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Educational Objectives and Expectations for Post-Graduation Achievement

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Abstract

This paper describes the evaluation of survey data collected from almost 1,300 Penn State engineering alumni who graduated in the years 1995 to 2000. Analyses were conducted to determine if there are differences in the respondents' perceptions of their education based on the initial career path chosen, namely, full-time employment versus entry directly into graduate study; and within these two categories, whether perceptions vary depending on graduates' decisions to pursue primarily technical or business/management tracks. Examination of the data provides evidence to suggest that their impression of the importance of various competencies and abilities is related to their choice of post-graduation activities. Depending on the selected career path, they rate the importance of these abilities differently, but tend to rate their preparedness in these areas similarly.

These findings are particularly relevant and valuable, given the definition of program educational objectives proposed by the Engineering Accreditation Commission of ABET, Inc., for the 2004-05 Engineering Criteria.[1] This proposal defines the educational objectives as "statements that describe the expected accomplishments of graduates during the first few years after graduation." The survey responses for Penn State alumni two to three years following graduation show that different kinds of achievement and measures of accomplishment apply to the different early-career paths. This raises questions that may need to be considered for curriculum design. For instance: What actions should we be taking to prepare our students for the broader aspects of their professional careers? What competencies and abilities should we emphasize in a curriculum constrained by a limited time frame? Examining the data from our surveys of recent graduates, which include information on the tasks they are actually performing in various roles, offers insights into these questions and gives us a starting point to begin to make decisions on how to prioritize the implementation of potential curricular improvements. Data collected over several years also allow us to examine patterns over time to make reasonable interpretations about the effectiveness of our programs and trends in graduates' perceptions of their education as the move into the workplace or pursue advanced degrees.

I. Origins of the Alumni Survey

For many years, the College of Engineering at Penn State has been surveying students and graduates concerning their perceptions of their undergraduate education, their early work experiences, and their future plans. Surveys of recent alumni have been carried out for over fifteen years to provide information from former students on impressions of their education and to track their early post-graduate education, professional development, and work activities. Approximately ten years ago, the College developed a new method of conducting the alumni survey and began surveying recent graduates. Starting with the class of 1995, graduates have been surveyed two to three years following the completion of their undergraduate education. This instrument was originally distributed in paper form, but was converted to an online version in 2001, which is now administered via the World Wide Web.[2]

The new expectations regarding formative assessment for engineering program accreditation served as an additional driver for a change in approach. It simply made sense to reformulate the surveys so that measures would result that could be used to effect change. The challenge was to design the new instruments so that the value of comparison with the results of previous surveys was not lost, while introducing the new content in a way that would not make for a time-consuming and ultimately off-putting format.

The most likely candidate for piloting this new strategy was the survey administered to recent alumni. Both the departments and the programs were interested in the perceptions of students relative to the eleven program outcomes specified in the general criteria of the Accreditation Board for Engineering and Technology and in gaining insight as to the curricular elements or experiences that students equate to their level of preparation in these areas. Specifically, the survey probes the various professional and workplace activities in which graduates are involved, as well as their perceptions of their undergraduate education and how well it prepared them for their chosen career path.

The alumni survey is administered every two years and is sent to alumni who graduated two and three years prior. One of the new emphases of the survey is to gain a better understanding of how the specific post-graduation activities in which our alumni are engaged relate to their perceptions of preparedness, as well as the importance they assign to selected competencies or abilities. In previous studies, we have evaluated how graduates in successive class years perceive various aspects of their education. For this study, the response data have been partitioned in a new way, categorizing alumni based on whether they pursued full-time employment directly after earning their undergraduate degrees or if they went on immediately to full-time graduate school.

II. Impact of Post-Graduation Activities on Perceptions of Preparedness and Importance of Selected Competencies

Following completion of the baccalaureate program, our engineering graduates typically select one of two post-graduate paths -- either full time employment or pursuit of full time graduate studies. Within both these groups of graduates, some tend to work or do advanced study in technical areas related to engineering, while others are employed or seeking further education in business-related/non-technical fields. Table 1 gives a breakdown into these groups for the almost 1,300 survey respondents from the graduating classes of 1995 through 2000. During this period, the proportions of graduates taking full time employment versus those going to graduate school full time remained relatively constant.

Table 1. Respondents' Breakdown into Various Categories

Full-time Employed			
in Engineering Jobs (design, product, process)	589		
in Business/Management/Non-technical	125		
in Research/Consulting	92		
in Other Roles	391		
Total		1,197	(94%)
Full-time Graduate School*			
in Engineering/Technical	58		
in Business/Other	5		
Total		69	(6%)

*Graduates who pursue graduate studies full-time immediately after earning their B.S. degrees. Note: Over 30% of graduates eventually pursue advanced studies within two to three years of graduation; 70-80% of these in engineering and 20-30% in business or MBA programs.

