Gender Differences in the Long-Term Impacts of Project-Based Learning

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Abstract

An externally-conducted alumni survey investigated long-term impacts of project-based learning (PBL) by studying 38 years of engineering graduates from Worcester Polytechnic Institute, a technology-focused university featuring a project-based curriculum. Web-based, asynchronous interaction with a stratified sample of alumni informed survey development. A Likert scale survey explored 39 areas of professional and personal impact of PBL experiences. Impact areas included professional skills, world views, and personal impacts. For each of 39 impact areas of PBL that the survey explored, a higher percentage of females reported "much" or "very much" positive impact when compared to males. Mann-Whitney *U* tests revealed that the differences in distributions were statistically significant for 34 of the 39 impacts ($p<.015$). This paper presents and discusses detailed findings regarding gender differences in long-term impacts of PBL on engineering majors. The discussion is informed by findings from post-survey interviews with male and female alumni.

Introduction

Forty years ago, Worcester Polytechnic Institute (WPI), a private, technologically-focused university, adopted an approach to undergraduate education emphasizing project-based learning (PBL) wherein students address real world challenges under faculty guidance. These project experiences are central to the WPI curriculum, are required for graduation, and have been systematically assessed both for program improvement and for documentation and achievement of learning outcomes. However, no formal studies have explored the long-term impacts of PBL experiences on WPI alumni, nor are other such studies apparent in the literature.

PBL is emerging as an increasingly common strategy in technological education, and the engineering education community could benefit from understanding how PBL prepares graduates for work and life. To gain insight into the long-term impacts of PBL on alumni, and to inform future iterations of its program, WPI contracted with an external evaluator to conduct an evaluation. The study, which began in July 2011 and will conclude in the summer of 2013, uses a mixed-model approach that incorporates the following data collection methods:

- A web-based asynchronous ideation exercise to generate survey questions
- A web-based alumni survey
- Individual interviews with a sample of alumni
- Individual interviews with representatives from employers of large numbers of WPI undergraduates

The study is addressing the following questions:

- What are the perceptions of WPI undergraduate alumni regarding the extent to which their formal project work as WPI students impacted them after having completed their studies?
- Both absolutely and relative to graduates from other institutions, what are the perceptions of employers—objective third parties—of WPI graduates (of the undergraduate program) regarding project-work-related professional skills and personal attributes?

Specifically, alumni were asked for their perceptions regarding the following:

- Professional behavior
- Ability to collaborate effectively
- Critical thinking skills
- Creative and interdisciplinary problem solving skills
- Communication abilities
- Leadership skills
- World views
- Personal attributes

When the segment of the study focusing on employers begins, they will be asked about the same issues.

This paper discusses findings from the alumni survey and preliminary findings from the alumni interview portion of the study. This study was designed as an evaluation, a process involving empirical investigation using methods and approaches from the social sciences to determine merit, worth, or value.[1] This was not designed as a research study and no hypothesis testing was planned. However, an informal review of survey results revealed that project work may have led to differences in perceived impacts for female respondents than for males, so those potential differences were explored through comparative analyses. The results of those subsequent analyses are reported herein.

Background

Project-based learning (PBL), an educational method involving application of knowledge toward solving an open-ended problem, has become increasingly common in engineering education worldwide, both in recognition of the benefits of active learning and in response to demands from employers and accrediting bodies.[2,3] PBL can be employed across the curriculum and at different stages of a student's education, and, given its social and contextual nature, may hold particular appeal for female engineering students. Busch-Vishniak and Jarosz[4] concluded from a survey of the literature that women are more motivated by social context and collaboration, and have suggested that more application and integration of context in the engineering curriculum could help attract and retain women.

A few studies have investigated the effect of gender on PBL, concluding that gender affects how students approach project work. Kilgore et al. describe the tendency of women toward context-orientation in engineering design tasks, and note that women learners tend to scope engineering

problems more broadly than men.[5] Kassab et al. describe higher levels of performance for teams led by female peers than those led by males.[6] This paper extends those findings with insight into how the long-term impacts of PBL differ by gender.

PBL at WPI: Since the early 1970s, all undergraduates at WPI have completed two significant open-ended projects comprising a total of at least eighteen credit hours: nine credit hours addressing an interdisciplinary problem (the Interactive Qualifying Project or IQP), and nine credit hours addressing a problem in the major field (the Major Qualifying Project or MQP). These project experiences do not take the form of courses, but rather are organized as independent inquiry, typically conducted in small student teams under faculty guidance in response to a problem posed by an external sponsor. The learning outcomes for these projects include problem identification and solution, research skills, application of knowledge in context, communication, and effective teamwork. All WPI faculty are expected to advise projects as part of their teaching responsibilities.

