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Perceptions of Professional Skills by Graduate Students—A Comparative Study between Engineering, Education and Biology*

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College graduates are increasingly expected to collaborate across disciplines in the modern workplace. In addition to possessing content knowledge, this requires them to be adept in professional skills, including written and verbal communication skills, team building and leadership, and to have an understanding of relevant global issues. A growing awareness exists among educators for the need to better equip students with professional skills for the changing workplace. Student perceptions related to the importance of these topics, and to their coverage in the formal curriculum have, however, not been examined. A comparative study between graduate students from three disciplines (Engineering, Education and Biology) is reported that quantifies these perceptions. A Likert survey was administered to graduate students in Engineering, Education and Biology, to determine their perceptions of the importance of professional skills to their careers, and whether such skills were addressed in their undergraduate and graduate curricula. Students from all disciplines rated professional skills as very important, and they also emphasized the lack of attention to these topics in their formal curricula. Interestingly, Engineering students rated pedagogy and interpersonal communication skills and proposal writing lower compared with students in Education and Biology. Engineering should investigate how the other disciplines incorporate content related to some of these important professional skills into their curricula. Other implications of the study for engineering students and educators are also discussed.

Keywords: professional skills; engineering education; global workplace; proposal development

1. Introduction

Content related to professional skills has been incorporated into Engineering courses at several universities due to requirements placed by the Accreditation Board of Engineering Technology (ABET) learning outcome based Engineering Curriculum 2000 [1], and by innovative curricula encouraged by the National Science Foundation (NSF) systemic reform programs, e.g., [2]. The need for professional skills is supported by a decade-long survey of engineers in industry and government, which showed that engineers spend 9.7% of their time in informal discussions ('receiving and communicating/sending'), 21.1% in input/receiving, and 27.3% in information output/sending, with electrical engineers spending about 55% of their time communicating [3]. Such professional skills include listening, message construction, working in groups, decision making, problem solving, leadership, multidisciplinary perspective, negotiation, conflict resolution, goal setting, understanding diversity, and globalization, and these have been identified as vitally important for successful careers [4–15]. Also, pedagogy (the art of teaching), and grant proposal writing skills are related professional skills that are also growing in relevance in industry and academia [7]. Despite the attempts cited above, Engineering education remains predominantly dependent on narrow, discipline-focused programs [16]. As an example, Baca [17] reported that engineers who were pressed into the role of project managers in industry tended to focus on technical issues, giving professional and/or management skills less credence, and consequently fell short of relating their game plans to the overarching strategy of the organization. Although there is increasing awareness among educators for the need for incorporating training in professional skills into the curriculum, what do graduate students think about such skills? The present study focuses on the perception of graduate students from Engineering, Education and Biology, on the importance of professional skills in their careers, and on their perception of its coverage in their curricula. This was motivated by a previous pilot survey of only Engineering graduate students that revealed student perceptions that such skills were important and were not being addressed adequately in the curriculum [18]. So, the present study surveyed a larger pool of Engineering graduate students, and also includes comparison groups of graduate students

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from two other disciplines, Education and Biology. The present study had three objectives. The first one was to determine graduate student perceptions of how well a topic was covered in their curriculum relative to how important they thought the topic was to their professional careers. A high score of importance but a low score of curricular coverage indicated that a topic of perceived importance was not addressed adequately in the curriculum. The second objective was to determine how each skill was scored between the particular degree programs, and to perform a comparative analysis to determine what Engineering students and educators might learn from the curricular coverage of professional skills by other disciplines. The third objective was to determine whether there were differences in perceptions between the responses of US and International students.

Pedagogy, including research findings from cognitive science, is explicitly addressed in the preparation of students in the colleges of education, but not typically addressed formally in Engineering or Biology departments. National Standards for teaching have been developed by Interstate New Teacher Assessment and Support Consortium, characterizing the knowledge beginning and developing teachers need to be successful [19]. Such knowledge includes an understanding of the central concepts in a particular content domain (e.g., science, mathematics, or social studies), knowledge of a variety of instructional strategies, knowledge of how students differ in their approaches to learning, and motivational and management strategies. However, teachers are heavily influenced by their prior experiences as students, leading to challenges as teachers attempt to teach in ways that are different from those experienced as students [20–21]. An understanding of how to successfully prepare and continue to encourage teachers to develop the knowledge necessary to become successful teachers is still lacking, and needs considerable empirical work [22].