Clearly, a large majority of graduates chose to pursue full-time employment opportunities directly out of college, a manifestation of the healthy employment market and attractive job offers extended to graduating engineering students during that period of time. The survey asked all alumni to rate (on a scale of 1 to 5) how well their undergraduate education prepared them in each of 22 competencies or abilities, as well as how important each competency or ability is to their current job or studies. Figure 1 shows the graduates' perceptions of preparedness with regard to these competencies and abilities. In each case, the full-time employment group is compared to the graduate school group.

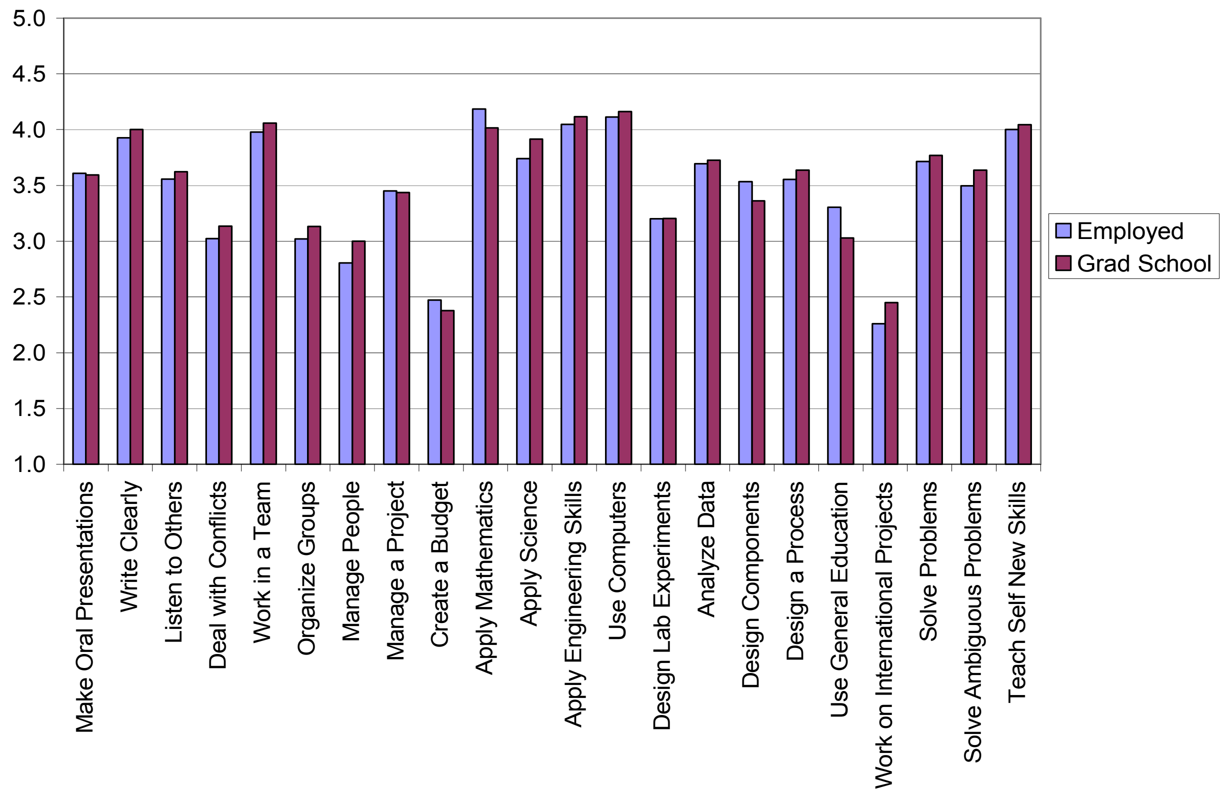

Figure 1. Perceptions of *Preparation* for Selected Competencies and Abilities

An examination of the data shows that perceptions of preparedness do not vary significantly based on initial career path. Whether working or pursuing further studies, the two groups of graduates were fairly consistent in their ratings of their level of preparation resulting from their undergraduate education. Not surprisingly, given the technical emphasis of our curriculum, all graduates tend to rate their competency in foundation subjects, computing, and engineering-related skills quite highly, while reporting less preparedness in budget and management areas.

