PBL BRIEF #9.0 SERIES
WPI ALUMNI SURVEY FINDINGS

9.7 Developing Ethics Through Project-Based Learning

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Briefer Brief

- Ethics is most often taught through professional codes of conduct and case studies within the context of specific disciplines and courses, yet there is little empirical evidence for which means of teaching ethics are effective.
- The majority of alumni of Worcester Polytechnic Institute's undergraduate STEM education attribute moderate to great influence on their ethical responsibility to their formal project work.
- Understanding of ethical responsibility was influenced by each of the three projects required for graduation, the optional project-based first-year seminar, and the percentage of courses a student took that included projects; surprisingly, courses in the major did not have a significant impact on ethical development.
- Findings point to interdisciplinary teamwork, community-based learning, and study away as aspects of PBL that can positively influence understanding of ethical responsibility.

Introduction

Undergraduate STEM education has long struggled with how to build ethics into the curriculum. Changes to ABET accreditation criteria for undergraduate engineering degree programs published in 1998 motivated a swelling of support for ethics requirements and curricula among colleges and universities in the following decade.[1] An ethics across the curriculum movement, while successful at a few exceptional universities (e.g., Utah Valley University[2]),[3] has largely met substantial challenges to systemic implementation.[4] Consequently, ethics is most often given uneven attention in stand-alone lessons highlighting professional codes of conduct and using case studies within the context of specific disciplines and courses.[5]

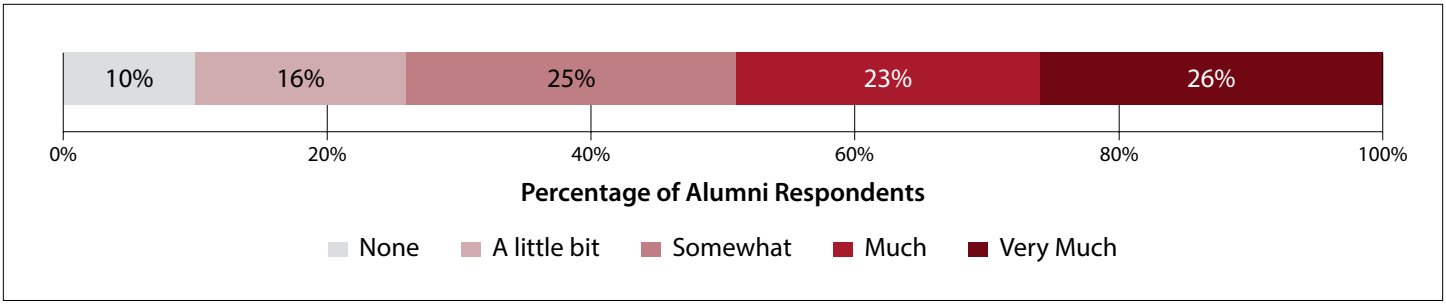
Yet there remains no consensus on the most effective means of teaching ethics to students[6] as there is little empirical evidence examining the impact of pedagogical approaches on students' ethical development.[7] We have found that project-based learning (PBL) offers a potential avenue for teaching students about ethics without the need to silo ethics off into a single course or a lesson that is detached from "doing STEM." PBL, particularly when done in teams and in community-engaged projects, offers opportunities for students to develop what Gilligan[8] calls an "ethics of care."[9]

This research describes emerging evidence from an alumni study of Worcester Polytechnic Institute's project-based education that suggests that PBL can be effective for developing students' ethics. The first section describes analyses that demonstrate the impact of WPI's PBL curriculum on students' development of ethics understanding. The brief then explores evidence of three aspects of the PBL students experienced at WPI that appear to support ethics development. The final section describes how we conducted the study and offers directions for future research.

Ethics as an Outcome of PBL

For over 50 years, Worcester Polytechnic Institute (WPI) has relied on PBL to develop an array of knowledge, skills, and mindsets among its STEM students. One of the undergraduate learning objectives, aligned with accrediting bodies' criteria, is to develop a sense of ethical responsibility. A recent alumni survey conducted in 2021 found that the majority of responding alumni attributed moderate to great gains in their understanding of ethical responsibilities to their formal project work while at WPI (see Figure 1).