Skills such as communication, teaching, mentoring, partnering, teamwork, managing complexity, maintaining appropriate standards and expectations are on par with the ability to do research and to read and analyze literature critically [23]. Also, Hurd [24] found that more than 50% of research scientists are currently working in industrial rather than university settings, and that 95% of scientific research reports are now multi-authored. Thus, professional skills such as teamwork and communication skills are also pertinent in the traditional physical sciences curriculum, such as in Biology. Interestingly, Biology departments do not have a national accreditation body, or any single professional society to monitor curricula. Therefore, there is no common senior experience between universities and typically no required professional development. Some universities have developed their own courses, but few have professional development emphasis in their programs. For instance, the Biology department at our university offers a course for first year graduate students that incorporates professional skills such as proposal development.

A lack of adequate courses addressing such skills, together with time constraints placed by research, precludes graduate students from reinforcing these essential survival skills. A follow-up to the Boyer Commission report [25–26] emphasized that as the range of employment for scientists and engineers expands, especially in the non-academic world, it is vital to begin developing these professional skills before leaving the university setting. In response to the increased demands to develop professional skills, as described above, and to address the discrepancy between the preparation of graduate students and the realities of both academic work and the labor market, an interdisciplinary team from engineering and education at our university (land grant, AAU, public university) developed a two-semester course sequence for Engineering graduate students to emphasize the role of professional skills in advanced engineering careers. The course was introduced to graduate Engineering students formally in 2006 to teach professional skills through four topic categories: Pedagogy and interpersonal communication skills, Team building and personal skills, Proposal development skills, and Globalization and gaining international experience. The two-semester course sequence [18] includes readings from books that cover several different areas: *How People Learn* [27], with a focus on the latest findings from cognitive science and their applicability to teaching; *The 7 Habits of Highly Effective People* [28] for discussion of some of the professional skills; and *The World is Flat* [29] for discussion of global trends and its effects on professionals. Other components of the course include lectures by guest speakers on topics ranging from how universities work and how to run successful research centers to leadership traits for engineers.

A pilot survey of 15 students at the end of the course one semester revealed that the Engineering curriculum did not address professional skills adequately, and that sustained instruction was critical for learning these skills [18]. As cited, the group decided to extend the study to a larger group, and to other disciplines such as Education and Biology, to understand students' perceptions across disciplines of the importance of these professional skills and whether these skills were addressed adequately in the undergraduate and graduate curricula. The present survey (Table 1) was administered to all

Table 1. Graduate student survey

Your status (circle one): Biology graduate student Education graduate student Engineering graduate student
Are you (circle one): U.S. Citizen International Graduate Student

Rate the importance, in your opinion, of:

(i) Your perception of the importance of the following skills/knowledge to your professional career

(ii) Your perception of the extent to which the following skills/knowledge was addressed in your undergraduate or graduate curriculum

RATE BY CIRCLING ON A SCALE OF 1–5: 1 being 'very little' and 5 being 'a lot'

		Part i Importance to your professional career	***Part ii Learnt from undergrad and grad engineering* curricula***
1	Cognitive science findings related to 'How people learn'	1 2 3 4 5	1 2 3 4 5
2	Deep understanding of content in your field	1 2 3 4 5	1 2 3 4 5
3	How to engage students in active learning	1 2 3 4 5	1 2 3 4 5
4	Use various assessment strategies	1 2 3 4 5	1 2 3 4 5
5	General pedagogical skills (e.g., lesson planning)	1 2 3 4 5	1 2 3 4 5
6	Interpersonal communication skills	1 2 3 4 5	1 2 3 4 5
7	Personal time management skills	1 2 3 4 5	1 2 3 4 5
8	How to mentor others	1 2 3 4 5	1 2 3 4 5
9	How to lead a team	1 2 3 4 5	1 2 3 4 5
10	How to assess a team's progress	1 2 3 4 5	1 2 3 4 5
11	Sensitivity to intercultural differences	1 2 3 4 5	1 2 3 4 5
12	Personal goal setting	1 2 3 4 5	1 2 3 4 5