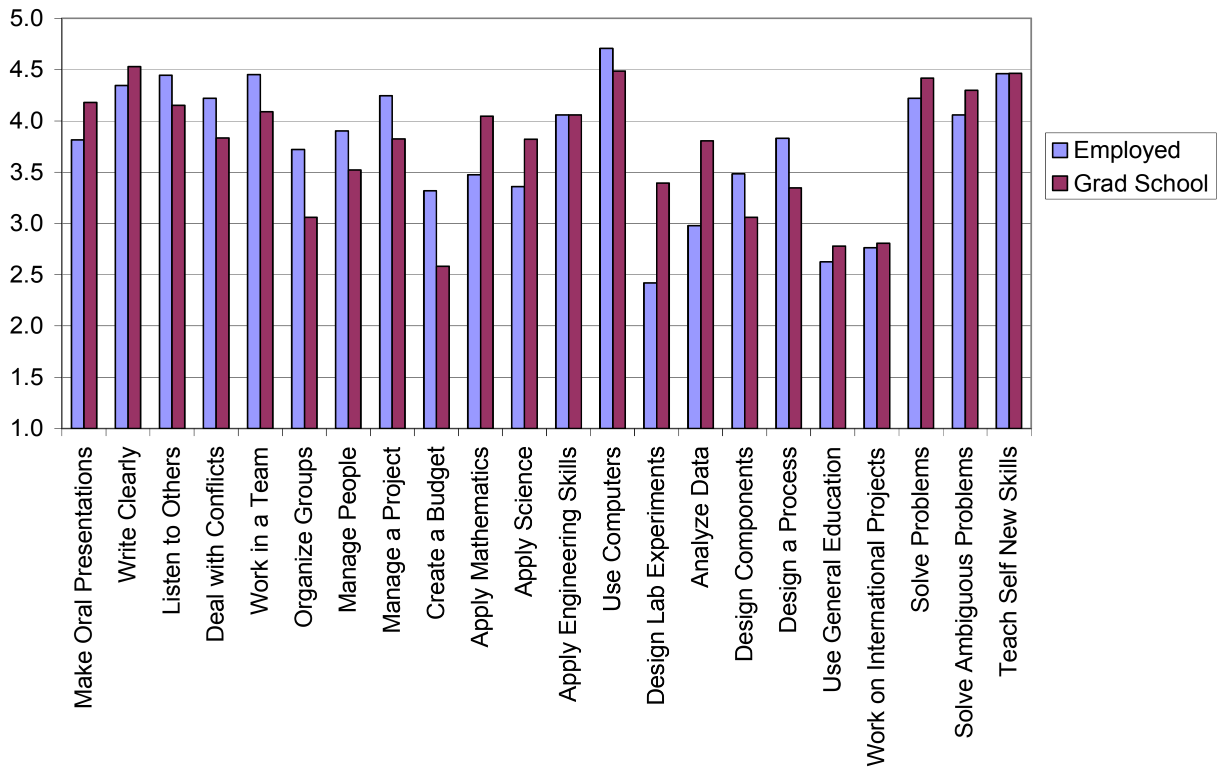

Figure 2. Perceptions of *Importance* for Selected Competencies and Abilities

Figure 2 shows the same graduates' perceptions of importance with regard to the these competencies and abilities. Here, unlike the response on preparedness, there appears to be certain skills which are much more important for students in graduate school and others that are more important for alumni who have chosen full-time employment. Graduates going on to graduate school tend to cite the technical knowledge and skills as more important, while those who take full-time jobs give higher importance to people- and budget-related attitudes and skills. To further examine these differences, statistical analysis was conducted to determine if there were significant differences in the data. Results of this analysis for comparisons between alumni in full-time employment and those in graduate school are shown in Table 2. Statistically significant results are indicated by shading.

Table 2. ANOVA Results – Breakdown by Grad School vs. Employed

	Question	P-Value (Prep)	P-Value (Imp)	Higher Group
A	Make Oral Presentations	0.833	0.024	Grad School
I	Write Clearly	0.844	0.251	
S	Listen to Others	0.450	0.008	Employed
T	Deal with Conflicts	0.403	0.000	Employed
H	Work in a Team	0.680	0.011	Employed
R	Organize Groups	0.438	0.000	Employed
P	Manage People	0.262	0.008	Employed
O	Manage a Project	0.748	0.000	Employed
Q	Create a Budget	0.570	0.000	Employed
C	Apply Mathematics	0.196	0.000	Grad School
K	Apply Science	0.224	0.012	Grad School
M	Apply Engineering Skills	0.975	0.940	
L	Use Computers	0.800	0.020	Employed
E	Design Lab Experiments	0.825	0.000	Grad School
F	Analyze Data	0.597	0.000	Grad School
G	Design Components	0.378	0.008	Employed
J	Design a Process	0.453	0.001	Employed
N	Use General Education	0.026	0.249	Employed
U	Work on International Projects	0.171	0.907	
B	Solve Problems	0.812	0.448	
V	Solve Ambiguous Problems	0.195	0.113	
D	Teach Self New Skills	0.603	0.802	

