AC 2012-2959: PREPARING THE ENGINEER OF 2020: ANALYSIS OF ALUMNI DATA

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Preparing the Engineer of 2020: Analysis of Alumni Data

The College of Engineering at the Pennsylvania State University aspires to educate engineers of 2020: engineers who are innovative, ethical, and good communicators, and have the skills to work globally and in multidisciplinary teams. For evaluation purposes, the University periodically sends out surveys in which engineering alumni are asked about how well prepared they perceive themselves to be for their post-graduation employment. Using the results from the 2010 administration of this survey, this study seeks to answer the following questions: (1) What are alumni’s perceptions of their preparedness in these areas: ethics, innovation, communication, project management, global and international work, and multidisciplinary teamwork? (2) Can clusters be identified from the survey results? (3) What undergraduate engineering experiences helped prepare them for these skills, and in what ways do they believe the University could have prepared them better?

An exploratory TwoStep cluster analysis was performed on survey data from 738 engineering alumni. Substantially different cluster solutions were obtained when the order of the input data was changed. Therefore, the authors concluded that a cluster analysis was not appropriate. Instead, the data was divided into three groups based on satisfaction: (1) Group A: participants who were very satisfied with their engineering education, (2) Group B: participants who were satisfied, and (3) Group C: participants who were below satisfied. The three groups reported different levels of preparedness.

Telephone interviews were conducted with members of each of the three groups. In this paper, preliminary results will be reported for Group A, the group of participants who were very satisfied. Twenty-six alumni classified as being in Group A participated in one thirty-minute telephone interview in which they described the undergraduate engineering experiences that helped prepare them for these skills, and identified ways in which they believed the University could better prepare students for these skills.

The methods described in this paper can be valuable for universities and departments interested in conducting program evaluations. The preliminary results presented in this paper will demonstrate some of the experiences that have and have not been effective in the process of preparing engineers of 2020, with the goal of propagating these effective experiences across departments.

Introduction

The National Academy of Engineering\(^1\) described the skills and attributes the engineer of 2020 should ideally have in order to continue to be relevant and successful, and to keep up with the changes and needs in society and the world. According to the National Academy of
Engineering\textsuperscript{1}, we should be educating engineers “who are broadly educated, who see themselves as global citizens, who can be leaders in business and public service, and who are ethically grounded” (p.5), as well as engineers who are creative and have leadership skills.

The Pennsylvania State University aspires to educate engineers of 2020, or, to use University terminology, we aspire to educate World-Class Engineers. The World-Class Engineer is aware of the world, solidly grounded, technically broad, effective in teams, innovative, and successful as a leader. The skills and attributes ascribed to the World-Class Engineer very closely align with those ascribed to the engineer of 2020, as illustrated by these examples:

- The World-Class Engineer is solidly grounded, or able to use his or her knowledge of the discipline to solve problems\textsuperscript{2}. Similarly, the engineer of 2020 has “strong analytical skills” and “practical ingenuity” (p.54), which allows him or her to identify and solve problems\textsuperscript{1}.
- The World-Class Engineer is innovative; for the engineer of 2020, creativity (also referred to as innovation) is an “indispensable quality”\textsuperscript{1} (p.55).
- The World-Class Engineer is able to work globally and internationally, as part of global and multidisciplinary teams. Similarly, the engineer of 2020 will be involved in work including “interdisciplinary teams, globally diverse team members, public officials, and a global customer base” (p.55)\textsuperscript{1}. For this reason, the engineer of 2020, just like the World-Class Engineer, needs to also have good communication skills.
- The World-Class Engineer can identify ethical implications and apply a professional code of ethics; the engineer of 2020 also needs to consider ethics\textsuperscript{1}.

The initial focus of this study was to look at how well the University is preparing World-Class Engineers. Upon looking at the similarities between the World-Class Engineer and the engineer of 2020, we decided to use the engineer of 2020 framework instead. We believe that the use of this framework permits our methods and findings to be valuable to a larger number of universities also interested in preparing engineers of 2020.