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Rate the importance, in your opinion, of:

(i) Your perception of the importance of the following skills/knowledge to your professional career

(ii) Your perception of the extent to which the following skills/knowledge was addressed in your undergraduate or graduate curriculum

RATE BY CIRCLING ON A SCALE OF 1–5: 1 being 'very little' and 5 being 'a lot'

		Part i Importance to your professional career	***Part ii Learnt from undergrad and grad engineering* curricula***
13	Proposal development process	1 2 3 4 5	1 2 3 4 5
14	Various sections of a typical proposal	1 2 3 4 5	1 2 3 4 5
15	How to design a budget	1 2 3 4 5	1 2 3 4 5
16	Agencies who fund research	1 2 3 4 5	1 2 3 4 5
17	Common mistakes made during the grant proposal Process	1 2 3 4 5	1 2 3 4 5
18	Proposal review process	1 2 3 4 5	1 2 3 4 5
19	Global trends in engineering careers	1 2 3 4 5	1 2 3 4 5
20	How global trends impact your career field	1 2 3 4 5	1 2 3 4 5
21	Your preparedness for the global marketplace	1 2 3 4 5	1 2 3 4 5
22	Cultural issues and their impact on globalization	1 2 3 4 5	1 2 3 4 5
23	Impact of globalization on the way companies do Business	1 2 3 4 5	1 2 3 4 5
24	Role of collaboration in the global marketplace	1 2 3 4 5	1 2 3 4 5

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**** 'engineering' was changed to 'biology' and 'education' when the survey was administered to those disciplines***

graduate students in those departments, unlike the one in Mohan *et al.* [18], which focused only on students who were enrolled in the cited course. The importance of the four topic categories covered in the survey is briefly described next, followed by a discussion of the details of the survey, analysis of student responses, and findings of the study.

1.1 Pedagogy and interpersonal communication skills

As stated, pedagogy and research findings from cognitive science are explicitly addressed in the preparation of students in colleges of education. However, Engineering students and faculty are not exposed to these findings in a formal manner. Teaching skills are increasingly important for finding engineering jobs in academia and industry [30]. The successful teacher (or team leader/manager) is a coach more than a lecturer, and should be able to vary styles depending on the learning patterns of the students, or of the team/staff [31]. If teaching is primarily the imparting of knowledge, mentoring is imparting procedures: ways of thinking, performing research, and approaching new problems. A good mentor relationship is personal: a mentee should have opportunities to discuss issues of ethical, ideological and philosophical concern, as well as more practical matters. Exposure to such findings will prepare a researcher or a scientist for a role as a manager to mentor junior colleagues.

According to *How People Learn* [27], findings from cognitive science relevant to both teaching and mentoring (also applicable in industry, in our opinion) include: 1) Students typically come to class with preconceptions about the topics being discussed. If the students' initial understanding is not engaged, they may fail to grasp new concepts and information that are taught, or they may only learn them for the purposes of a test and then revert to their preconceptions outside the classroom; 2) Students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application; and 3) Instruction should emphasize a metacognitive approach so that students are aware of their own learning, which then enables them to define learning goals and to monitor their progress in achieving them.

Bransford *et al.* [27, pp. 19–21] provides the following implications for pedagogy:

1. Teachers (and team leaders/managers) must draw out and work with the pre-existing understanding that students bring with them. This contrasts with the model of the learner as an empty vessel, and instead requires the teacher to create tasks and conditions to understand the preconceptions students have, and to address those adequately prior to instruction in the specific topic. It also encourages the use of formative assessment tools to monitor learning continuously, with understanding. Such instruction is characterized as 'learner-centered';
2. Teachers must teach the subject matter in depth, providing many examples that illustrate the same concept at work, to provide a firm foundation of factual knowledge. In-depth coverage of fewer topics in an area is thus more beneficial than superficial coverage of many;
3. Teachers must integrate metacognitive skills into the curriculum to strengthen student ability to monitor their own thinking.