*shading indicates a statistically significant result, with $\alpha=0.05$

With the exception of applying what was learned through the courses selected to meet the general education curriculum requirements, there were no statistically significant differences in the levels of perception of preparedness between the two groups. However, there were many instances where there were statistically significant differences in perceptions of importance. The graduate school group as a whole reported that making oral presentations, using mathematics, designing lab experiments, performing data analysis, and applying science are more important. On the other hand, the group engaged in full-time employment assigned higher importance to designing components, working in a team, designing a process, using computers, managing a project, managing people, creating a budget, organizing groups, listening to others, and dealing with conflicts.

These same differences carry over to the perceptions of importance within the various groups (employed and grad school) depending on the graduates' technical or business orientations. For instance, as shown in Table 3 for alumni entering graduate school, whether they study advanced engineering topics or business training does not seem to influence their perception of their preparedness from their prior undergraduate studies. However, perceptions of importance again vary greatly. Those in a technical engineering curriculum find subjects or activities such as using mathematics, designing lab experiments, data analysis, and applying science more important. Those in a non-technical, business curriculum find skills like working in a team, writing clearly, management, and creating a budget to be more important.

Table 3. ANOVA Results – Breakdown by Grad School Classification (Engineering or Business)

	Question	P-Value (Prep)	P-Value (Imp)	Higher Group
A	Make Oral Presentations	0.764	0.080	
I	Write Clearly	0.858	0.013	Business
S	Listen to Others	0.035	0.013	Engineering (Prep); Business (Imp)
T	Deal with Conflicts	0.083	0.000	Business
H	Work in a Team	0.729	0.006	Business
R	Organize Groups	0.579	0.000	Business
P	Manage People	0.166	0.000	Business
O	Manage a Project	0.958	0.001	Business
Q	Create a Budget	0.134	0.000	Business
C	Apply Mathematics	0.028	0.032	Business (Prep); Engineering (Imp)
K	Apply Science	0.187	0.012	Engineering
M	Apply Engineering Skills	0.622	0.100	
L	Use Computers	0.492	0.084	
E	Design Lab Experiments	0.937	0.000	Engineering
F	Analyze Data	0.931	0.001	Engineering
G	Design Components	0.654	0.139	
J	Design a Process	0.020	0.001	Business (both)
N	Use General Education	0.683	0.116	
U	Work on International Projects	0.170	0.598	
B	Solve Problems	0.143	0.929	
V	Solve Ambiguous Problems	0.869	0.827	
D	Teach Self New Skills	0.967	0.570	

*shading indicates a statistically significant result, with α=0.05

As seen in Table 4, for the graduates who go on to full-time employment there is somewhat greater difference in perceptions of preparedness among those who are engaged in primarily engineering compared to business-related functions. This is evident particularly in the areas of creating a budget, listening to others, and dealing with conflicts. In all cases where there were significant differences in perceptions of preparedness, the graduates who went on to jobs in engineering felt that they were more prepared than those who went on to careers involving either business or research/consulting. As with those going to graduate school, the perceptions of importance of various educational components varied with the kind of work employed graduates were doing. Those in engineering fields found skills such as using mathematics, teaching themselves new skills, data analysis, designing components, applying science, using computers, and applying engineering skills to be more important. Those in business or non-engineering jobs found oral presentations and using their general education to be more important. And those in research and consulting fields found skills like problem solving, designing lab experiments, working in a team, and designing a process to be more important to their jobs.

Table 4. ANOVA Results – Breakdown by Employment Classification (Engineering, Research/Consulting, or Business/Non-engineering)