**Context of the study**

For evaluation purposes, the University periodically sends out surveys in which engineering alumni are asked about how well prepared they perceive themselves to be for their post-graduation employment. As described in Barron, et al. (2004)\textsuperscript{3}, these surveys are sent out electronically, every two years, to alumni 2-3 years after obtaining their undergraduate degree. The survey asks details about the alumni’s career paths (for example, full-time employment or graduate school), the importance of certain skills and abilities in their current jobs, how well prepared they perceive themselves to be in these skills and abilities, and how satisfied they were with their engineering education\textsuperscript{3}. 
This study is part of a larger, multi-year study that seeks to understand the undergraduate engineering experience and how the University’s College of Engineering is preparing undergraduates for their future careers. To do this, quantitative and qualitative methods will be used to study both alumni’s and current undergraduates’ experiences. This paper shares the initial stages of the larger study, in which we seek to learn what skills alumni use in their current jobs, how well prepared they perceive themselves to be to use these skills, and what undergraduate experiences helped them learn these skills.

**Research questions**

The research questions answered in this paper are: (1) What are alumni’s perceptions of their preparedness in these areas: ethics, innovation, communication, project management, global and international work, and multidisciplinary teamwork? (2) Can clusters be identified from the survey results? (3) What undergraduate engineering experiences helped prepare them for these skills, and in what ways do they believe the University could have prepared them better?

**Methods**

The 2010 version of the alumni survey was completed by 738 participants. As mentioned above, typically the survey is sent to alumni who have been in the workforce 2-4 years. In this particular administration, the survey was sent later than usual, as the survey questions and interface were being redesigned. Therefore, in this study, these alumni had graduated between 2005 and 2007 and thus were in the workplace for approximately 3-5 years when the study occurred. During 2005-2007, a total of 3715 students graduated from the College of Engineering; e-mail contact information was available for 1893. The response rate on the survey, based on the number of alumni with available contact information, was 39%.

For this study, we focused on the preparedness and importance items. For these items, participants were given different skills and abilities and asked to rate themselves as being very prepared, somewhat prepared, or not prepared for each one. Specifically, participants were asked about their preparedness in ethics, sustainability, innovation, applying engineering skills, communication, designing to meet customer needs, data analysis, project management, global and international work, and multidisciplinary teamwork. Participants were also asked to rate whether each of these skills was not important, somewhat important, or very important to their jobs. Figure 1 shows how these items were presented in the alumni survey.
A correlation analysis was conducted to determine the relationship between the level of importance and the level of preparedness for each individual skill. The gamma statistic was used, since its use is recommended for ordinal data with a limited number of possible responses, such as our survey data. The importance and preparedness items were not highly correlated, as shown in Table 1.
Table 1. Importance and preparedness item correlations

<table>
<thead>
<tr>
<th>Item</th>
<th>Gamma statistic (importance-preparedness correlation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apply engineering skills</td>
<td>0.374</td>
</tr>
<tr>
<td>Design to meet needs</td>
<td>0.117</td>
</tr>
<tr>
<td>Analyze data</td>
<td>0.373</td>
</tr>
<tr>
<td>Work for customers outside the US</td>
<td>0.120</td>
</tr>
<tr>
<td>Teams with people from different countries</td>
<td>0.212</td>
</tr>
<tr>
<td>Globally distributed teams</td>
<td>0.130</td>
</tr>
<tr>
<td>Teams with people from other disciplines</td>
<td>0.251</td>
</tr>
<tr>
<td>Innovative solutions</td>
<td>0.525</td>
</tr>
<tr>
<td>Oral presentations</td>
<td>0.205</td>
</tr>
<tr>
<td>Write effectively</td>
<td>0.195</td>
</tr>
<tr>
<td>Project management skills</td>
<td>0.296</td>
</tr>
<tr>
<td>Identify ethical implications</td>
<td>0.339</td>
</tr>
<tr>
<td>Apply code of ethics</td>
<td>0.426</td>
</tr>
<tr>
<td>Consider sustainability</td>
<td>0.341</td>
</tr>
</tbody>
</table>

Ultimately, our goal was to interview a subset of these alumni to learn about what experiences in their undergraduate engineering education were effective at preparing them for these skills. Before doing this, we were interested in finding a way to classify the survey participants into groups that had similar responses. These would be groups from which we would then select participants for the interviews.