Figure 1. Growth in Understanding of Ethical Responsibilities Attributed to Project Work



Further examination allows us to assess which project experiences contributed to developing this sense of ethical responsibility. We used hierarchical multiple linear regression to model the effects of student demographics, response bias, courses in the major, and PBL experiences. Student demographics and a measure of response bias all had significant effects on alumni's reported growth in understanding of ethical responsibilities (see Table 1); this suggests that controlling for their influence while modeling educational experiences is necessary. All experiences of PBL had significant positive effects on ethics development. Among these, the third-year technology and society project and the percentage of courses that used PBL had the greatest influence on ethics development (see Table 1).

Table 1. Hierarchical Multiple Linear Regression Model of Influences on Ethics Development From Project Work

	Model 1: Student Demographics					Model 2: Major Courses					Model 3: Project Experience				
Effect	β	SE	95% CI		p	β	SE	95% CI		p	β	SE	95% CI		p
			LL	UL				LL	UL				LL	UL	
Intercept	2.11	.20	1.73	2.50	<.001	1.53	.27	.99	2.06	<.001	-.88	.34	-1.55	-.21	.01
Woman	.14	.06	.20	.44	<.001	.15	.06	.21	.44	<.001	.11	.06	.13	.36	<.001
BIPOC	.10	.08	.13	.46	<.001	.10	.08	.13	.46	<.001	.08	.08	.09	.41	<.01
Major	.06	.05	.19	.23	.02	.07	.05	.03	.24	.02	.06	.05	.01	.21	.03
Career Satisfaction	.18	.04	.99	.36	<.001	.16	.04	.17	.33	<.001	.14	.04	.14	.30	<.001
Courses in Major						.09	.06	.07	.31	<.01	.03	.06	-.04	.19	.21
Humanities & Arts Project											.06	.05	.01	.20	.03
Society & Tech Project											.26	.05	.42	.63	<.001
Capstone											.09	.06	.08	.31	<.001
R^2	.06					.07					.09				
Δ R^2	.06					.07					.16				
F for Δ R^2	21.09					9.68					47.30				
p	<.001					<.01					<.001				

Note. Dependent Variable: Gains in Ethics as measured by the survey items, "Indicate the extent to which your WPI formal project experience expanded your understanding of ethical responsibilities" and "…expanded your awareness of how your decisions affect and are affected by others." Response options were on a five-point scale with "not at all," "a little bit," "moderately," "much," and "very much."

BIPOC = Black, Indigenous, People of Color; includes any individual who indicated a race or ethnicity other than White and Asian.

Significance set at $p \leq .05$.

Developing Ethics During Teamwork

The alumni study also allowed us to understand some of the factors that shape students' development of ethics through projects. The first of these is teamwork. All students at WPI engage in interdisciplinary teams during their third year, as well as potentially during an optional first-year seminar. Alumni who reported that their experiences were positive while working as part of interdisciplinary teams reported significantly greater development of their understanding of ethical responsibilities than those who had negative team experiences (see Table 2). Those with positive team experiences also indicated stronger growth in their awareness of how their decisions affect and are affected by others. In terms of size, the effect sizes are moderate and similar to the size of the effects of meta-cognitive strategies and feedback on student learning.

Interdisciplinary teamwork during project-based learning offers students the opportunity to practice being in relation to others. From the perspective of ethical responsibility, people are morally responsible for actions that they do or do not take. In order to build accountability for ethical responsibility, people need to be aware of their place and role in relation to the world we inhabit. Teamwork in project-based learning can be an ideal place to develop this ethical awareness as students build and navigate *relationships* with their teammates. Being aware that we are connected to each other (in teamwork, in a workplace, in a neighborhood) is crucial to building a *relational mindset*, a concept that has been receiving an increasing amount of attention in the study of professional ethics.[10]

Table 2. Differences in Development of Ethical Understanding by Alumni With Positive and Negative Experiences of Interdisciplinary Teamwork

	Interdisciplinary Teamwork						
	Negative Experience		Positive Experience				
Learning Outcome	M	SD	M	SD	*t*	*p*	*Cohen's d*
Understanding of ethical responsibilities	3.01	1.23	3.68	1.21	-9.61	<.001	-.55
Awareness of how your decisions affect and are affected by others	3.08	1.10	3.84	1.07	-12.45	<.001	-.70