	Question	P-Value (Prep)	P-Value (Imp)	Higher Group	Lower Group
A	Make Oral Presentations	0.030	0.002	Engineering (Prep); Bus/Non-engr (Imp)	Research/Consult(Prep); Engineering (Imp)
I	Write Clearly	0.104	0.419		
S	Listen to Others	0.041	0.904	Engineering	Business/Non-engr
T	Deal with Conflicts	0.005	0.360	Engineering	Research/Consulting
H	Work in a Team	0.134	0.000	Research/Consulting	Business/Non-engr
R	Organize Groups	0.044	0.722	Engineering	Research/Consulting
P	Manage People	0.332	0.177		
O	Manage a Project	0.047	0.264	Engineering	Research/Consulting
Q	Create a Budget	0.000	0.569	Engineering	Research/Consulting
C	Apply Mathematics	0.769	0.000	Engineering	Business/Non-engr
K	Apply Science	0.895	0.001	Engineering	Business/Non-engr
M	Apply Engineering Skills	0.002	0.000	Engineering (both)	Research/Consult(Prep); Bus/Non-engr (Imp)
L	Use Computers	0.209	0.006	Engineering	Business/Non-engr
E	Design Lab Experiments	0.462	0.000	Research/Consulting	Business/Non-engr
F	Analyze Data	0.833	0.000	Engineering	Business/Non-engr
G	Design Components	0.006	0.000	Engineering (both)	Bus/Non-engr (both)
J	Design a Process	0.205	0.000	Research/Consulting	Business/Non-engr
N	Use General Education	0.065	0.020	Business/Non-engr	Engineering
U	Work on International Projects	0.242	0.177		
B	Solve Problems	0.871	0.021	Research/Consulting	Business/Non-engr
V	Solve Ambiguous Problems	0.784	0.083		
D	Teach Self New Skills	0.834	0.001	Engineering	Business/Non-engr

*shading indicates a statistically significant result, with α=0.05

The above results demonstrate that the importance ascribed by graduates to various aspects of their undergraduate education is related to the particular post-graduation activity group they belong to; that is, whether they are among those who go on to full-time employment or graduate school, and also on the particular emphases of the post-graduate activity, namely, a technical or business-related orientation. It is noted that the causal relationship, here, is not completely clear, since two interpretations are possible. The first is that there is an initial difference among the groups and subgroups, *before* they become involved in the post-graduation activities, which then influences their perceptions/responses. Alternatively, it could be reasoned that the respondents' *current* engagement in various post-graduation activities, each involving somewhat different sets of tasks or professional emphases, is responsible for causing the group differences.

We would argue, however, that it is not so important which framework -- the past experiences which influenced the selection of post-graduation activity, or the current activities themselves – actually influence the perceptions. Either way, the perceptions clearly differ, and it would not be unexpected that the importance assigned to the various knowledge bases, attitudes and skills by the respective groups and subgroups would be related to what these graduates are actually doing. Those with full-time jobs are typically spending much of their time working in teams, preparing documentation, managing people and projects, etc. These activities become even more prominent for employed graduates who have business/management oriented roles, as opposed to strictly technical engineering, research or consulting functions. The same kind of pattern is evident for the two subgroups of graduate students; those pursuing advanced study in engineering versus those on a business track.

III. Relationship between Attitudes on Importance and Perceptions of Preparedness

In order to gain a better understanding of the relationships between preparedness and importance, a "preparation index" was devised for the selected competencies and abilities by analyzing the responses only for graduates who rated an ability as either "important "or "very important" (a 4 or 5 on the rating scale). Those rating themselves as either "very prepared" or "adequately prepared" were assigned a value of 1. Those rating themselves as "very unprepared" or "marginally prepared" were assigned a value of -1, and those rating themselves as "neutral" were assigned a value of 0. These values were summed and normalized by the total number of students who rated the specific ability as "important" or "very important" to arrive at the numerical value of the preparation index. As defined, the preparation index ranges from +1 to -1. An index of +1 would indicate that all respondents who rated a skill as important or very important to their job feel their education prepared them adequately to apply that skill; conversely, an index of -1 would indicate that all felt that they were not adequately prepared. A value of 0 means that equal numbers of students felt prepared and unprepared to apply a specific ability.

Figure 3 gives a plot of preparation index versus the percent of graduates who rated each skill as important or very important for the class of 2000 graduates. As a general guideline, items with indices less than 0.6 are considered to be an indication that the portion of the curriculum related to that competency or ability should be investigated. Most of the abilities receive satisfactory ratings from graduates, particularly those dealing with the technical portions of their education. Points P ("manage people'), R ("organize groups to work effectively"), and T ("deal with conflict in the workplace") all fall below the cut-off of 0.6 and are rated important by more than 50% of the respondents. Data with negative values (points U and Q) correspond to the ability to work effectively on international projects (U) or to create a budget (Q), and indicate that the majority of graduates rating these items as important to their jobs felt under-prepared. These items were rated as important by approximately 45% of the respondents. The data point N corresponds to application of general education in their careers and indicates that, although the preparation index for this educational component is given a value close to the cut-off indicating satisfactory preparation, it is not seen by a significant proportion of graduates as being very relevant to job performance or further study.