Using SPSS, an exploratory TwoStep cluster analysis was performed on the preparedness items to see if the participants could be classified into groups, or clusters. A cluster analysis aims to find groups in data, where “objects in the same group are similar to each other, whereas objects in different groups are as dissimilar as possible” (p.1). Prior to the analysis, neither the potential characteristics of the groups nor the number of resulting groups are necessarily known. There are different methods of cluster analyses, including the k-means and hierarchical methods, but only the TwoStep method accepts categorical variables. Because our data was categorical, the TwoStep method was used. To run the cluster analysis, the standard SPSS procedure and default settings were used.

When the order of the input data was changed, cluster solutions varied considerably. The analysis would sometimes identify two, and sometimes three, clusters. Even when the same number of clusters was identified, the clusters varied in number of participants and characteristics among the different analyses. When using the TwoStep method, results may in fact depend on the order of the cases. In addition, the analyses always reported a marginal
cluster quality. For these reasons, we decided that a cluster analysis was not an appropriate method to classify participants.

Instead, we decided to classify participants based on their level of satisfaction with their engineering education, specifically within their major. The survey included an item that asked participants to rate their level of satisfaction on a five-point scale: from very dissatisfied to very satisfied. Using the responses to this item, participants were classified into three groups: participants who were very satisfied with their engineering education (Group A), participants who were satisfied (Group B), and participants who were below satisfied (Group C). This latter group is a combination of participants who reported themselves as being neither satisfied nor dissatisfied, and those who were dissatisfied with their engineering education (no participants were very dissatisfied). These three groups will be further described in the following section.

Finally, we interviewed 47 participants: 26 from Group A, 17 from Group B, and 4 from Group C. While this paper will focus on the responses from Group A, summaries of responses from all groups will be presented in a future paper. A semi-structured interview protocol was used, in which participants were asked about the different skills, how they used these skills in their jobs, in what ways the University prepared them to use these skills, and in what ways the University could better prepare students to use these skills. The interviews, conducted via phone, were recorded and transcribed.

A postdoctoral researcher with a background in engineering education analyzed the interview data. To analyze this data, the coder followed some of the steps suggested by Creswell. First, the data was read to “get a sense of the whole” (p.251). Next, the coder went through the data and assigned codes, or words/phrases that described different parts of the text. Then, the codes were revised and applied to the data. The coder went through this process first to analyze the participants’ responses pertaining to each individual skill, and then to identify themes and experiences that were common across skills and participants.

Results

The following sections will present descriptive statistics of the sample and the groups and also describe participants’ perceived levels of preparedness in aggregate form and by level of satisfaction, and provide preliminary results from the interviews with participants from Group A, the very satisfied group.

Descriptive statistics

Table 2 shows the number of participants and the average GPAs for Groups A, B, and C, as well as for the total sample and population.
Table 2. Descriptive statistics

<table>
<thead>
<tr>
<th></th>
<th>Total participants</th>
<th>Female participants</th>
<th>Male participants</th>
<th>Average GPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>341 (100%)</td>
<td>82 (24%)</td>
<td>259 (76%)</td>
<td>3.26</td>
</tr>
<tr>
<td>Group B</td>
<td>346 (100%)</td>
<td>88 (25%)</td>
<td>258 (75%)</td>
<td>3.20</td>
</tr>
<tr>
<td>Group C</td>
<td>51 (100%)</td>
<td>13 (25%)</td>
<td>38 (75%)</td>
<td>3.11</td>
</tr>
<tr>
<td>Total sample</td>
<td>738 (100%)</td>
<td>183 (25%)</td>
<td>555 (75%)</td>
<td>3.20</td>
</tr>
<tr>
<td>Population</td>
<td>3715 (100%)</td>
<td>615 (17%)</td>
<td>3100 (83%)</td>
<td>3.14</td>
</tr>
</tbody>
</table>

A one-sample t-test was used to determine if the sample of 738 participants was representative of the whole population of 3715 (the number of College of Engineering graduates for 2005-2007), in terms of GPA. The results indicate a significant difference, with one-sample t(796)=2.911, p<0.05. However, the mean difference is very small (3.14 for population, 3.20 for total sample), and statistical significance was likely impacted by the large sample size. One-sample t-tests were also used to determine if each of the groups was significantly different to the whole population, in terms of GPA. The GPA for Group A was significantly different from that of the population, but the GPAs for groups B and C were not. An analysis of variance (ANOVA) indicated that there were no statistically significant differences (F(2,735)=2.023, p=0.133) among the GPAs for groups A, B, and C.