This framework for learning applies to both adults, and to children in K-12 education [32]. Learning and mastery of professional skills relevant to the engineering workplace involves an appreciation of these advances in cognitive science, and usage of the corresponding methods proposed to improve 'teaching' skills. As an example, awareness of cognitive science findings related to 'how people learn' can provide the basis, in many instances, for realizing why colleagues react as they do in individual and group settings, with both technical and personal biases. The knowledge and understanding of these cognitive findings is important to enhance expertise in the other three topic areas discussed below.

1.2 Team building and personal skills

Companies use teams as an integral part of their product development, process improvement and manufacturing activities. Further, management techniques such as concurrent engineering, total quality management, and business process reengineering are founded upon the concept of people working effectively in teams [14]. Similarly, research is becoming a collective enterprise in industry and academia, implying that graduate students in science and engineering are more likely to work as members of management or research teams. Engineering courses are being designed to provide students with the opportunity to experience teamwork first hand, so as to impart the skills necessary to work effectively in teams [14, 33].

As an application of the findings from cognitive science mentioned above (from *How People Learn*), consider an example of a team beginning work on an engineering design project. In such a case, team members bring preconceptions (including misconceptions) to the design meetings; if not adequately discussed and addressed, such preconceptions will considerably diminish the effectiveness of the team in accomplishing project goals. Awareness of possible misconceptions can enable the team leader to give them adequate importance, and to devise techniques to elicit them from members (which includes mentoring) and, importantly, to budget sufficient time to discuss them (much as an effective K-12 teacher would do). Similarly, the team leader needs to ascertain the depth of technical knowledge that members possess, and accordingly encourage/mentor some to pursue opportunities to strengthen their content knowledge. Finally, team members can be trained in metacognitive skills to monitor their own contributions to team work, and to their own overall growth. Hence, the importance of networking and working in teams should be addressed as part of seminars or lectures on leadership skills.

1.3 Proposal development skills—written communication

Buckley [34] noted, 'We listen to a book a day, we speak a book a week, read the equivalent of a book a month, and write the equivalent of a book a year.' Engineers are routinely required to write project reports and proposals. This requires the ability to organize thoughts and communicate effectively [3, 30]. Developing a proposal entails communicating to a panel about several aspects of work including relevance, originality, importance, soundness, adequacy, implementation, feasibility, sustainability, dissemination, evaluation and budget [35]. These invisible concepts are hard to learn unless taught in a formal setting.

1.4 Globalization and gaining international experience

Over the last decade, understanding of the global supply chain, diversity in the work force, and the changing socio-economic global landscape has been growing in relevance for students. The National Science Foundation [36] has stressed the need to 'educate a globally-engaged science and engineering workforce capable of performing in an international research environment in order to remain at the forefront of world science and technology'. Students are increasingly taking advantage of fellowships from federal agencies for studying abroad, and universities are also proactively advertising study abroad opportunities for students.

Employers and educators are thus aware of the need for incorporating training in professional skills into the college curriculum. However, it is unclear how graduate students themselves perceive these professional skills. We conducted a survey of graduate students (M.S. and Ph.D.) from multiple disciplines to ascertain student perceptions related to the topics, and analyzed their responses to determine potential implications for Engineering students and educators.

2. Design of survey and objectives

The Dean's offices in Engineering, Education (math and science education only), and Biology at our university sent electronic surveys to all their graduate students requesting completion via survey monkey. The students were informed that their participation was voluntary. The survey (Table 1) was developed by faculty from Engineering and Education, after their experience with developing and co-teaching a joint course for engineers focusing on professional skills. Surveys such as these are less expensive to develop, administer and analyze than other types of assessment methodologies and, by limiting the response choices, data collection can be repeated over time [37]. The questionnaires were designed to measure student perception of importance towards future careers and adequacy of curricular coverage in four professional skill areas: Pedagogy and interpersonal communication skills, Team building and personal skills, Proposal development skills, and Globalization and gaining international experience.