The projects can be completed either on the WPI campus or off campus at one of a network of Project Centers located around the globe. Projects completed on campus are usually conducted part time across the academic year, whereas off-campus projects are conducted in a full-time immersion, preceded by required academic preparation on campus. Thus, the on-campus and off-campus experiences are quite different. Admission to off-campus programs is based on an application process, but over 90% of applicants are offered an off-campus project, so the program is not highly selective. As is typical for technology-focused universities, the majority of alumni have been male, but in recent years females have constituted about 30% of undergraduates. Female students have consistently participated in off-campus projects at higher rates than male students.

Method

Instrument: Findings from a pre-survey online asynchronous ideation exercise with a sample of alumni stratified for year of graduation, sex, and major revealed that the formal project work that WPI alumni participated in was a significant and important aspect of their undergraduate experience that had far-reaching implications and impact beyond time spent at WPI. Alumni reported that as a result of their formal project work at WPI, they:

- Received excellent professional preparation
- Developed habits of thoughtfulness and broadness of mind
- Developed a stronger personal character
- Had opportunities expanded
- Enjoyed travel
- Experienced personal enrichment
- Developed insights regarding business and industry
- Felt connected with a community
- Had “real world” experiences

These findings were used to inform the development of the web-based alumni survey. While the ideation prompts were phrased neutrally, grounded in the core question of "Which aspects of your time as an undergraduate at WPI most deeply affected you?" the findings from the ideation exercise indicated that the project experience was positive for almost all alumni who had completed project work. Thus, the survey was designed to evaluate only positive impacts, based on the prior knowledge that project work had largely positive impacts on alumni.

The ultimate goal of the survey was to gather information on the impact that formal project work at WPI had on alumni after they had completed their undergraduate studies at WPI. In an effort not to bias alumni, however, this precise intention was not articulated to potential respondents; they were instead informed of a broader intention of the survey: to get a better understanding of the experiences they had as undergraduates.

The core of the survey consisted of 50 Likert scale items. The first 11 core items asked alumni to indicate the extent to which each of the following aspects of their time as undergraduates had affected them after they had completed their undergraduate studies at WPI:

- Length of the academic terms
- Greek life
- Sports/athletics participation (any level)
- Other WPI clubs/organizations
- Humanities and arts courses
- Courses in their majors
- Interactive Qualifying Project
- Major Qualifying Project
- Peers at WPI /fellow WPI students
- Relationships with professors
- Travel (WPI-related)

These items relied on a seven-point Likert scale, with response options ranging from "Negatively, Much" to "Not At All" to "Positively, Much," with an additional eighth response option of "Not Applicable."

The remaining 39 core items asked alumni to indicate the extent to which their formal project experience at WPI had impacted their abilities, perceptions, understanding, or development regarding areas relevant to their professional lives, their world views, or their personal lives. Of these 39 items, 24 targeted impact on professional impact and advancement, six targeted impact on world views, and nine targeted impact on personal lives. These items relied on a five-point Likert scale with response options ranging from "Not At All" to "Very Much," with an additional sixth response option of "Not Applicable." Exact phrasing of items can be found in the appendix.

Additionally, the survey contained several items designed to gather the following demographic information from respondents: major, year of graduation, sex, current primary place of residence, type of project work completed at WPI, whether project work was completed on or off campus.

(The number of items varied, depending on the number of projects that had been completed.) Another item asked respondents to self-identify if they would like to be contacted by the external evaluator in the future regarding the possibility of participating in a follow-up interview.

The survey was developed by the external evaluator solely for the purpose of this study. Time and budget constraints precluded statistical determinations of either validity or reliability. The external evaluator used the following to inform development of the survey:

- Findings of the ideation exercise
- Input from WPI stakeholders based on findings from the ideation exercise
- WPI Undergraduate Learning Outcomes
- Items from two instruments that WPI uses in its institutional assessment efforts—the National Survey of Student Engagement (NSSE) and the Engineering Exit Assessment from Educational Benchmarking, Inc. (EBI)
- Feedback from a pilot test of the survey with 16 volunteer students who had been in their senior years at WPI at the time of the pilot

Because a wide variety of relevant sources impacted survey development, the external evaluator and WPI stakeholders believed the final version of the survey had a high degree of face validity. The evaluator applied for approval from WPI's Institutional Review Board (IRB) to conduct the survey and an exemption was granted.