Table 2 also shows there was a slight overrepresentation of female participants in our survey sample of 738 (25% were female), compared to the total population of 3715 (17% were female).

Perceived levels of preparedness: Aggregate

To look at participants’ perceived levels of preparedness in ethics, innovation, communication, project management, global and international work, and multidisciplinary teamwork, we first of all considered whether these skills were important to their jobs. If participants reported that the skills were somewhat or very important to their jobs, we would then include them in the analysis of level of preparedness. The rationale behind this filtering of the data is that only those participants for whom a skill is important or somewhat important in their job are in a position to judge how well they are prepared to perform that skill.

Figure 2 shows the aggregate results of importance and preparedness for the subset of participants for whom a skill was somewhat or very important. The x-axis represents the percentage of participants who reported each skill to be somewhat or very important to their jobs. The y-axis represents the average of the participants’ reported levels of preparedness, where 0 is not prepared, 0.50 is somewhat prepared, and 1.00 is very prepared.
These results indicate that the participants feel that they are well prepared in the following areas: applying engineering skills, analyzing data, and communication (written and oral). They are less prepared in ethics, innovation, designing to meet customer needs, multidisciplinary teamwork, working in teams with members from different countries, project management, and sustainability. They feel least prepared for working in globally distributed teams and working for customers outside the US.

Perceived levels of preparedness: By satisfaction level

Group A, or the group of participants who were very satisfied with their engineering education, consisted of 341 participants (82 female, 259 male).

Figure 3 shows the results for this group. Alumni in Group A perceived themselves to be well prepared in applying engineering skills, analyzing data, communication (written and oral),
innovation, ethics, and designing to meet needs. They were less prepared, although still somewhat prepared, to work in multidisciplinary teams and in teams with members from different countries, project management, and sustainability. They perceive themselves to be the least prepared to work for customers outside the US and to work in globally distributed teams. Although these were the areas with the lowest preparation in this group, they mostly reported themselves as being somewhat prepared, not unprepared, for these skills.

Figure 3. Perceived levels of preparedness: Group A

Group B, or the group of participants who were satisfied with their engineering education, consisted of 346 participants (88 female, 258 male).
Figure 4 shows the results for this group. Alumni in Group B perceived themselves to be well prepared for applying engineering skills and analyzing data. They were less prepared, although still somewhat prepared, in communication (written and oral), innovation, ethics, working in teams with members from different countries, designing to meet customer needs, and working in multidisciplinary teams. They are the least prepared for project management, sustainability, working in globally distributed teams, and working for customers outside the US. The graphs illustrate that the overall perceived levels of preparedness for Group B are lower than those for Group A.

Figure 4. Perceived levels of preparedness: Group B
Group C, or the group of participants who were below satisfied with their engineering education, consisted of 51 participants (13 female, 38 male).

Figure 5 shows the results for this group. Alumni in this group perceived themselves to be somewhat prepared in communication (oral and written), ethics, working in teams with members from different countries, analyzing data, multidisciplinary teamwork, and applying engineering skills. They did not feel as well prepared for the remaining skills. Again, the graphs illustrate that the overall perceived levels of preparedness for Group C are lower than those for Groups A and B.

Figure 5. Perceived levels of preparedness: Group C
Using the sum of preparedness scores for each group (that is, the sum of the scores for all items), an analysis of variance (ANOVA) was used to determine if there were any significant differences across the three groups. The ANOVA indicated significant differences F(2, 728)=52.176, p<0.005. Tukey’s HSD tests indicated that at the 0.05 level of significance, all group comparisons of summed preparedness scores were significantly different.

**Preliminary results from interviews with Group A**

In addition to survey results, we were interested in interviewing a subset of the participants in order to learn about and understand the experiences in their undergraduate engineering education that were effective at preparing them. Interviews were conducted with 26 participants from Group A, the very satisfied group. There were 8 female and 18 male participants, representing eleven different departments. At the time of the interview, two of these participants were graduate students, eighteen were employed full-time as engineers, and six were employed full-time not as engineers. The participants were asked to describe the undergraduate engineering experiences that helped them learn about ethics, innovation, communication, project management, global and international work, and multidisciplinary teamwork. They also provided suggestions on how the University could better prepare students for these skills.