Note: n = 1,145; statistical significance set at $p < .05$

Interdisciplinary teamwork often tackles urgent ethical issues, sometimes called 'wicked problems,'[11] that reflect the complexities of social, technological, and environmental systems. The urgency and complexity of these issues provide a rich ground for exploring the range and nuance of ethical choices. Every attempt to tackle a wicked problem is different from others as the internal composition of the same problem might be understood differently from one team to the next. Students thus need to navigate different knowledge systems to tackle the lack of clarity presented by wicked problems and avoid shortsighted or reductionist responses to a complex problem. As students take various perspectives on a wicked problem, they are taught how to apply a relational mindset to working with teammates, consider that problem's implications for various stakeholders, and see relationships as being a core part of problem-solving.

Developing Ethics Through Community-Based Learning

The survey also asked alumni the extent to which they learned about working with members of the local community during their third-year society and technology project. These projects are sponsored by community-based organizations, government agencies, industry partners, and other members of either the university's local community or the community of one of our 50 global project centers. During the course of the project, students are charged with determining community needs, in addition to the sponsor's stated objectives, as well as with considering unintended consequences on various groups within the community. Those who reported a positive experience learning about working with the community indicated significantly greater development of

understanding of ethical responsibilities than those who reported a negative experience learning about working with the community (see Table 3). Those with positive experiences also indicated stronger growth in their awareness of how their decisions affect and are affected by others. Again, the effect sizes are moderate.

Table 3. Differences in Development of Ethical Understanding by Alumni With Positive and Negative Experiences of Learning to Work With the Community

	Learning to Work With the Community						
	Negative Experience		Positive Experience				
Learning Outcome	M	SD	M	SD	*t*	*p*	*Cohen's d*
Understanding of ethical responsibilities	3.16	1.24	3.96	1.09	-11.54	<.001	-.70
Awareness of how your decisions affect and are affected by others	3.32	1.11	4.08	.96	-12.30	<.001	-.73

Note: n = 1,145; statistical significance set at $p < .05$

Community engagement creates spaces for a dialogue that involves stakeholders who are not always well-represented in course-based curricula. Community-engaged learning introduces students to diverse ways of thinking about the topics that are at the center of their academic studies. Students are thus encouraged to ask 'why' they do the work they are trained to do within their discipline: Why is research and scholarship valuable to the larger world beyond the classroom or research lab? Community-engaged PBL helps students think about the deeper meanings of their education that go beyond professional advancement.

Learning to work with a community to carry out a project can also reduce students' habits of techno-solutionism. As part of their personal, intellectual, and professional maturation, students often enter college with the instinct to reduce complex issues to problems that can be fixed by technical interventions. This is known as techno-solutionism[12], which silences social actors and their ethical concerns at the expense of technical solutions. In community-engaged PBL, students learn about local communities' interests, needs, aspirations, and visions—which are often not well-represented in mainstream educational frameworks. In doing so, they develop an ethical vision of science and engineering that prioritizes humans over technology.

Developing Ethics through Working in Diverse Environments

Finally, two survey items allowed us to examine the impact of traveling off campus and working in a diverse environment on the development of ethics. The first item asked alumni the extent to which working in a diverse environment while at WPI had a negative or positive impact on them. As with the previous mechanisms assessed, those who indicated they had a positive experience working in diverse environments also reported significantly higher ethical development on both indicators than those who had negative experiences as a result of working in diverse environments (see Table 4). The effect sizes of these relationships are moderate and comparable to the impact of high school achievement on success at university.

The second item describing the development of ethics in PBL at WPI was whether or not the alumni had traveled off campus to complete any of their required projects at one of the university's 50 global project centers. Alumni who had traveled off campus to complete at least one of their projects reported significantly greater growth in their understanding of ethical responsibilities and in their awareness of how their decisions affect and are affected by others compared to alumni who did not complete any of their projects off campus (see Table 5). The effect sizes of these relationships are a bit smaller in size than all of the others examined, more similar to the relationship between achievement in high school and career performance.

