



PBL BRIEF #9.0 SERIES

WPI ALUMNI SURVEY FINDINGS



WPI

9.3 PBL at Scale: Developing Skills and Knowledge through Multiple Projects

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Briefer Brief

- A robust evidence base does not yet exist regarding how much PBL is needed to reap the full promise of the approach.
- Many of the skills that are in high demand by employers are better developed through PBL when students are provided multiple opportunities to practice them through projects.
- Low doses of PBL were insufficient for learning most professional skills and for developing technical knowledge. This may provide context for understanding why some studies have found that a single isolated experience of PBL does not positively impact learning.
- With a moderate dose of projects in about half of a student's courses, there are significant increases in both professional skills and technical knowledge and skills.
- A similar increase was found for a subset of skills in moving from a moderate dose to a large dose of projects in nearly all courses.

Introduction

A large evidence base has established that project-based learning (PBL) is a stronger pedagogical approach than teacher-centered, lecture-based methods of teaching¹ for a range of outcomes. What we do not yet know is the conditions under which PBL is most effective.² For example, is it reasonable to expect a single experience of student-centered, active learning to reverse the expectations and behaviors instilled in students through a decade of teacher-centered, passive learning? It seems more likely that students might need to experience PBL at scale to reap the full benefits of this style of teaching.

This research brief explores the outcomes associated with providing students with multiple opportunities to experience PBL. After describing the scale of projects at WPI, the brief leverages findings from a 2021 alumni survey to outline the benefits of multiple project experiences for developing professional skills, technical knowledge and skills, learning processes, and for preparing students for career success and for personal transformation.

PBL at Scale

All undergraduate students at WPI are required to complete three major projects to graduate, with an optional additional fourth project. Two of these projects comprise a quarter of the junior and senior years. The senior year project is a capstone in the major where students work with faculty advisors on a significant research or design project. The junior year project asks students to solve some problem at the intersection of science, technology and society. The vast majority of students do this in collaboration with a sponsoring organization, many at sites off-campus, locally or around the world. The third project is a capstone in the humanities and arts, and can be a creative endeavor (designing lighting for a play, composing music or doing a performance) or a significant exploration of a humanities-related problem or there at a deeper level of intellectual engagement than possible in a traditional course. The optional project is in the first year where students, after exploring the breadth and depth of one of the world's great problems, propose a potential solution to this problem for a localized population, culminating in a campus-wide poster presentation.

This scale of PBL is unique to WPI. In June 2023, Duke University facilitated a symposium of colleges and universities at the forefront of PBL practice in the US. The convening included 15 institutions, of which five were providing at least 750 students per year with project experiences: Ball State University, Clemson University, Duke University, Georgia Tech, and WPI. Of these, WPI is the only university to provide PBL at full scale to all students.

PBL AT SCALE: DEVELOPING SKILLS AND KNOWLEDGE THROUGH MULTIPLE PROJECTS

In addition to expecting all students to engage in multiple projects, many courses at WPI include PBL in various forms. For example, students in a biodiversity course authored an open educational resource titled [‘Biodiversity Loss in the Age of the Sixth Mass Extinction’](#). An industrial engineering course asked students to [analyze the process flow of Covid testing](#) on campus. Robotics courses ask students to design and build robots of increasing sophistication as they move through the curriculum.

On average, approximately two thirds of alumni indicated that half of their courses or more included projects (see Figure 1); this has doubled over the past four decades from 43% to 85% of students (see Figure 2). In 2018, an independent study conducted by the One8 Foundation found that 69% of faculty use projects in at least one course that they teach, allowing us to triangulate high levels of course-based PBL.