Experiences were classified as either being ways in which the University directly prepared the participants, or being ways in which the University indirectly prepared them. The former refers to experiences that are part of the engineering curriculum; it is required and mandatory that students participate in these experiences. The latter refers to experiences offered or enabled by the University; these experiences, while being offered by the University, were not part of the engineering curriculum and were not mandatory, so only students who chose to participate benefited.

Ways in which the University directly prepared students for these skills include providing opportunities for students to participate in group work or group assignments, discussing some of these skills and topics as part of different courses, and requiring that students complete a senior design project and/or enroll in other design courses.

Being required to participate in group work, or working in groups with other students, was one way the participants believed the University prepared them well. They reported these types of activities as helping them learn and develop the skills necessary for effective communication, working in multidisciplinary teams, and project management.

One participant talked about how group work helped her with her communication, presentation, and teamwork skills as follows:
“Every class had at least two or three group projects that we had to do and then give a presentation on at the end. And then we're graded on both the quality of our work and the quality of the presentation. And the communication skills that you learn and the team building skills that you learn and even just presentation skills and being able to speak in front of a group of people – those are skills that [the University] provided us that we don't see as strongly coming from other coworkers or other new hires from other universities.”

Another participant described how these group activities helped prepare her for multidisciplinary teamwork:

“Well, I guess just working on group projects even though you’re still in the same major, for the most part. Everyone’s good at different things, and they all kind of tend to take a specific role in the project. So I think just teamwork in general helps prepare you for that because not everyone is good at the same thing, and it kind of helps me learn how to involve different aspects of a project together.”

These projects, because they tended to be open ended, had the additional benefit of helping participants develop innovation skills. Two participants described it as follows:

“I would say that there was a general problem-solving mentality and environment in a lot of the project-based classes where we were given an open-ended problem and allowed to attack it that way and not given necessarily a defined problem all the time.”

“So I think given some freedom on projects to try some new ideas. And I think some of them – not all of them even worked. But it didn’t always affect your grade so badly as long as you could justify why you did it. So those kind of opportunities were always good.”

Regarding ethics and project management, many participants indicated that these topics were discussed in some of their courses. While the courses were not focused on these topics, the topics were discussed in some of the course lectures and activities. For example:

“The class…it was more on the design and analysis of reactors, …it’s one of the things you really can’t talk about design and changes in reactors without talking a little bit about ethics...”

“In my experience, the way the [department] structured a lot of the classes, the project management was kind of locked into it. And I think that that was really effective because we were learning the concepts and the technical as well as the management side of things at the same time.”
Participants described how senior design and other design courses helped them learn about project management and develop the skills to be innovative and work in multidisciplinary teams. One participant thought his senior design project gave him some project management experience:

“…mostly the senior project where we set up our timeline and try to use our Gantt charts to try and figure out where we started from and where it needs to end – what needs to happen at what time, how we’re going to get there kind of thing…it’s probably the biggest thing where we had a very large project and a number of people working together that we had to coordinate everything.”

This participant considered his senior design project a great way to learn to be innovative:

“The [senior design] was pretty good actually because it gave you a lot of freedom. It said, ‘Here's the project. Here's what we ultimately need for goals out of the project. And then you make it work.’ So, I guess that was directly what I'm talking about: Here's a handful of problem solvers you have – apply them. I think that's kind of one of the best ways that creativity can be encouraged in the undergraduate curriculum.”

Participants mentioned two main ways in which the University indirectly prepared them for the skills mentioned in this paper: extracurricular activities and minors. Extracurricular activities were especially beneficial in helping participants learn to work in multidisciplinary teams and develop communication skills. One participant, for example, mentioned joining the Toastmasters Club, which helped him improve his speaking and presentation skills.

Some participants minored in leadership or entrepreneurship, and they believed these minors were instrumental in preparing them for ethics, innovation, multidisciplinary teamwork, and project management. One participant had a Spanish minor, and he considered this good preparation to work on projects or products for customers outside the US.