Recruitment: Upon request, WPI furnished the external evaluator with a database of graduates from years 1974 through 2011; since the class of 1974 was the first to graduate after project work became part of the curriculum, this was the earliest year included in this study. Of the 21,498 living alumni in the database of graduates from years 1974 through 2011, there were 20,023 who met the following criteria for inclusion into the selection pool:

- Completed at least one formal project at WPI
- Granted "permission to contact" to the WPI Office of Alumni Relations
- Furnished the Office of Alumni Relations with either a ground address or an e-mail address

Not all alumni were accessible via both e-mail and ground mail, however. Given the possibility that differences in the type of contact information that alumni furnish to WPI are indicative of differences in attitudes towards WPI or experience while attending WPI, a stratified random sample was selected according to avenues of accessibility.

The number of alumni recruited for each strata was determined through consideration of the following: desired confidence level (95%) and confidence interval ($\pm$3%), anticipated response rate (approximately 20%), and recruitment costs. Because no individually-based recruitment costs were associated with e-mail recruitment, a population sample was selected for those for whom only e-mail addresses were available. Because the recruitment approach for each of the strata for which ground addresses were available involved individually-based recruitment costs, a randomly selected sample was chosen from each of these strata. After recruitment efforts began, bounced-back e-mail messages and returned hard copy letters indicated that some of the contact

information in the database was no longer valid. Table 1 conveys the stratification of the sample pool, along with the numbers of valid records for each strata.

Table 1. Stratification of Sample Pool

Type of available contact information	Participants		
	Number in original database	**Number attempted to recruit**	**Number with valid contact info**
Ground mail only	7033	4696	4624
e-mail only*	716	716	516
Ground mail AND e-mail	12274	4947	4932 ^
Total	**20023**	**10359**	**10072**

*This group included alumni who were living outside of the U.S. at the time of the survey. Treating non-U.S.-resident alumni as those who were only accessible via e-mail made recruitment of alumni from this group logistically manageable.

^Of this figure, ultimately ground mail addresses were valid for 4,888 and e-mail addresses were valid for 3,916; there were only 15 alumni in this group for whom both the ground address and the e-mail address ultimately were invalid.

To increase response rates, a multi-phased recruitment effort was used for this survey. All randomly selected alumni received each of the following: a pre-recruitment message sent from individuals from WPI that the external evaluator believed would positively influence the likelihood of alumni to participate, a recruitment message sent from the external evaluator, and at least one reminder.

For alumni who graduated prior to 2000, a pre-recruitment message was sent out from a dean emeritus. For alumni who graduated in 2000 or later, a pre-recruitment message was sent out jointly from two current deans. For alumni with ground addresses but no e-mail addresses, hard copy letters were mailed on May 2, 2012. For alumni with e-mail addresses, e-mail messages were sent on May 9, 2012, by the external evaluator on behalf of the relevant dean or deans. These messages 1) informed alumni that WPI had commissioned a survey of WPI graduates, 2) explained that the purpose of the survey was to develop an understanding of how the undergraduate education and overall experiences of WPI undergraduates impacted their lives and careers, 3) indicated that the external evaluator would be contacting them shortly with details about the survey, and 4) appealed to alumni to complete the survey. These pre-recruitment messages did not include any information about how to access they survey nor did they include any information regarding incentives for taking the survey.

To further encourage responses, the external evaluator offered incentives to alumni to take the survey. A $1 pre-paid cash incentive was sent with hard copy recruitment letters on May 14, 2012, to all randomly selected alumni with ground mail addresses. Along with an e-mail recruitment message that was sent on May 18, 2012, entry in a cash raffle (for one of four cash

prizes: US $250, US $100, US $100, US $50) was offered to all alumni with e-mail addresses. Those with both ground and e-mail addresses received the pre-paid cash incentive plus the offer of entry into the cash raffle.

Pre-paid cash incentives were used with those with ground addresses because research has shown that a recruitment letter mailed with a small cash incentive significantly increases participation in an online survey.[7] Researchers have suggested that a small cash payment increases participation rates because it invokes the norm of reciprocity, a strong social normative standard leading individuals to strive to repay favors freely given.[8,9]

The external evaluator sent three e-mail reminders to all alumni who had e-mail addresses and one hard copy reminder to those alumni who had only ground mail addresses. All reminders (whether sent via e-mail or ground mail) included information on the cash raffle incentive.

Participants: Informed consent was obtained from all respondents. After the survey closed, the data file was reviewed for duplicate records. Three alumni had completed the survey twice. (This was determined by noting duplicated names or e-mail addresses that had been provided regarding either the raffle or interview.) For these alumni, the first survey that each completed was retained and the second was removed.

In all, 2,532 alumni completed the survey. Table 2 shows the response rates for each sample strata and the sample as a whole. Of the 2,532 participants, six indicated that they had not completed either an IQP or an MQP, so they were excluded from analyses, yielding a data set of valid records from 2,526 WPI alumni. As a whole, this sample of 2,526 has a confidence interval of $\pm$1.8% at a confidence level of 95%.

