community College Research and Policy; Starobin, S. S., Schenk, T., Jr., Laanan, F. S., Rethwisch, D. G., & Moeller, D. (2013). Going and passing through community colleges: Examining the effectiveness of Project Lead The Way in STEM pathways. *Community College Journal of Research and Practice, 37*(3), 226-236.

[10] Prentice, M. (2009). Service-learning's impact on developmental reading/writing and student life skills courses. *Community College Journal of Research and Practice, 33*(3-4), 270-282.

[11] Starobin and colleagues (2013); Taggart, A., & Crisp, G. (2011) Service learning at community colleges: Synthesis, critique, and recommendations for future research. *Journal of College Reading and Learning, 42*(1), 24-44.

[12] Cassuto, L. (2013). PhD attrition: How much is too much? A disturbing 50 percent of doctoral students leave graduate school without finishing. The Chronicle of Higher Education, http://www.chronicle.com/article/PhD-Attrition-How-Much-Is/140045

[13] Hutchison, M. (2016). The empathy project: Using a project-based learning assignment to increase first-year college students' comfort with interdisciplinarity. *Interdisciplinary Journal of Problem-Based Learning, 10*(1), 9; Knight, D. B., Lattuca, L. R., Kimball, E. W., & Reason, R. D. (2013). Understanding interdisciplinarity: Curricular and organizational features of undergraduate interdisciplinary programs. *Innovative Higher Education, 38*(2), 143-158; Brassler, M., & Dettmers, J. (2017). How to enhance interdisciplinary competence—interdisciplinary problem-based learning versus interdisciplinary project-based learning. *Interdisciplinary Journal of Problem-Based Learning, 11*(2).

[14] See the National Science Foundation's Dear Colleague Letter: Growing Convergence Research, accessed 4/13/20 at https://www.nsf.gov/pubs/2018/nsf18058/nsf18058.jsp?WT.mc_id=USNSF_25&WT.mc_ev=click

Works Cited

Ahern, A., Dominguez, C., McNally, C., O'Sullivan, J. J., & Pedrosa, D. (2019). A literature review of critical thinking in engineering education. *Studies in Higher Education, 44*(5), 816-828.

Brownell, J., & Jameson, D. A. (2004). Problem-based learning in graduate management education: An integrative model and interdisciplinary application. *Journal of Management Education, 28*(5), 558-577.

Brundiers, K., & Wiek, A. (2013). Do we teach what we preach? An international comparison of problem- and project-based learning courses in sustainability. *Sustainability, 5*, 1725-1746.

Ching, Y. H., & Hsu, Y. C. (2013). Peer feedback to facilitate project-based learning in an online environment. *The International Review of Research in Open and Distributed Learning, 14*(5).

Hart, J. L. (2019). Interdisciplinary project-based learning as a means of developing employability skills in undergraduate science degree programs. *Journal of Teaching and Learning for Graduate Employability, 10*(2), 50-66.

Hilton, M., & Sankaranarayanan, S. (2019, February). Online Mob Programming: Effective Collaborative Project-Based Learning. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education* (pp. 1283-1283).

Koh, J. H. L., Herring, S. C., & Hew, K. F. (2010). Project-based learning and student knowledge construction during asynchronous online discussion. *The Internet and Higher Education, 13*(4), 284-291.

Mallinson, C. (2018). Technology-enhanced project-based learning: A platform for graduate student research and outreach on campus and in the community. *Journal of English Linguistics, 46*(3), 229-245.

National Academies of Sciences, Engineering, and Medicine. (2018). *Graduate STEM Education for the 21st Century*. Washington, DC: The National Academies Press.

Sleeter, N., Schrum, K., Swan, A., & Broubalow, J. (2019). "Reflective of my best work": Promoting inquiry-based learning in a hybrid graduate history course. *Arts and Humanities in Higher Education*, DOI: 10.1177/1474022219833662.

Stolk, J. D., & Martello, R. (2015). Can disciplinary integration promote students' lifelong learning attitudes and skills in project-based engineering courses. *International Journal of Engineering Education, 31*(1), 434-449.

Wurdinger, S., & Qureshi, M. (2015). Enhancing college students' life skills through project based learning. *Innovative Higher Education, 40*, 279-286.

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