Table 4. Differences in Development of Ethical Understanding by Alumni With Positive and Negative Experiences of Working in a Diverse Environment

	Working in a Diverse Environment						
	Negative Experience		Positive Experience				
Learning Outcome	M	SD	M	SD	*t*	*p*	*Cohen's d*
Understanding of ethical responsibilities	3.06	1.20	3.24	1.09	-10.38	<.001	.58
Awareness of how your decisions affect and are affected by others	3.75	1.19	3.91	1.04	-11.49	<.001	.63

Note: n = 1,145; statistical significance set at p < .05

Table 5. Differences in Development of Ethical Understanding by Alumni Who Did and Did Not Travel Off Campus for PBL

	Did Not Travel		Traveled				
	Off Campus		Off Campus				
Learning Outcome	M	SD	M	SD	*t*	*p*	*Cohen's d*
Understanding of ethical responsibilities	3.04	1.34	3.57	1.24	-8.04	<.001	-.42
Awareness of how your decisions affect and are affected by others	3.24	1.22	3.69	1.14	-7.65	<.001	-.39

Note: n = 1,842; statistical significance set at p < .05

Global research experiences help students cultivate ethical responsibility in two major ways: *learning to listen* and *learning to be uncomfortable*. Listening—unlike hearing—requires attention. When students travel, they encounter peoples and cultures they are not familiar with. Students are encouraged to enter these encounters with curiosity. Without a curious mindset, cultural and social differences would be flattened. Students would experience diversity, but not be able to recognize the value of seeing themselves through the lens of difference.

Experiencing diversity is like hearing a multitude of sounds at a carnival: a joyful experience, yet often difficult to separate one sound from another. Listening is attending to a particular voice against this background. In a project-based learning framework, this is particularly important when students engage with the communities whose voices are not always present in mainstream conversations. In establishing relationships with these communities, it becomes an ethical responsibility to listen to those voices. In many higher education institutions, diversity is considered a value. If the appreciation of diversity is not combined with *the ethical responsibility to listen to others*, communities—especially under-resourced and marginalized ones—would be considered passive tokens of diversity.[13] However, with ethical listening, these communities are seen as valuable for their own cultures and histories.

Successful global learning experiences connect *ethical listening to an ethic of discomfort*.[14] Many global projects take place in communities in the Global South that were once colonies of Western powers. Some of these locations have histories connected to Euro-American enslavement or imperialism in previous centuries. Students sometimes work with indigenous communities, for example, in New Mexico, Hawaii, Australia, or New Zealand, all of which have been deeply impacted by settler-colonialism linked to Euro-American identity. In global research projects, students learn about complex histories that involve power and violence. Students are expected to understand local communities' visions and aspirations while amplifying these communities' voices. Sometimes local communities ask students to change their research directions. Sometimes local communities put limits on how the research will be conducted. Students then need to move outside their comfort zones and question their beliefs and assumptions regarding their cherished ways of

thinking about the world. Global learning experiences are designed to encourage reflection on such situations of discomfort, and connect such reflections to self-transformation.

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, yielding a low—but typical—response rate of 14%.

The sample included in the analyses presented here includes 61% men, 39% women, and less than 1% nonbinary 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 nonbinary and gender-fluid students are underrepresented).

Conclusions & Future Research

We find evidence that projects can be powerful experiences of authentic ethics with real-world consequences, building ethical mindsets and habits over time. Our initial analyses also provide some empirical support for specific types of PBL experiences that might be particularly well-suited to conveying ethics education, namely projects that involve teamwork, engage the community, and require students to operate within new cultural environments. However, we are limited by the data, which come from an alumni study not designed to capture the nuances of ethics education. Future research on the potential value of PBL for ethics education would need to be designed to capture more nuanced data to provide conclusive evidence of the mechanisms that are at work.

Making PBL a site for ethics education might allow future research to explore how pedagogies serve specific functions of higher education. Martin, Conlon, and Bowe (2021) argue that a multilevel analysis of ethics education is needed to escape the disconnect often found in higher education research that focuses exclusively either on individual actors or on policies. Their review assesses teaching practices of instructors, institution-wide implementation of ethics programming, the influence of accreditation policies, and the broader culture of engineering education as mutually reinforcing forces; bringing these four levels of social reality together shifts their recommendations to engineering education for ethics, rather than fitting ethics into engineering education in a technocratic way. If this is the goal of future research and practice, then PBL might serve as a fruitful site for further exploration.

Notes

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