Of this sample of 2,526 alumni, 1,792 (71%) were engineering majors. Of this subset of 1,792 engineering majors, 1,763 identified their sex and indicated that they had completed both Project One and Project Two. Of these 1,763 engineering majors who had completed both projects and identified their sex, 1,382 (78%) were male and 381 (22%) were female.

Analyses: The analyses reported herein include only those alumni who were engineering majors, had completed both an IQP and an MQP, and had identified their sex.

For each of the 50 core survey items, frequencies for each response option were obtained and converted to percentages (number of responses/number of all responses for that item). In addition, for the 11 core items that asked alumni to indicate the extent to which various aspects of their time as undergraduates had affected them after they had completed their undergraduate studies at WPI, percentages were collapsed across the response options of "Positively, Somewhat," "Positively, Moderately," and "Positively, Much." Also, for the 39 core items that asked alumni to indicate the extent to which their formal project experience at WPI had impacted their abilities, perceptions, understanding, or development regarding areas relevant to their professional lives, their world views, or their personal lives, percentages were collapsed across the response options of "Much" and "Very Much."

To determine whether or not differences in perceived impact of project work between males and females were statistically significant, Mann-Whitney *U* tests were conducted. (Mann-Whitney *U* tests were conducted instead of *t*-tests because the survey data were ordinal in nature and the number of males differed from the number of females.)

Table 2. Survey Participants, Stratified According to Avenue of Contact

	Participants				
Avenue of contact	**Number in original database**	**Number attempted to recruit**	**Number with valid contact info**	**Number of responses**	**Response rate (# of responses/ # valid)**
Ground mail only	7033	4696	4624	595	13%
e-mail only*	716	716	516	118	23%
Ground mail AND e-mail	12274	4947	4932 ^	1819	37%
Total	**20023**	**10359**	**10072**	**2532**	**25%**

*This group included alumni who were living outside of the U.S. at the time of the survey. Treating non-U.S.-resident alumni as those who were only accessible via e-mail made recruitment of alumni from this group logistically manageable.

^Of this figure, ultimately ground mail addresses were valid for 4,888 and e-mail addresses were valid for 3,916; there were only 15 alumni in this group for whom both the ground address and the e-mail address ultimately were invalid.

Mann-Whitney *U* tests were conducted for the 39 core items that asked alumni to indicate the extent to which their formal project experience at WPI had impacted their abilities, perceptions, understanding, or development regarding areas relevant to either their professional lives, their world views, or their personal lives.

Results

Of the 11 different aspects of undergraduate experience that were asked about with regard to long-term impact, responses indicated that almost all alumni believed that the IQP and MQP had positively impacted them after having completed their undergraduate studies. Of the respondents in these analyses, 90% indicated that after having completed their undergraduate work at WPI, the IQP had affected them positively either "somewhat," "moderately," or "much," and 96% indicated that the MQP had affected them positively either "somewhat," "moderately," or "much." Collapsing responses across both projects revealed that 98% of respondents believed that either the IQP, the MQP, or both had affected them positively either "somewhat," "moderately," or "much" after having completed their undergraduate work at WPI.

For each of the 39 impact areas of PBL that the survey explored, a higher percentage of females reported "much" or "very much" positive impact when compared to males. Mann-Whitney *U* tests revealed that the distributions of female responses were statistically significantly different than those of male responses for 34 of the 39 areas of impact that the survey investigated ($p \leq .015$ for all comparisons). While the Mann-Whitney *U* test compares the distributions of *all* of the data from two independent groups, for ease of interpretation by the reader, each of the tables that follows presents the percentages of alumni who responded either "much" or "very much." (Note that the *n*s provided in each cell refer to the number of individuals in the group the cell refers to who were included in the analysis and not to the number who responded either "much" or "very much.") Items in each table are presented in descending order by magnitude of the difference between males and females with regard to the percentages who responded either "much" or "very much." When differences between male and females distributions were statistically significant, the percentages responding "much" or "very much" and the *p*-values are bolded. Also to aid in interpretation, the percentage of all engineering majors (regardless of sex) who responded either "much" or "very much" is also provided.

World Views: Of the three main areas of impact that the survey explored—personal, professional, and world views—gender differences in perceptions of impact of project work were most pronounced in the area of world views. Table 3 reveals that of the six survey items that addressed impact of PBL on world views, statistically significant gender differences were found for all of them. For all six world-view-relevant areas of impact, the percentage of females reporting either "much" of "very much" impact exceeded the percentage of males reporting the same between 12 and 20 percentage points.