Figure 1. Student Experiences of Courses with PBL at WPI

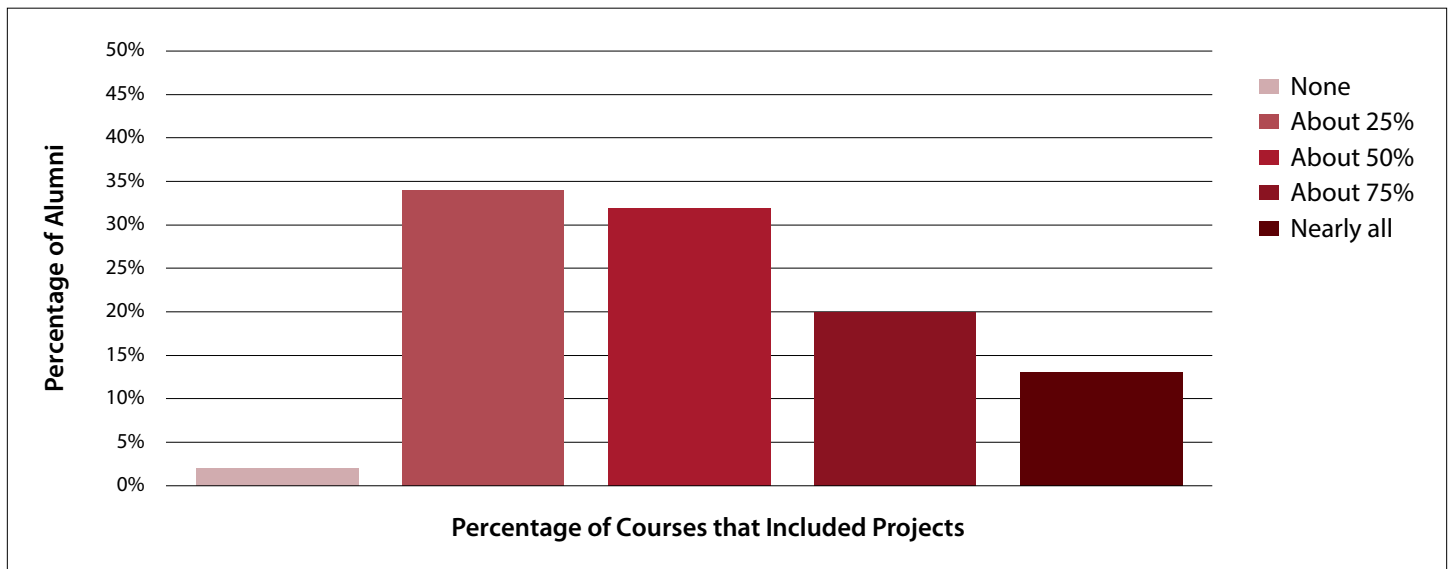
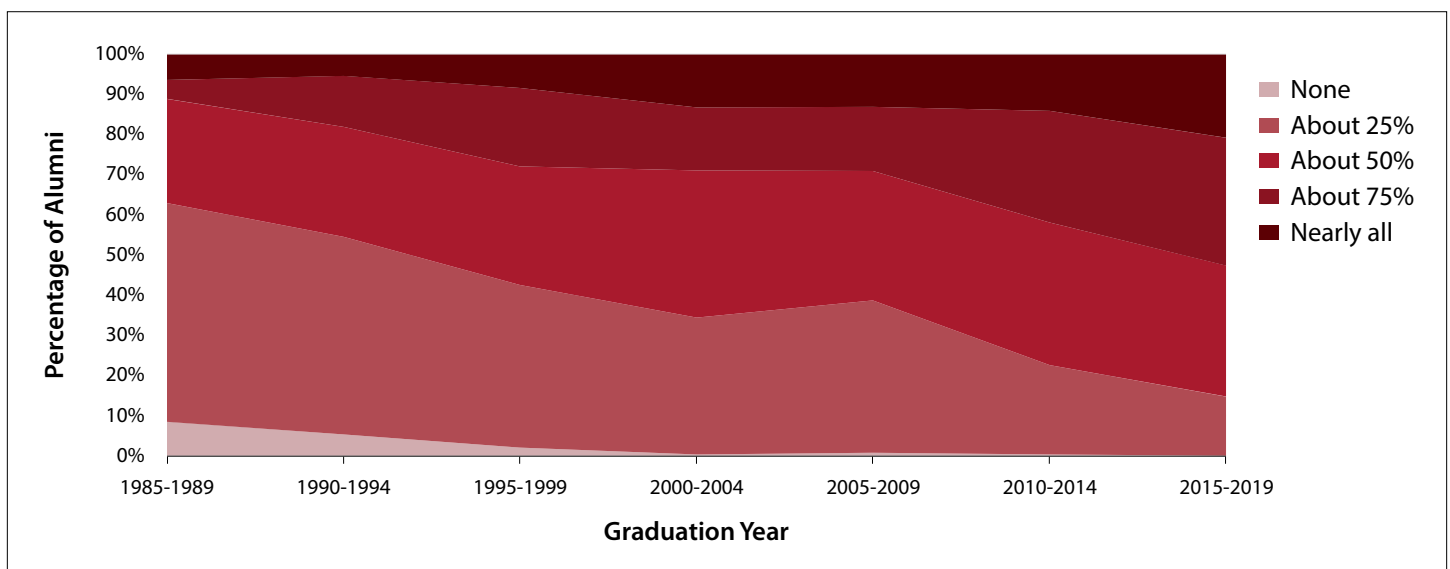


Figure 2. Change in Percentage of Courses with PBL Reported by Alumni over Time at WPI



Developing Professional Skills

Many of the skills that are in high demand by employers are better developed through PBL when students are provided multiple opportunities to practice them. In this study of WPI alumni, we assessed whether those who had more courses that included projects reported greater gains in a set of skills that are highly sought after by employers. A one way analysis of variance revealed that there was a statistically significant difference between at least two groups in each of four professional skills (see Table 1).