Indices were calculated in this manner for each competency or ability and for each class of graduates from 1995 through 2000. The results are shown in Table 5. Inspection of the data shows fluctuation in the index values of some items over time, particularly those with lower index values. However, it does not show any clear trends, indicating that the perceptions of preparation of graduates has not changed much over time.

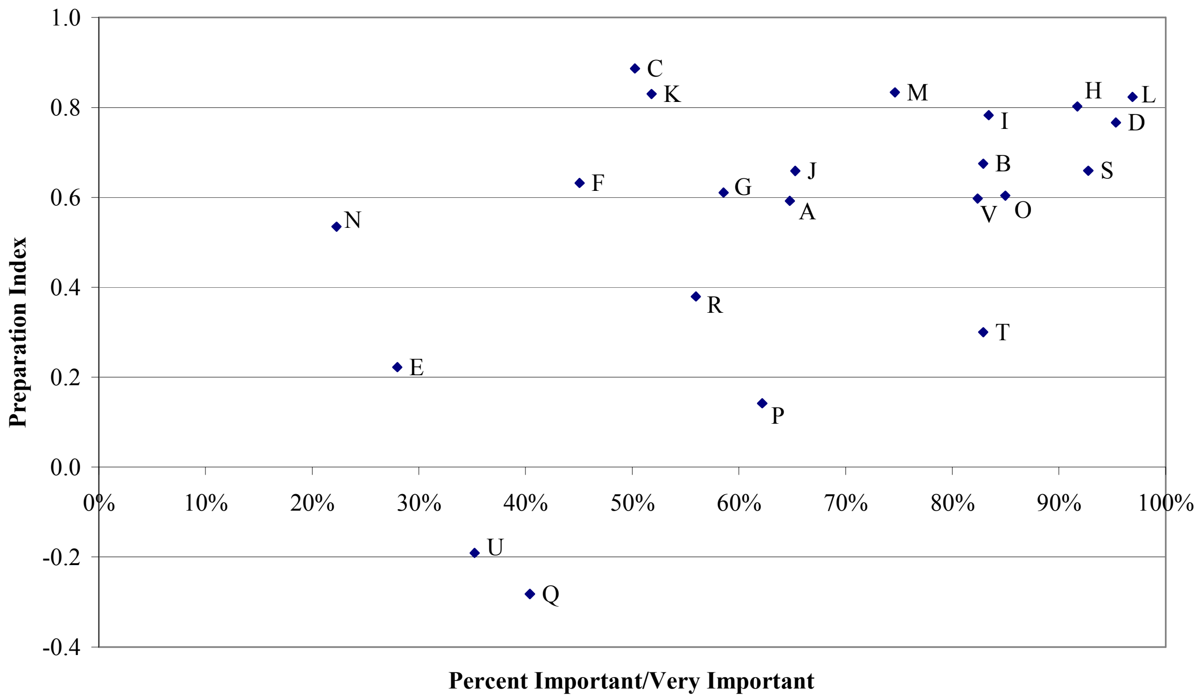

Figure 3. Preparation Index versus Percent Rating Skills as Important or Very Important for Class of 2000 Graduates

Table 5. Preparation Index Values for Selected Competencies and Abilities

		1995	**1996**	**1997**	**1998**	**1999**	**2000**
A	Make Oral Presentations	0.51	0.52	0.42	0.61	0.61	0.59
I	Write Clearly	0.63	0.69	0.70	0.75	0.79	0.78
S	Listen to Others	0.44	0.46	0.43	0.56	0.52	0.66
T	Deal with Conflicts	0.06	0.12	0.06	0.19	0.10	0.30
H	Work in a Team	0.63	0.73	0.74	0.72	0.70	0.80
R	Organize Groups	0.15	0.14	0.17	0.35	0.19	0.38
P	Manage People	-0.09	-0.11	-0.08	0.18	-0.11	0.14
O	Manage a Project	0.38	0.46	0.41	0.50	0.39	0.60
Q	Create a Budget	-0.29	-0.26	-0.27	-0.06	-0.14	-0.28
C	Apply Mathematics	0.91	0.83	0.93	0.89	0.95	0.89
K	Apply Science	0.87	0.85	0.84	0.75	0.84	0.83
M	Apply Engineering Skills	0.88	0.87	0.87	0.87	0.88	0.83
L	Use Computers	0.58	0.69	0.72	0.81	0.88	0.82
E	Design Lab Experiments	0.33	0.33	0.56	0.43	0.26	0.22
F	Analyze Data	0.69	0.74	0.65	0.68	0.69	0.63
G	Design Components	0.62	0.67	0.44	0.67	0.64	0.61
J	Design a Process	0.56	0.67	0.62	0.61	0.68	0.66
N	Use General Education	0.41	0.41	0.56	0.62	0.58	0.53
U	Work on International Projects	-0.24	-0.17	-0.60	-0.10	-0.25	-0.19
B	Solve Problems	0.71	0.64	0.65	0.57	0.58	0.68
V	Solve Ambiguous Problems	0.51	0.58	0.46	0.51	0.48	0.60
D	Teach Self New Skills	0.74	0.73	0.72	0.74	0.72	0.77