Table 3. Gender Differences in Impact of Project-Based Learning on World Views

Area of Impact	**% Responding "Much" or "Very Much"**			***p***
	Engineering Majors	**Males**	**Females**	
Ability to understand people of other cultures	33 (*n* = 1376)	**29** (*n* = 1082)	**49** (*n* = 294)	**<.001**
Respect for cultures outside of own	30 (*n* = 1443)	**26** (*n* = 1138)	**46** (*n* = 305)	**<.001**
Ability to understand people of other racial and ethnic backgrounds	31 (*n* = 1391)	**27** (*n* = 1090)	**45** (*n* = 301)	**<.001**
Understanding of the connections between technology and society	53 (*n* = 1750)	**50** (*n* = 1372)	**63** (*n* = 378)	**<.001**
Understanding of global issues	33 (*n* = 1645)	**30** (*n* = 1299)	**43** (*n* = 346)	**<.001**
Ability to view issues from several different perspectives	58 (*n* = 1747)	**55** (*n* = 1367)	**67** (*n* = 380)	**<.001**

Of particular note in this table are the three items for which the largest discrepancies exist between male and female "much" and "very much" ratings of impact. For project impact on ability to understand people of other racial and ethnic backgrounds, ability to understand people

of other cultures, and expansion of respect for cultures outside of one's own, the percentage of females indicating that project work impacted them either "much" or very much" in each of these areas was about 20 percentage points higher than the percentage of males. In addition, of all 39 areas of impact explored through the entire survey, the largest discrepancies between percentages of males and females reporting either "much" or "very much" impact existed for these three items.

These findings reveal that through project work at WPI, females—to a considerably larger extent than males—developed skills that not only could be useful in managing challenges of the global workplace, which rely on effective cross-cultural communication, but that transcend issues of basic communication and understanding and address the more critical need to respect and meet others on their own terms.

Professional Impact: For most survey items targeting project impact in areas of professional relevance, compared to males, females perceived project work as having been more positively impactful. Table 4 reveals that higher percentages of females perceived project work to be more positively impactful in areas involving collaboration (e.g., managing a project, managing interpersonal dynamics, and functioning on a team), communication (e.g., communicating visually, orally, and in writing), and information processing (e.g., making connections across disciplines, integrating information from multiple sources, developing ideas, and solving problems). Females also perceived project work to be more positively impactful than males in terms of the extent to which it contributed to their development of a solid knowledge base, their ability to take responsibility for their own learning, and their general abilities to function effectively in the "real world" and interact effectively within a professional capacity.

Table 4. Gender Differences in Professional Impact of Project-Based Learning

Area of Impact	**% Responding "Much" or "Very Much"**			***p***
	Engineering Majors	**Males**	**Females**	
Aware of how decisions affect and are affected by others	44 (*n* = 1724)	**40** (*n* = 1353)	**57** (*n* = 371)	**<.001**
Understanding of ethical responsibilities	36 (*n* = 1647)	**32** (*n* = 1292)	**49** (*n* = 355)	**<.001**
Be an effective leader	56 (*n* = 1728)	**54** (*n* = 1359)	**66** (*n* = 369)	**<.001**
Effectively manage a project	68 (*n* = 1751)	**66** (*n* = 1373)	**78** (*n* = 378)	**<.001**
Communicate effectively visually	54 (*n* = 1750)	**52** (*n* = 1372)	**63** (*n* = 378)	**<.001**
Effectively manage interpersonal dynamics	61 (*n* = 1748)	**59** (*n* = 1370)	**69** (*n* = 378)	**<.001**
Make connections across disciplines	54 (*n* = 1747)	**52** (*n* = 1368)	**62** (*n* = 379)	**<.001**
Function effectively on a team	69 (*n* = 1725)	**67** (*n* = 1354)	**76** (*n* = 371)	**<.001**