The graduate students rated question items from 1 (very little) to 5 (a lot) for both how important they felt the item was to their academic or professional career, and how well the item was covered in their undergraduate and graduate curriculum. Each question item pertained to one of the four professional skills, with about 5–6 question items per skill. The students were not informed of the professional skill categories or which questions fell under which categories. The average of a student's responses to each question item pertaining to a particular skill was used to represent the student's response for that professional skill category. This was done for all four professional skill categories for both how they viewed the importance of the skill and its coverage in the curriculum. The mean responses (scores) for each discipline were taken as the average of responses from all students from that discipline. These scores were compared across each of the four professional skill categories of pedagogy, team building, proposal development, and globalization, and across the three graduate student degree programs, Engineering, Education and Biology. Scores were also compared across each of the four professional skill categories between the perceived importance of the skill to careers, and its coverage in the undergraduate and graduate curriculum.

As cited earlier, there were three objectives in analyzing these comparisons. The first objective was to determine graduate student perceptions of how well a topic was covered in their curriculum relative to how important they thought the topic was to their professional careers. A high score of importance but a low score of curricular coverage indicated that a topic of perceived importance was not addressed adequately in the curriculum. The second objective was to determine how each skill was scored between the particular degree programs. The scores were compared by degree programs to determine if differences existed between the disciplines. First, means of the responses in these categories were analyzed to determine differences between the disciplines. To determine the significance of these differences, a two-way analysis of variance (ANOVA) was performed to analyze the responses separately in each of the four topic categories, across the three degree programs and the two areas of either perceived importance or curricular coverage. The first variable was the degree program, while the other variable was either the curricular coverage or the perceived importance category. A *t*-test was conducted on the variances found to determine significant differences between the responses. Statistical significance was taken as $p < 0.05$, and determined by *p*-values of variance found in the data.

The third objective was to compare the responses between US and International students. The same survey response data were used for this part of the study, but responses were separated by the student nationality instead of degree program. The same type of analysis was performed using a two way ANOVA calculated separately in each of the four professional skill categories. The variables for this ANOVA were the nationality of the student (US or International), and again the perceived importance or the curricular coverage. A *t*-test was conducted on the variances found to determine significant differences as before. The objective of this section was to compare the responses in each of the professional skill categories to look for differences between the US and International students. The data were analyzed using the R programming language [38] and software environment for statistical computing and graphics.

3. Findings and discussions

A total of 117 students responded from all three disciplines, with the following breakdown: 50 from Engineering (37 males, 13 females; 24 M.S. students, 26 Ph.D. students); 38 from Education (9 males, 29 females; 10 M.S. students, 28 Ph.D. students), and 29 from Biology (10 males, 19 females; 2 M.S. students, 27 Ph.D. students). There were 85 US students (28 from Engineering, 38 from Education, and 19 from Biology) and 32 International students (22 from Engineering, none from Education, and 10 from Biology.)

Table 2 shows the analysis of the survey of graduate students ($n = 117$) from Engineering, Education and Biology, in the four topic categories, Pedagogy, Team Building, Proposal Writing, and Globalization. The numbers reported for each category represent the means of student responses, while the weighted mean represents the responses of all students across the disciplines. Table 3 shows the comparison between the responses of US and International students. An analysis of the responses in

Table 2. Student responses across three disciplines

Topic	Discipline	Importance to professional career*** (means)	Addressed in the curricula (means)
Pedagogy and interpersonal communication	Engineering ($n = 50$)	3.84	3.04
	Education ($n = 38$)**	4.59	3.58
	Biology ($n = 29$)	4.03	3.32
	Weighted mean	4.17	3.32
Team building and personal skills	Engineering	4.06	2.99
	Education	4.25	2.81
	Biology	4.02	2.83
	Weighted mean	4.12	2.88
Proposal development	Engineering	3.85	2.29
	Education	3.72	2.22
	Biology ***	4.34	3.08
	Weighted mean	3.95	2.50
Globalization and gaining international experience	Engineering *	3.74	2.50
	Education	3.54	2.25
	Biology	3.22	2.27
	Weighted Mean	3.51	2.34

A score of 1 meant 'very little' emphasis and 5 meant 'a lot' of emphasis.
Disciplines marked with statistical significance (***$p < 0.001$,**$p < 0.005$,*$p < 0.01$) scored significantly higher in the topic compared with the others.