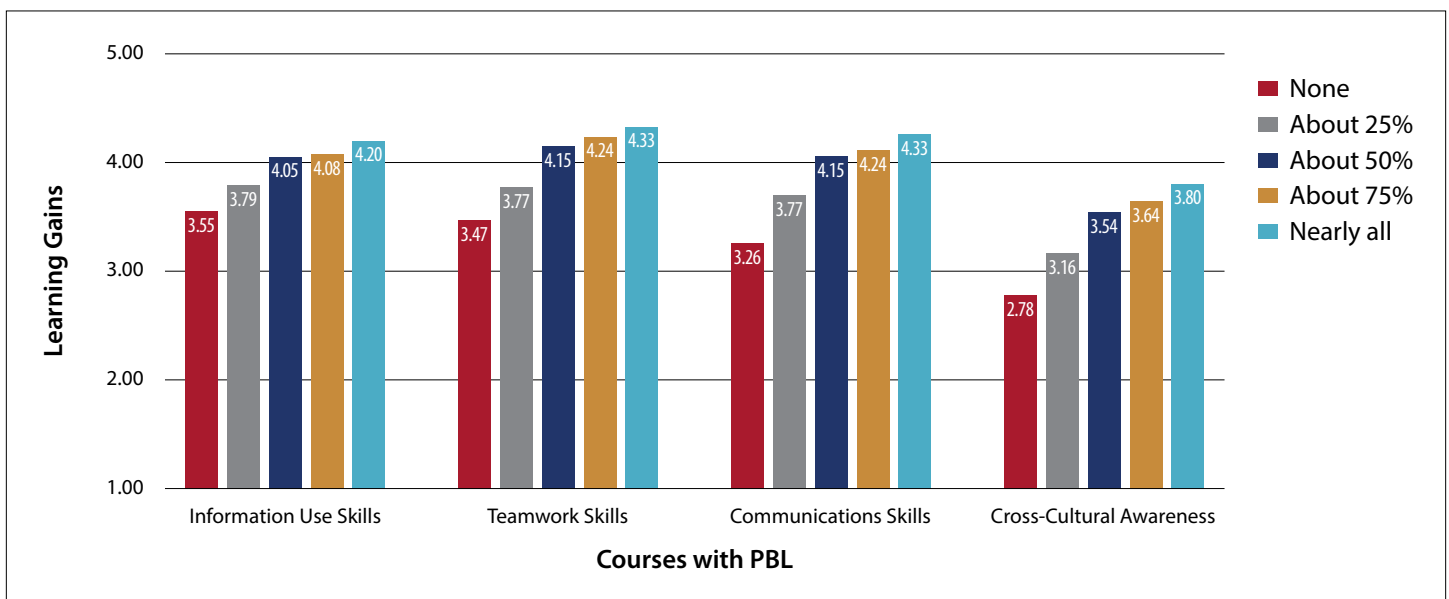
Table 1. One-Way ANOVA of Gains in Professional Skills by Dosage of Course-Based PBL

Variable	Courses with PBL										F (4,1931)	p	η ²
	None		About 25%		About 50%		About 75%		Nearly All				
	M	SD	M	SD	M	SD	M	SD	M	SD			
Information Use Skills	3.55	1.08	3.79	.87	4.05	.77	4.08	.75	4.20	.79	19.39	<.001	.04
Communication Skills	3.26	1.04	3.70	.98	4.06	.88	4.11	.84	4.26	.81	31.31	<.001	.06
Teamwork Skills	3.46	1.18	3.76	1.00	4.15	.85	4.24	.84	4.33	.83	32.89	<.001	.06
Cross-cultural Awareness	2.78	1.13	3.16	1.07	3.54	1.00	3.64	1.01	3.80	1.00	28.93	<.001	.06

Note. Variables were measured by the survey item, “Indicate the extent to which your WPI formal project experience...contributed to...” followed by items combined into the composite variables listed after exploratory factor analyses and Cronbach’s alphas were examined. Response options were on a five-point scale with “not at all,” “a little bit,” “moderately,” “much,” and “very much.” Significance set at $p \leq .05$.