Table 4. Gender Differences in Professional Impact of Project-Based Learning				
Area of Impact	**% Responding "Much" or "Very Much"**			***p***
	Engineering Majors	**Males**	**Females**	
Integrate information from multiple sources	67 (*n* = 1759)	**65** (*n* = 1379)	**74** (*n* = 380)	**<.001**
Function effectively in the "real world"	64 (*n* = 1745)	**62** (*n* = 1368)	**71** (*n* = 377)	**.005**
Speak clearly and effectively	50 (*n* = 1750)	**48** (*n* = 1370)	**57** (*n* = 380)	**<.001**
Develop ideas	71 (*n* = 1759)	**69** (*n* = 1378)	**77** (*n* = 381)	**<.001**
Solve problems	70 (*n* = 1753)	**68** (*n* = 1374)	**76** (*n* = 379)	**.002**
Deliver effective presentations	53 (*n* = 1736)	**51** (*n* = 1360)	**59** (*n* = 376)	**<.001**
Take responsibility for own learning	74 (*n* = 1757)	**72** (*n* = 1377)	**79** (*n* = 380)	**.001**
Write clearly and effectively	57 (*n* = 1762)	**56** (*n* = 1381)	**63** (*n* = 381)	**<.001**
Interact effectively within a professional capacity	66 (*n* = 1741)	**65** (*n* = 1362)	**71** (*n* = 379)	**<.001**
Develop a solid base of knowledge	59 (*n* = 1760)	**58** (*n* = 1381)	**62** (*n* = 379)	**.015**
Master fundamental concepts and methods in the major	60 (*n* = 1759)	59 (*n* = 1379)	63 (*n* = 380)	.203
Use current technology	61 (*n* = 1743)	61 (*n* = 1368)	62 (*n* = 375)	.518

The most striking gender differences in the area of professional relevance of impact of project work, though, are seen in perceptions of impact of project work on awareness of how decisions affect and are affected by others and on understanding of ethical responsibilities. For both of these complex-to-comprehend issues that are especially important and relevant to the field of engineering, the percentage of females indicating that project work at WPI impacted them either "much" or "very much" exceeded the percentage of males responding likewise by 17 percentage points.

Professional Advancement: Four items on the survey spoke to the extent to which project work directly impacted professional advancement. While males and females responded comparably regarding the extent to which they believed their project work provided knowledge or experience that helped them to change their minds about future plans and about the extent to which they believed their project work provided them with professionally beneficial connections, they differed in their perceptions that project work provided them with opportunities that students from other universities did not have, and that their project work enhanced their ability to succeed in business or industry. Compared to males, the percentage of females was nine points greater

regarding perceived unique opportunities conferred through project work, and it was seven percentage points greater regarding the impact of project work on their ability to do well in business or industry. See Table 5 for details.

Table 5. Gender Differences in Impact of Project-Based Learning on Professional Advancement

Area of Impact	% Responding "Much" or "Very Much"			*p*
	Engineering Majors	Males	Females	
Opportunities that students from other universities did not have	64 (*n* = 1758)	**62** (*n* = 1377)	**71** (*n* = 381)	**<.001**
Succeed in business or industry	57 (*n* = 1741)	**55** (*n* = 1366)	**62** (*n* = 375)	**.012**
Knowledge or experience that helped to inform future plans	36 (*n* = 1741)	36 (*n* = 1368)	39 (*n* = 373)	.144
Professionally beneficial connections	21 (*n* = 1743)	20 (*n* = 1365)	23 (*n* = 378)	.392

Personal Impact: The ideation exercise that preceded the survey that is at the core of this report revealed that project work at WPI was producing unintended personal effects that extended beyond WPI's undergraduate learning outcomes. Alumni reported that as a result of their projects their lives were enriched in non-academic and non-work-related ways, they learned better how to achieve balance between work and life, and their feelings of being able to "make a difference" in the world increased. They also stated that their projects caused them to feel more connected to both WPI and to communities outside of WPI that they had become affiliated with through their projects. Even beyond this, though, they indicated that their project work also had increased their desire to maintain involvement with both of these types of communities.

The results of the survey reinforced these initial findings and also revealed that females perceived these positive impacts to a greater extent than males had. Table 6 conveys these differences. Perhaps two of the most surprising revelations from the ideation exercise were that project work was personally enriching and contributed to ability to achieve work/life balance. The differences in percentages of "much" and "very much" responses between males and females for these items were rather large at 14 and 11 percentage points, respectively.

Another gender difference in the area of personal impacts that is also conveyed in Table 6 is very much germane to WPI learning outcomes, though: character development. One of the Undergraduate Learning Outcomes for WPI states that graduates "will have the skills, diligence, and commitment to excellence needed to engage in lifelong learning." Gender differences aside, survey responses showed that over two-thirds of engineering majors believed that their WPI project work helped them develop a stronger personal character to a degree of "much" or "very much." While this overall result is quite notable, the gender difference is, as well: 76% of female engineering majors indicated their WPI project work helped them develop a stronger personal character while 65% of male engineering majors indicated the same, a difference of 11 percentage points.