Table 3. Comparison of responses of US and International students

Topic	Discipline	Importance to professional career (means)	Addressed in the curricula (means)
Pedagogy and interpersonal communication	US (n = 85)	4.15	3.20
	International (n = 32)	4.02	3.67
Team building and personal skills	US	4.04	2.78
	International*	4.24	3.31
Proposal development	US	3.91	2.38
	International	3.99	2.89
Globalization and gaining international experience	US	3.46	2.22
	International*	3.70	2.77

A score of 1 meant 'very little' emphasis and 5 meant 'a lot' of emphasis.
US or International marked with statistical significance (*$p < 0.01$) scored significantly higher in the topic than the other.

each of the topic categories is provided next, followed by findings from the study, and implications for Engineering students and educators.

Pedagogy and interpersonal communication skills. The weighted mean of responses (i.e., average across all disciplines) to items in this category were 4.17 for importance to careers, and 3.32 for curricular coverage. Interestingly, the weighted mean values for both the importance to professional careers and for curricular coverage were the highest among the four topics. Also, the difference in the weighted means was the lowest (0.85) in comparison to the other topics.

Although Pedagogy is formally addressed in Education, this discipline has the largest difference in means (1.01) between the importance of this skill and its curricular coverage. Education students also scored Pedagogy the highest (mean of 4.59) for any discipline across all topics as far as importance to their career. This seems to suggest that although Pedagogy is an essential skill for Education students, graduate students in Education felt that this skill was not adequately addressed in their curricula. No statistical difference was observed between US and International students for this topic category ($p > 0.05$).

Team building and personal skills. The weighted mean responses to items in this category were 4.12 for importance to careers, and 2.88 for curricular coverage. The overall difference in the weighted means was the second highest (1.24) in comparison with the other topics, suggesting that this topic needs to be formally emphasized in the curriculum, particularly in Education and Biology.

For example, graduate students in Education rated the importance of this topic the highest (4.25), but rated curricular coverage the lowest. Also, as expected, Engineering rated this topic the highest (2.99) in curricular coverage probably due to this topic being adequately addressed via having students work in teams for laboratory and capstone projects.

The mean score for US students on team building was less than the score by international students by 0.36. This difference was statistically significant ($p < 0.05$) indicating a higher rating of this topic by international students.

Proposal development skills. The weighted mean responses to items in this category were 3.95 for importance to careers, and 2.5 for curricular coverage. The difference in the weighted means was the highest (1.45) in comparison with the other topics. This is significant as it suggested the largest gap between the perception of importance to career and curricular coverage to be the topic of proposal development. This highlights the need to formally address this topic in the curriculum in all the three disciplines.

Interestingly, compared with the other two disciplines, Biology students rated proposal development the highest in both importance to careers (4.34) and curricular coverage (3.08). This score for perception of importance to careers by Biology students was the second highest for any discipline among all the topics. Also, the difference between Biology and the other disciplines was the largest of any topic and was statistically significant ($p < 0.001$). This indicated a strong emphasis on proposal development in Biology, which could be of interest to the other disciplines. No statistical difference was observed between US and International students for this topic ($p > 0.05$).

Globalization and gaining international experience. The weighted mean responses to items in this category were 3.51 for importance to careers, and 2.34 for curricular coverage, with a difference of 1.17. It is noted that Engineering rated this topic the highest of the three disciplines in both perception of importance (3.74) and curricular coverage (2.50). Biology had the lowest score for perception of importance (3.22) across all topics for the three disciplines. US students rated Globalization lower compared with international students, and the difference of 0.39 was found to be statistically significant ($p < 0.05$).

3.1 Perceived importance of professional skills was rated significantly higher than curricular coverage by students from all disciplines

Engineering, Education, and Biology graduate students perceived the need of professional skills (Pedagogy, Team Building, Proposal Writing, and Globalization) as being very important for their careers, and also that they were not addressed adequately in their undergraduate and graduate curricula. Statistical analysis of the responses showed that perceived importance of professional skills was higher than curricular coverage in each of the four categories ($p < 0.001$). This suggests that students believe the professional skills were not addressed adequately, and this further emphasizes the need for formal training in these skills.