We found that low doses of PBL were insufficient for learning most professional skills. There were no significant differences in learning skills for using information effectively, managing collaborative teamwork, communications skills, or cross-cultural awareness between those who had no projects in their courses and those who had projects in about 25 percent of their courses (see Figure 3).

Figure 3. Dosage Effects of Projects in Courses on Professional Skills Development



With a moderate dose of projects in about half of a student’s courses, there are significant increases in learning across all of these professional skills. Those with no courses that included projects indicated between moderate and much gains in using information effectively, managing collaborative teamwork, and communicating effectively, compared to those with projects included in about 50 percent of their courses, who reported much gains in each (see Figure 3). Cross-cultural awareness increased from between a little bit and moderate to moderate gains.

For two types of skills, there were further significant gains for those who had projects included in nearly all of their courses, though the gains were smaller (see Figure 3). The size of the effect of the extent to which projects are included in courses is small for using information effectively ($\eta^2 = .04$) and medium for managing collaborative teamwork ($\eta^2 = .06$), communicating effectively ($\eta^2 = .06$), and cross-cultural awareness ($\eta^2 = .06$).

but typical—response rate of 14%. The sample included in the analyses presented here includes 61% men, 39% women, and less than one percent non-binary or gender-fluid alumni. The majority of respondents were white (89%), 6% identified as Asian, 4% identified as Hispanic/Latino (any race), 1% identified as Black/African American or African, and 1% identified as Middle Eastern or North

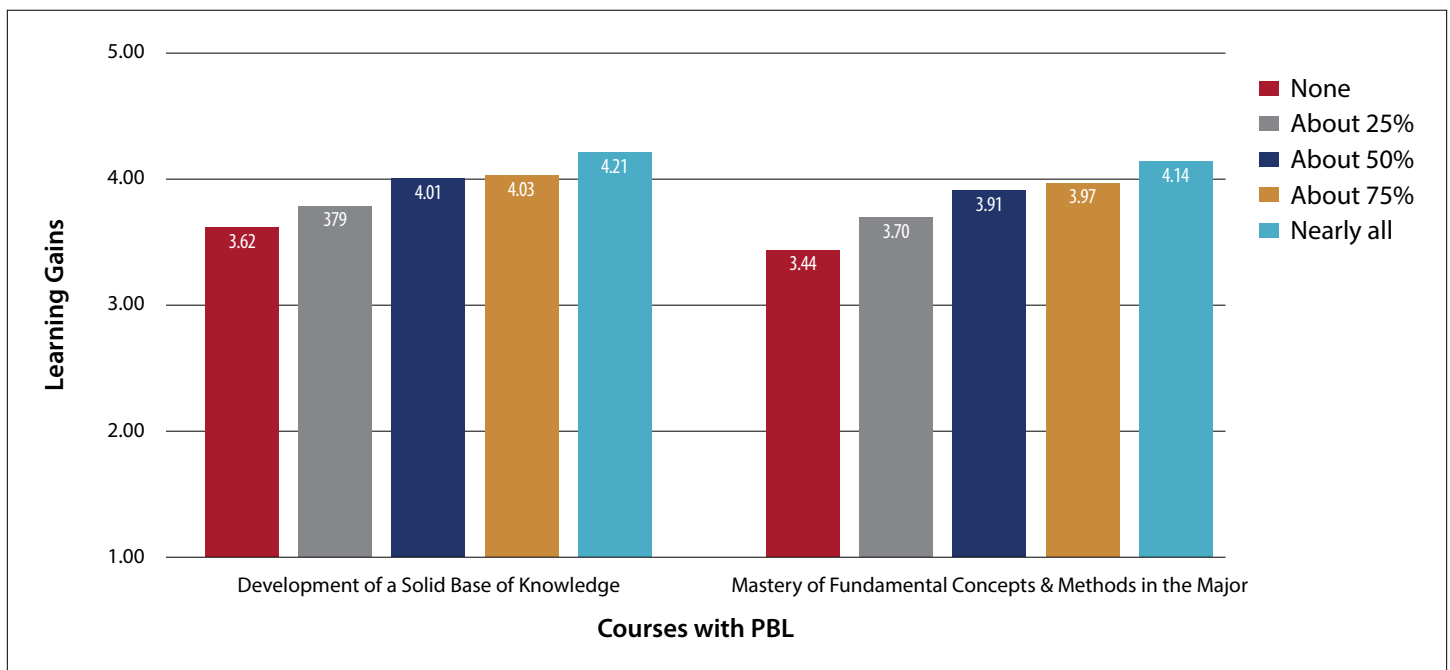
African. Within the sample, 62% were engineering majors, 35% were science majors, and 3% majored in other subjects, such as business or social sciences, without also earning a science or engineering degree. These characteristics reveal a sample that is largely representative of alumni demographics within these years. (Women students are slightly overrepresented and non-binary and gender fluid students are underrepresented).