Table 6. Gender Differences in Personal Impact of Project-Based Learning				
Area of Impact	**% Responding "Much" or "Very Much"**			***p***
	Engineering Majors	**Males**	**Females**	
Enriched life in ways that were not necessarily academic or work-related	46 (*n* = 1699)	**43** (*n* = 1333)	**57** (*n* = 366)	**<.001**
Feeling connected to a community unrelated to my university	24 (*n* = 1669)	**22** (*n* = 1310)	**30** (*n* = 359)	**.001**
Helped develop a stronger personal character	67 (*n* = 1760)	**65** (*n* = 1380)	**76** (*n* = 380)	**<.001**
Helped learn how to achieve work/life balance	32 (*n* = 1693)	**30** (*n* = 1320)	**41** (*n* = 373)	**<.001**
Increased desire to stay involved with my university's community	23 (*n* = 1750)	**20** (*n* = 1370)	**30** (*n* = 380)	**<.001**
Feeling connected to my university's community	37 (*n* = 1747)	**35** (*n* = 1370)	**43** (*n* = 377)	**<.001**
Feelings of being able to "make a difference"	42 (*n* = 1745)	**40** (*n* = 1369)	**47** (*n* = 376)	**.012**
Increased desire to stay involved w/community unrelated to my univ.	17 (*n* = 1656)	**16** (*n* = 1301)	**21** (*n* = 355)	**.006**
Feelings that own ideas are valuable	54 (*n* = 1753)	53 (*n* = 1375)	56 (*n* = 378)	.212

Discussion

The differences in perceptions of female and male alumni regarding the impact of their project work at WPI are striking, but not easily interpreted. In this section, we attempt to tie the findings from these comparative analyses to previous work, and draw upon interviews with survey participants to offer a deeper understanding of their perceptions. While the interviews have not yet been analyzed as part of the larger study, the voices of participants provide possible explanations for some survey findings.

First, some comments on the interview process: The interviews were designed to gain a better understanding, in general, of why project work had the impacts that it did on WPI alumni. One question asked interviewees if they believed their project experiences may have differed from those of the opposite sex. After this question was met with puzzlement by many interviewees—who indicated that they had witnessed no differences between the experiences of males and females—the question was asked after a brief explanation of gender differences in survey responses was provided.

The strongest differences in perception between females and males were in domains such as cross-cultural understanding, global awareness, social impact, work/life balance, ethics, leadership, and communication, the contextual, non-technical skills and attributes for engineers sometimes collectively referred to as professional skills. Shuman et al. summarize arguments

regarding the importance of these professional skills from educators, employers, and policymakers, describe how they can be promoted through high-engagement curricular strategies such as PBL, and discuss how they can be assessed.[10]

The differences in professional skill development from PBL found in this study are consistent with Busch-Vishniak and Jarosz's broad survey of the literature concluding that female students are more motivated by opportunities for social context and collaboration than males.[4] It is plausible that this higher motivation leads to greater engagement by females in project work, resulting in greater educational impact. The motivational effect of PBL was described by one female interview subject who said "I think that these projects are a great way to apply what students learn in the classroom in a way that positively impacts society," adding "I think women especially connect with that societal aspect of these projects and that helps enhance their engineering education." This alumna went on to say that before her PBL experience, "I wasn't interested in engineering because I didn't see the societal component to it…I used to think it was just like men behind desks doing calculations…and engineering can be much more rewarding than just that and these projects, I think, helped me to recognize that the… traditional engineering education I was getting in the classes can be applied to projects that really made a difference to people, and I think that women identify with that and that it helps them really enjoy engineering…"

One alumna spoke about the collaborative nature of PBL, saying that her off-campus project work "allowed us to build more intimate connections with people at [WPI] because we were living with the people we were working with," and indicated that she hadn't been able to create such connections on campus. Another said that "[b]eing part of a team was a wonderful experience." A male interviewee noted that PBL requires a lot of communication, and offered that "[w]omen generally value communication processes more than men do." On the other hand, some male and female interviewees dismissed the notion that there might be differences in impact based on gender.

Some female interviewees described the project experience as empowering, and several offered that the project experiences prepared them for work in the male-dominated field of engineering. A woman who noted that when she was in high school she was not allowed to take a drafting class because she was a girl said that WPI "did a really good job of not making you feel that there were any limitations on you as a woman, which was different from other aspects of life." Another woman explained that project work "gave me an opportunity to shine in a man's environment." It is possible that systematic analysis of the alumni interviews will provide more insight into the differences reported by male and female alumni.

It is interesting to note the two professional impact areas of project work for which female responses were not statistically different than those of males: the abilities to "use current technology" and to "master fundamental concepts and methods in the major." Both of these abilities are arguably more likely to be acquired in courses than in project work. Furthermore, neither ability is related to collaboration or social context, the aspects of engineering work which Busch-Vishniak and Jarosz concluded were more motivating for females than for males.[4]

As explained earlier, this survey was designed to determine the extent of positive impacts of project work on WPI alumni, based on the strongly positive impacts described spontaneously by alumni during the ideation exercise that informed the survey. Certainly, it is not the case that all impacts of project work are positive or neutral for all participants. Exploring negative aspects of project work could also be valuable and might be the focus of future study.