The different ways in which the University directly and indirectly prepared the participants, as described in the interviews, are summarized in Table 2.
Table 3. Experiences that prepared the participants (n=26)

<table>
<thead>
<tr>
<th>Experience</th>
<th>Communication</th>
<th>Work for customers outside the US</th>
<th>Ethics</th>
<th>Innovation</th>
<th>Multi-disciplinary teams</th>
<th>Project management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group work/projects</td>
<td>12%</td>
<td></td>
<td></td>
<td>35%</td>
<td>42%</td>
<td></td>
</tr>
<tr>
<td>Mentioned in courses</td>
<td></td>
<td>35%</td>
<td></td>
<td></td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>Senior design and other design courses</td>
<td></td>
<td></td>
<td>42%</td>
<td>15%</td>
<td>27%</td>
<td></td>
</tr>
<tr>
<td>Extracurricular activities</td>
<td>4%</td>
<td></td>
<td></td>
<td></td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td></td>
<td>8%</td>
<td>8%</td>
<td>8%</td>
<td>8%</td>
<td>4%</td>
</tr>
</tbody>
</table>

Finally, participants were asked to share what experiences the University could incorporate into the curriculum to better prepare students for these skills. They mentioned including more projects and group projects, creating courses that would focus on some of these skills, incorporating real-world components, and re-designing the senior design courses to include different disciplines.

Participants believed including more design and open-ended projects in the curriculum would help students learn to be innovative. They believed these types of open-ended activities give students the opportunity to think of “unique solutions.” Two participants who talked about the need for more projects with the goal of developing innovation described it as follows:

“But maybe some more opportunities to do your own projects or choose from a bunch instead of going in and turning some dials according to this prescribed little lecture they had planned.”

“When you’re in college and taking classes and regurgitating what the teacher teaches you, that’s tough. I think that really falls to the teachers in those courses to create – push the students and create some innovative projects to incorporate with the criteria that they’re teaching.”

According to the participants, incorporating more of these projects into the curriculum would have the additional benefit of helping students learn about project management.

When it came to learning about ethics and project management, the suggestion to create a course or seminar specifically on these topics was a common theme in participants’ responses. It was suggested that in addition to learning about project management, a project management course/seminar could be used to introduce students to project management tools and software.
Participants commented on the need for including real-world components and/or examples as ways of helping students learn about ethics, project management, and innovation. One participant described the types of real-world examples that could help students learn about ethics. In his words:

“It seems like once you get into the workforce, you hear there’s all these different standards out there that don’t really get talked about in college from corruption policies and stuff like that that are widely known in the industry but aren’t really talked about in college…and maybe even talking about some of the specific examples about product substitution, quality control, stuff like that that’s easy – encountered every day and not something that’s too far-fetched.”

An example of a real-world component that would help students learn about project management would be “interfacing with industry,” or “reach[ing] out to businesses or areas where things apply.” In this way, students would be able to see how project management is applied in the professional setting. This approach would also help students learn to be innovative, by exposing them to real problems and asking them to find possible solutions. One participant described it as follows:

“…I think throwing in a class that gave students real-world applications – talk with companies or whatever and get these real-world problems and expose them to. ‘This is an actual problem that’s actually happened. Here’s the problem; you have to come up with a solution.’”

One last suggestion offered by the participants was re-designing the senior design courses to include different disciplines. This, they believed, would be an excellent way to help students learn to work in multidisciplinary teams. One participant described what she believed this should look like:

“So, perhaps…senior design projects maybe that's linking a mechanical engineering student with an architectural student with perhaps a business student to try and make a more integrated project that achieves not only engineering principles but also policy aspects and business principles. So, something like that might be beneficial because I don't think there is a huge element of that. Like even in my senior design project, we were really only asked to approach the technical aspects, whereas in the real world, that's not really reasonable. Even if you have the best technical product in the world, if it costs a million dollars and your baseline is $100,000, it really doesn't matter.”
The different ways in which the University could better prepare students, as described in the interviews, are summarized in Table 4.