Developing Technical Knowledge and Skills

Much of the scholarly discussion of PBL centers around the ways it can support professional skills development; however, there are also benefits for developing technical knowledge and skills. One way analyses of variance revealed that there was a statistically significant difference between at least two groups in development of a solid base of knowledge, with $F(4,1928) = 10.35, p < .001$, and in mastery of fundamental concepts and methods in the major, with $F(4,1928) = 10.47, p < .001$.

As with professional skills, a small dose of course-based PBL did not impact gains in technical skills. There were no significant differences between those with projects in none of their courses and those with projects in about 25% of their courses for either measure of technical skills (see Figure 4).

Figure 4. Dosage Effects of Projects in Courses on Technical Knowledge & Skills Development



With a moderate dose of projects in about half of a student's courses, there are significant increases in developing technical knowledge and skills (see Figure 4). Dunnett T3 test for multiple comparisons found that the mean of development of a solid base of knowledge was significantly greater for those with projects in about 50 percent of their courses than for those with projects in about 25 percent of their courses ($p = .002$, 95% C.I. = .06, .38). For mastery of fundamental concepts and methods in your major, Dunnett T3 test for multiple comparisons also found that the mean was significantly greater for those with projects in about 50 percent of their courses than for those with projects in about 25 percent of their courses ($p = .009$, 95% C.I. = .03, .39).

Once again, there were further significant gains for those who had projects included in nearly all of their courses (see Figure 4). The Dunnett T3 test indicated that the difference in development of a solid base of knowledge was on the cusp of significantly different between those with projects in about 50 percent of their courses and in nearly all courses, with $p = .05$ (95% C.I. = .00, .41). For mastery of fundamental concepts and methods, the difference between these two groups is statistically significant ($p = .02$, 95% C.I. = .02, .45). The size of the effect of the extent to which projects are included in courses is small for both types of technical skills development ($\eta^2 = .02$ for each).

Discussion And Future Research

The scale of PBL at WPI provides the opportunity to assess whether this student-centered pedagogy has a greater impact when students experience more of it than a single course. We found that there is indeed a dosage effect in which minimal, scattered contact with projects does not necessarily translate into skills development; more consistent experience with projects did. This may provide context for understanding why some studies have found that a single isolated experience of PBL does not positively impact learning in alignment with theory.

The study also found that there is a diminishing return on scaling projects. In other words, it is not the case that more is always better – after students experienced a moderate amount of projects (in about half their courses), some skills did not further develop more strongly with additional project work. This deserves further attention in future studies of PBL at scale at other institutions. There may be important implications for building community among faculty who hold a mix of perspectives regarding student-centered, active learning strategies.

The WPI Alumni Study

WPI conducted an alumni survey of its signature PBL offerings in 2021. A survey with closed and open-response items was

emailed to 15,528 alumni who graduated from WPI between 1980 and 2019. Data were collected through Qualtrics. One reminder was sent one week after the original invitation to participate to alumni who had not yet submitted a response.

Of those invited, 2,236 alumni responded. In the analyses presented here includes 61% men, 39% women, and less than one percent non-binary or gender fluid alumni. The majority of respondents were white (89%), 6% identified as Asian, 4% identified as Hispanic/Latino (any race), 1% identified as Black/African American or African, and 1% identified as Middle Eastern or North African. Within the sample, 62% were engineering majors, 35% science majors, and 3% majored in other subjects, such as business or social sciences, without also earning a science or engineering degree. These characteristics reveal a sample that is largely representative of alumni demographics within these years. (Women students are slightly overrepresented and non-binary and gender fluid students are underrepresented).

Notes

¹Zhang, L., & Ma, Y. (2023). A study of the impact of project-based learning on student learning effects: A meta-analysis study. *Frontiers in psychology*, 14, 1202728; Wijnia, L., Noordzij, G., Arends, L. R., Rikers, R. M., & Loyens, S. M. (2024). The effects of problem-based, project-based, and case-based learning on students' motivation: A meta-analysis. *Educational Psychology Review*, 36(1), 29; Chen, C. H., & Yang, Y. C. (2019). Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators. *Educational Research Review*, 26, 71-81.

²Hung, 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*, 24, 943-957.



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