Ongoing and Future Work

It is likely that some of the differences in female and male perceptions found in this alumni survey are due to differences between off-campus and on-campus projects. As mentioned earlier, WPI female students participate in off-campus projects at a rate greater than that of male students; 52% of the female alumni who participated in the survey completed an off-campus project, compared to 39% of the male alumni. Off-campus projects generally involve more preparation, greater consideration of social context, and more collaboration than those done on campus, and they often take place overseas. Assessment conducted at WPI has consistently indicated greater achievement of learning outcomes from off-campus projects than from those done on campus, which is not surprising given the differences in preparation and experience. Preliminary findings from the alumni survey confirm this, with alumni who completed off-campus projects reporting stronger positive impacts in many of the same areas for which there were strong differences by gender. Subsequent analysis as part of this ongoing study will explore the relation between the gender differences and the differences in participation in off-campus projects in an attempt to better understand the interaction of these factors.

The ongoing analysis of alumni interviews may also shed further light on the survey results. For example, the analysis will explore the extent to which women made comments pertaining to motivational factors such as social context and collaboration, and will also investigate more closely the experiences of male alumni to consider what factors might limit the positive impacts that they experience. In addition to providing evidence regarding differences between how female and male students experience PBL, those results can also be of use to WPI to better understand and improve student project experiences.

In addition, the interviews that are planned with employers who hire WPI alumni will provide opportunities to further understand differences in how men and women benefit from PBL. These interviews will be designed to explore employers' perceptions of how WPI male and female alumni differ in terms of qualities and professional skills, and how the work preparation and performance of those alumni compare to those who graduated from programs not featuring a project-based approach to engineering education. It is our hope that the larger study, when complete, will provide evidence that is useful to institutions considering if and how to devote curricular space and institutional resources to project-based learning, as well as insight into how those curricular changes might help attract and retain more women in engineering.

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Appendix: Exact phrasing of survey items targeting project impact on professional skills, world views, and personal life

Response options: Not At All, A Little Bit, Moderately, Much, Very Much, Not Applicable

Indicate the extent to which your formal project experience at WPI (either through Project One, Project Two, or both) <u>enhanced your ability to</u>:

Write clearly and effectively
Speak clearly and effectively
Communicate effectively visually
Deliver effective presentations
Interact effectively within a professional capacity
Effectively manage interpersonal dynamics
Function effectively on a team
Effectively manage a project
Be an effective leader
View issues from several different perspectives
Understand people of other racial and ethnic backgrounds
Understand people of other cultures
Integrate information from multiple sources
Make connections across disciplines
Identify, analyze, and solve problems creatively through sustained critical investigation
Develop ideas
Use current technology
Succeed in business or industry
Function effectively in the "real world"

Achieve work/life balance
Take responsibility for own learning

Indicate the extent to which your WPI formal project experience (either through Project One, Project Two, or both) <u>expanded your</u>:
Understanding of the connections between technology and society
Understanding of global issues
Awareness of how your decisions affect and are affected by others
Respect for cultures outside of own
Understanding of ethical responsibilities

Indicate the extent to which your WPI formal project experience (either through Project One, Project Two, or both) <u>contributed to</u>:
Development of a solid base of knowledge
Mastery of fundamental concepts and methods in your major
Feelings of being connected to the WPI community
A desire to maintain involvement with the WPI community
Feelings of being connected to a non- WPI community
A desire to maintain involvement with a non- WPI community
Feelings that you could "make a difference"
Feelings that your own ideas are valuable

Indicate the extent to which your WPI formal project experience (either through Project One, Project Two, or both) contributed to <u>helping you develop a stronger personal character</u>. A strong personal character is characterized by things like taking pride in your work, operating according to a strong work ethic, persevering through adversity, being self-motivated, feeling self-confident, feeling self-aware, and operating according to a well-defined code of personal values.

Indicate the extent to which your WPI formal project experience (either through Project One, Project Two, or both) contributed to <u>enriching your life in ways that were not necessarily academic or work-related</u>. Life enrichment in this sense would include things like appreciating travel, enjoying new cultures, developing new personal interests (for example theater, food, or exercise), and developing and maintaining deep and lasting friendships.

Indicate the extent to which your formal project experience at WPI (either through Project One, Project Two, or both) <u>provided you with</u>:
Professionally beneficial connections
Opportunities that you believe students from other universities did not have
Knowledge or experience that helped you change your mind about your future plans