3.2 Pedagogy was rated highest, while Globalization rated the lowest, in both importance and curricular coverage

Pedagogy and interpersonal communication skills. This category was rated the highest in both importance and curricular coverage when averaged across Engineering, Education and Biology. The survey questions pertaining to Pedagogy (for example, deep understanding of content, how people learn, and assessment strategies) are also relevant in an academic setting, possibly leading to higher scores in this category. As expected, graduate students in Education scored this topic the highest for both importance and curricular coverage, compared with students from Engineering and Biology ($p < 0.005$). Pedagogy is formally addressed in the preparation of undergraduates and graduates in the colleges of Education and directly applies to their careers, and may explain their higher ratings.

Team building and personal skills. The importance of team building has always been strongly advocated in the undergraduate/graduate Engineering curriculum, and also emphasized by ABET EC 2000. Team building was rated as the second highest in its perception of importance towards career development and the second highest in terms of curricular coverage. The survey revealed no significant differences ($p > 0.05$) between the three disciplines on either perception of the importance of team building or its curricular coverage. This indicates that curricular coverage may be similar for all the three disciplines. Engineering typically requires students to work in groups on laboratory projects and capstone courses. Similarly extensive field work and data collection in Education would require the students to coordinate and interact with colleagues. The same is true in Biology with extensive bench-work in teams, helping them hone these skills.

Proposal development skills. As cited, proposal writing skills are growing in relevance in both industry and academia. Analysis from the study revealed that Biology students scored this topic higher on both perception of importance and coverage in their curriculum. The differences between ratings of Biology students was significant ($p < 0.001$) compared with both Engineering and Education students, suggesting that there may be greater emphasis on proposal development in Biology. One reason for Biology rating it higher compared with the other degrees may be that wet-lab research continually requires comparatively larger grants to maintain personnel, equipment and supplies. Another reason for this higher rating by Biology students may be their required first year course that incorporates proposal writing. In any case, this does suggest that Proposal Development needs to be formally addressed by colleges of engineering and education.

Globalization and gaining international experience. Globalization and diversity have been growing in relevance and have been identified to be vitally important for successful careers. However, among the four major skill categories in the survey, the mean score for globalization was the lowest on both perception of importance and curricular coverage. Among the three disciplines, Engineering ranked this category the highest, compared with Biology and Education ($p < 0.05$). A factor that could contribute to the relatively larger score by engineers may be the rapid growth of international divisions for major companies, and may be possibly due to outsourcing that requires them to constantly hone their skills. However, the low mean score for this category by all disciplines may also imply a lack of awareness of this subject, which may be noteworthy for educators.

3.3 Team Building and Globalization were rated higher by international students

International students rated team building higher than US students ($p < 0.05$). Intercultural differences, the work environment and the need to excel in a foreign land may contribute towards greater emphasis on this topic by international students. Also, international students may have scored higher since the survey questions focused more on intercultural differences, role of collaboration and global trends. Lack of exposure to some of these specific topics on the part of US students may also have contributed to their scoring them lower.

The findings from the survey were based on pilot data, and more extensive studies should be performed to validate the reported trends. Such extensive surveys could also gather and analyze the responses based on gender, degree type (undergraduate, M.S. or Ph.D.) and years within the program, area of focus within the discipline, whether the student has had a background as a teaching assistant, and career destination.

4. Implications for Engineering students and educators

The comparative study of the perceptions of students from three disciplines has several implications for Engineering students and educators. First, Engineering students ($n = 50$) perceived all four professional skills categories to be very relevant to their careers, and that opportunities for gaining such skills were insufficient in their undergraduate and graduate curricula.

Second, Engineering students reported curricular coverage of Proposal development skills (2.29) to be the lowest, followed by Globalization (2.50), Team building skills (2.99), and Pedagogy (3.04). This suggests that Engineering educators should proactively survey expectations of students at their institutions, and find strategies to address perceived deficiencies.

Third, the comparative study provides insights into what Engineering might learn from other disciplines. For instance, proposal development was rated significantly higher by students from Biology, possibly because they have more exposure to such skills in their curriculum. Since technical writing has been an area that needs improvement in Engineering, educators should consider studying the Biology curriculum to determine how they address it. Similarly, the category of Pedagogy and interpersonal communication skills is perceived as being very important by Education students and, based on the successful two-course seminar series for Engineering students [18], it appears that Engineering educators will benefit from studying how colleges of education incorporate such skills into their curricula.