IV. Impact on Curriculum Design

What does the feedback from graduates mean for engineering education? In fact, the message conveyed by the survey data and this way of organizing them is not so surprising or unanticipated, although there are some interesting differences among graduates from the various majors (the subject, potentially, of a future paper). We have long known that the engineering curriculum is designed so as to make the basic science, mathematics and technical knowledge in the major discipline the highest educational priority. Design, computing, problem solving, effective communication and teamwork skills have also been given considerable attention as high priority educational outcomes, especially in recent years. Less emphasis has been placed on developing interpersonal or "people" skills, project management, or international aspects of engineering. The general education curriculum featuring courses in the arts, humanities and social and behavioral sciences constitutes a significant part of degree requirements, but have not been deliberately tied to professional needs or career paths. Anecdotal feedback has always indicated that graduates' perceptions of the importance of various curricular elements relates strongly to the career paths they choose, and that they do not see a strong relevance or correlation of general education course content to their professional lives. The real value in this kind of study, then, is not new revelations, but the quantitative character of the evidence. Taking the study one step further underscores this point. Figures 4 and 5 contrast the tasks being actually performed by graduates who take full-time jobs compared to those going to graduate school, and among those with full-time employment who are serving different functions such as in engineering, business, or research/consulting roles. Clearly, the importance these groups assign to various aspects of their education is closely correlated to the tasks they are being asked to perform.

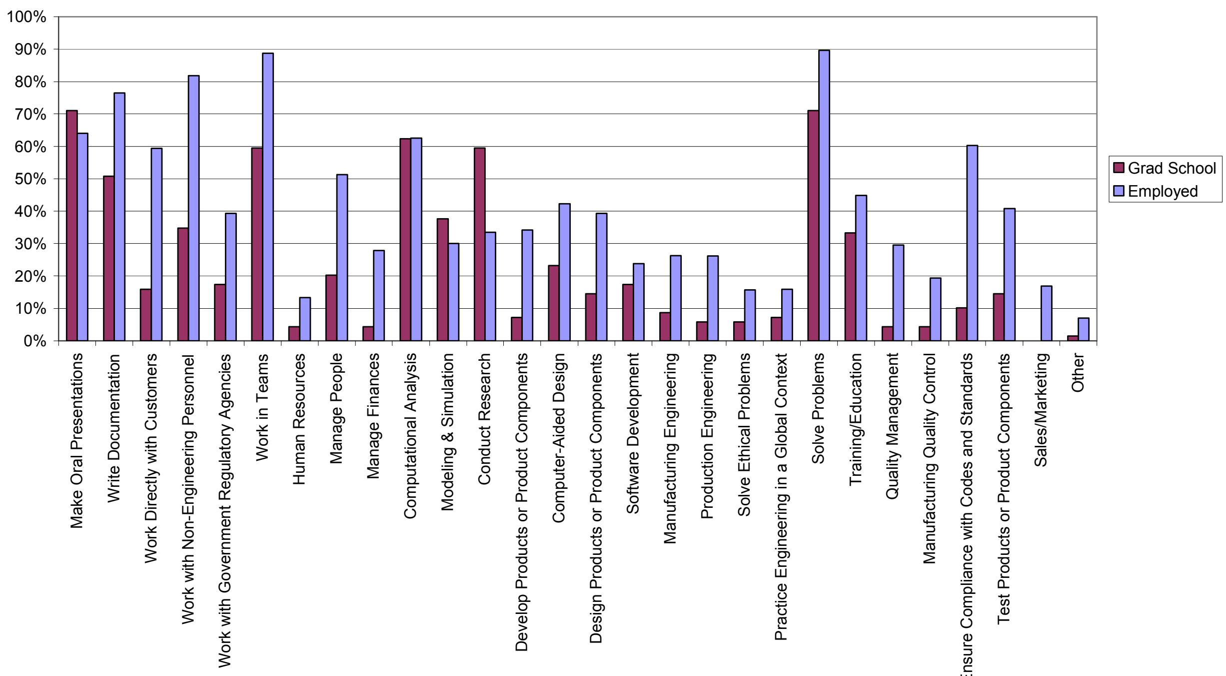

Figure 4. Percent of Graduates Entering Graduate School or Taking Full-time Employment Who Report Performing Various Tasks