Table 4. Experiences that could better prepare students (n=26)

<table>
<thead>
<tr>
<th>Experience</th>
<th>Ethics</th>
<th>Innovation</th>
<th>Multidisciplinary teams</th>
<th>Project management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projects/Group projects</td>
<td></td>
<td>19%</td>
<td></td>
<td>15%</td>
</tr>
<tr>
<td>Courses on the topic</td>
<td>8%</td>
<td></td>
<td></td>
<td>19%</td>
</tr>
<tr>
<td>Real-world component</td>
<td>15%</td>
<td>8%</td>
<td></td>
<td>12%</td>
</tr>
<tr>
<td>Senior design project including different disciplines</td>
<td></td>
<td></td>
<td></td>
<td>42%</td>
</tr>
</tbody>
</table>

While participants seemed to easily think of experiences that prepared them and experiences that could help prepare future students in the areas of communication, ethics, innovation, multidisciplinary teams, and project management, this was not the case when asked about their preparation for global and international work. Participants could not identify specific ways in which they were prepared for this type of work.

They did, however, identify some ways in which students could be better prepared to work globally. These include offering an international business course, requiring that students learn a second language, encouraging work abroad internship or co-op experiences, and encouraging and providing opportunities for undergraduate research.

Discussion

In this paper, we looked at alumni’s perceived levels of preparedness in different skills, based on their responses to an electronic survey. The preparedness-importance plots (Figures 2-5) show the levels of preparedness reported by participants who considered these skills to be somewhat or very important to their jobs. Three groups emerged based on participants’ satisfaction with their engineering education: (1) Group A: participants who were very satisfied with their engineering education, (2) Group B: participants who were satisfied, and (3) Group C: participants who were below satisfied. The plots indicate that overall, participants in Group A perceived themselves to be better prepared than those in Group B, who in turn perceived themselves to be better prepared than those in Group C. This suggests a correlation between perceptions of preparedness and satisfaction, where participants who perceive themselves to be better prepared will also be more satisfied with their engineering education.
A brief description of the University’s College of Engineering may begin to explain some of the differences in preparedness. The College of Engineering at Penn State offers twelve undergraduate majors. All of the programs are four years except for Architectural Engineering (AE), which is a five-year program. For the four-year programs, the total credits required for graduation range from 129 to 132; 160 credits are required for AE. The programs have science and math course sets that are aligned with accreditation requirements. The majority of the remaining credits are engineering science, both inside and outside of the major. All majors except Computer Engineering have a first-year design course, in addition to the capstone design course. Chemical Engineering has the greatest number of laboratory courses at five. The programs have an emphasis on math, science, and engineering science with a focus on analysis. Thus, they are similar to the common model of U.S. programs described by Sheppard, Macatangay, Colby & Sullivan.

The degree requirements of these programs all include the University’s General Education core. The core includes nine credits of communication and 22 credits for courses in the arts, humanities, social sciences, and health. Many students also take a first-year seminar in their intended major. The General Education core requires that students take one course with an international focus. Students seeking greater international exposure have a range of options including the pursuit of study or work abroad, but few choose this route. None of the programs requires a course on ethics, although students can take such courses to satisfy the General Education requirements. Generally, ethical considerations are integrated into the design courses.

Given the characteristics of the engineering programs, the responses to the surveys were broadly what would be expected. The alumni report highest levels of preparation in their engineering skills, where the curricula place greatest emphasis. They feel less prepared for design and experimental tasks, which receive substantially less emphasis in the curricula. The alumni feel least prepared for global tasks and project management. Those students who feel well prepared for global tasks likely took advantage of study or work abroad experiences, including those offered through the Engineering Leadership Development Minor. Students in Architectural and Civil Engineering receive courses on project management. For the remaining majors, project management would typically be incorporated into design courses. Departmental differences, therefore, may also have affected alumni’s perceived levels of preparedness.

While the College of Engineering characteristics begin to explain the different levels of preparedness among the different skills, they do not explain the differences in preparedness among the three groups. Students in one same program may in fact experience the program in different ways. For example, students taking the same courses but with different instructors could experience the courses differently. As such, their perceived levels of preparedness in certain areas may be different. In addition, it is important to consider that preparedness can also depend on each individual student: the path he or she decides to take, the type and level of
involvement in extracurricular activities, and the student’s motivation and interest. In other words, within the same program, students take different paths, and each individual path can determine how well prepared students perceived themselves to be.