Fourth, considering the fact that among all the disciplines, Engineering students rated globalization (3.74) the highest as far as importance to careers, educators should consider more international study and internship opportunities for their students.

Fifth, students should be proactively encouraged by faculty and administration to pursue opportunities to reinforce professional skills while still at school, by using existing opportunities such as joining appropriate campus organizations. Student advisement presently focuses largely on matters related to the curriculum. Advisors and counselors could also highlight the various college and campus organizations that the students should take advantage of to hone their professional skills.

Finally, Engineering has had a successful collaboration with Education to design a two-course Engineering seminar sequence "Preparing Engineering Faculty and Professionals" (1 cr hour each semester; [18]). The two-course sequence was enthusiastically received by Engineering graduate students from all disciplines and is presently in its 6th year of offering. Senior undergraduates have been permitted to enroll with instructor consent for the past two years. Educators should consider offering such courses to undergraduate and graduate Engineering students at their institutions.

Some additional suggestions are provided for Engineering educators. A strategy used by several schools to encourage teamwork is to increase homework grades turned in by teams over the work of individuals [39]. Such teamwork and collaboration encourages the student development of communication skills, facilitated through critique of weekly reports the teams present. The instructors also observe the internal social dynamics of the team and provide feedback and advice. Assessment of the project involves evaluating the organizational ability of the team and the manner in which the team presents itself and works as a unit to achieve its goals. This includes separate grades for those elements for which an individual is responsible, and for the contribution of each member as rated by the other members of the team [38].

To further encourage teamwork and interdisciplinary skills, cross-disciplinary programs with management, biology and other life sciences departments, and also with K-12 institutions have been developed by several Engineering schools [40]. To enable students to appreciate and further improve their communication skills, it is recommended that Engineering schools have focused courses (as the one cited above) and discussions about teaching and learning, including the use of technology as a tool to promote learning. For instance, all Engineering teaching assistants could be required to take such courses to enhance their interactions with students. The Biology department at the University of Missouri has required a seminar course for their graduate students, 'Professional Survival Skills,' of which proposal writing is an important segment. In the course, all students write a grant proposal, submit it to the instructor for a critique, to their peers for peer-review, and then to an extramural agency. Several of the proposals written thus far have been funded, including three NSF and two EPA predoctoral fellowships. Engineering educators should consider offering such opportunities to their own undergraduates and graduate students. All such learning opportunities for students can be implemented in a range of depth of coverage including workshops, 1 hour elective courses, full courses or even a minor program.

Lastly, it is suggested that Engineering educators also work with their faculty to expose them to the recent advances in cognitive science and pedagogy (e.g., [27]), and to provide them with additional ideas for effective teaching. This can be accomplished via focused workshops by experts on pedagogy to highlight findings that are routinely taught to students in colleges of education as they prepare K-12 teachers. Such findings include the importance of addressing prior conceptions that students bring to class, the importance of in-depth coverage of topics, the role of metacognition, and the various ways of assessing student learning (see [18]).

5. Conclusions

Although educators and employers are aware that professional skills are important and should be given more emphasis in formal curricula, the present study provides insight into the viewpoint of graduate students, and reveals several trends relevant to Engineering and to the other disciplines surveyed. Graduate students across three disciplines uniformly indicated that they felt the professional skills to be very important in their careers (3.93 out of 5), and also that they were not being covered adequately in their curricula (2.76 out of 5). Education graduate students felt that Pedagogy was very important (4.59 out of 5), as somewhat expected, and based on our own experience, this suggest that Engineering educators could benefit by investigating how Education incorporates such content into their curriculum. A similar analysis of how Biology incorporates proposal writing skills could be beneficial since their students rated proposal writing very highly (4.34 out of 5) as far as importance to their careers. Team building was rated the highest for career preparedness by Engineering students, due possibly to the important reforms undertaken by ABET and by concerned Engineering educators. In general, differences between students from the different disciplines were stronger than differences between US and International students.

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