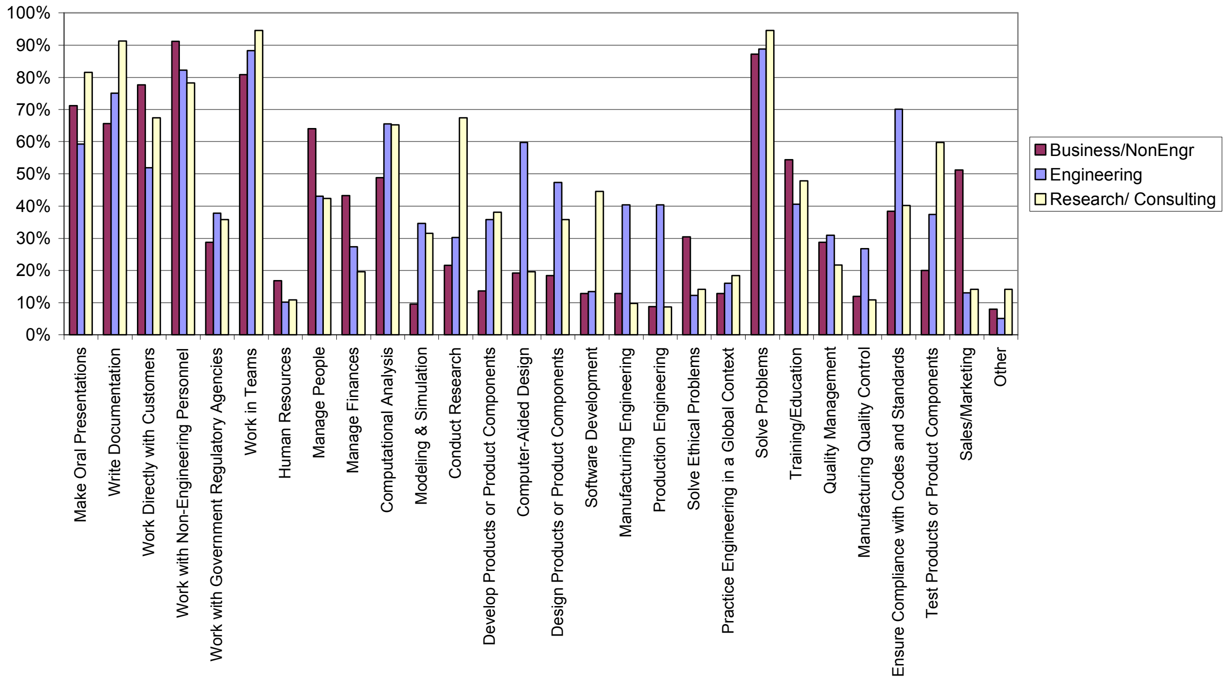

Figure 5. Tasks Performed by Graduates Working Full-time As a Function of Their Employment Emphasis or Function

Given the tight constraints on curricular structure and content imposed by both University-governed and accreditation requirements, major shifts in the credit distribution among the technical and non-technical components of the curriculum is not feasible. Nor would it be desirable to compromise the technical content for some or all students based on their projected career paths, since these are not typically determined until late in the college experience and, in any case, change significantly over the course of graduates' careers. Rather, it is important to look closely at the outcomes expected for each part of the engineering curriculum and how they interrelate, integrate with and build on one another to best prepare students for the a wide range of post-graduation environments and initial professional aspirations.

V. Conclusions

In order to address the findings recounted in this study, we are exploring a number of ways to revise the engineering curriculum and broader undergraduate experience at both the College and Department/Program levels at Penn State. These include: (1) providing better counsel to students on General Education course selections that will create more coherency and professional relevance, where appropriate; (2) exploiting available opportunities to integrate professional topics and skills into the technical curriculum, especially design-intensive and project-based courses and through other extensive problem-solving experiences; (3) developing a new course or courses emphasizing professional skills and core leadership competencies in a global environment; (4) creating enough curricular flexibility to allow students to incorporate or access elective elements (supplementary course work, academic minors, concurrent majors, etc.) to address specific career interests and prospects; and (5) expanding existing co-curricular options and introducing new avenues for student engagement in undergraduate research, community outreach, work and study abroad, and industry internships that provide practical workplace and/or laboratory exposure. A process for assessing how students access or experience various topics and competencies is being developed, which should assist in identifying potential collaborations across the broader curriculum and co-curricular activities.

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