Participants from Group A who participated in the phone interviews mentioned activities in their undergraduate engineering experience that helped them learn about ethics, innovation, communication, project management, global and international work, and multidisciplinary teamwork. They also suggested different activities they believe could have better prepared them, and could better prepare future students, for these skills.

Group work and group projects in their different courses helped prepare alumni for communication, multidisciplinary teamwork, and project management. They believe incorporating more of these group activities into the curriculum would continue to help students develop their project management skills and their ability to work in multidisciplinary teamwork, as well as help them become more innovative.

Certain types of group work can, in fact, help students develop these skills. For example, courses using problem-based learning (PBL), in which students work in small groups\(^8\), have been shown to have the potential to improve students’ communication and teamwork skills\(^9,10\).

The participants mentioned that one of the main ways in which they learned about project management and ethics was by having it mentioned and briefly discussed as part of different courses. These courses did not focus directly on these topics, but the topics were occasionally included as part of some lectures or assignments. While this method of preparing students for ethics and project management was helpful, participants suggested the University have courses or seminars that focused specifically on these topics.

Having courses or modules on ethics is a way in which ethics can be included in engineering education\(^11\). According to Barakat\(^11\), these courses or modules on ethics should discuss, among other topics, codes of ethics and how these should be used, and examples and case studies encountered in engineering practice. The participants agreed, specifically mentioning the need for including real-world examples as a way to teach about ethics.

Senior design and other design courses prepared alumni for innovation, multidisciplinary teamwork, and project management. One way to better prepare students for multidisciplinary teamwork, according to the participants, was modifying the design projects to include students from other disciplines. Because the National Academy of Engineering\(^12\) recommends that “interdisciplinary learning” be a part of the undergraduate engineering curriculum (p.55), this is a measure universities can consider implementing in order to introduce students to other disciplines and prepare them to work with these disciplines. One example of a design project
that included students from different disciplines is described by Iordanova, Forgues, Jemtrud, Farah, and Tidafi. They had teams consisting of “architects,…engineers in building mechanical systems,…cost estimation engineers and…structural engineer[s]” (p.208) work on a design project. Their study indicated positive results. Students indicated that they learned about “the aspects treated by each discipline and…the way to collaborate” (p.210).

As described above, the University’s College of Engineering follows the common model of U.S. programs described by Sheppard, et al. Therefore, the findings and suggestions gleaned from this study can be relevant to other institutions that follow this common model and/or aspire to educate engineers of 2020.

Conclusions and future work

The results from this study identified some areas for future research. First of all, analysis of the interviews showed that participants were unable to identify specific experiences that prepared them for international work. It is unclear if this is because they did not have any such experiences or because they simply did not make the connection that certain experiences were preparation for global work. Future research will attempt to further learn about the types of experiences designed and provided by the University that have the goal of preparing students for global and international work. Future research will also attempt to determine the effectiveness of these experiences.

Additionally, analysis of the interviews revealed that minors seem to provide excellent learning opportunities for preparing engineers of 2020. Minors helped participants learn about ethics, innovation, multidisciplinary teamwork, and project management. Of all the experiences mentioned by the participants, minors seemed to provide opportunities that prepared students for the most number of skills. Because minors tend to be optional for students, future research can look at what experiences from the minors are the most helpful to students and how these experiences can be incorporated into the engineering curriculum. In this way, students who do not choose minors can be exposed to some of the benefits found in these programs. Departments can also consider encouraging students to pursue minors that would complement and enhance their engineering education.

In terms of the TwoStep cluster analysis, we were disappointed that the results were inconsistent. We had originally considered this to be an appropriate method for this data because our goal was to find a way to classify participants, not items (in which case a factor analysis would have been appropriate), and because our data was categorical. The inconsistency of the results may have been due to our number of participants. If the TwoStep method was originally intended for datasets consisting of millions of cases, it may not have been appropriate to use this method on a dataset of 738.
Our next steps include collecting and analyzing interview data from alumni from Groups B and C. We will also focus on finding new methods to analyze and classify our alumni survey results, methods that either classify participants in groups with similar characteristics, as was our original intent, or methods that deal with this data in entirely different, yet appropriate, ways.

References