Using an International Survey to Inform Scenarios of the Future of Engineering Education

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BACKGROUND
Technological, economic, and social changes will reshape undergraduate engineering education, but there is little consensus on its future. IEEE created a Curricula and Pedagogy Committee (CPC) and charged it with forecasting the future of engineering education in general and specifically to make recommendations regarding roles that IEEE will play in preparing for and crafting that future. The IEEE CPC used scenario planning to consider possible trends in engineering education and is opening its thoughts to public scrutiny. The IEEE CPC developed a survey to compare scenarios that it developed with patterns formed from respondents' views of the future.

PURPOSE
The CPC Committee functions as a research team seeking to learn (1) what is the current state of practice in higher education programs in fields of interest for IEEE?, (2) how are engineering programs forecasting practices that need to be in place to meet the needs of the profession in 10 years?, and (3) what services and collaborations might transform current practice to meet those needs?

DESIGN/METHOD
A survey was developed by the IEEE CPC. To examine how engineering programs might innovate and adapt, the survey included questions about current and future instructional practices and uses of instructional technologies. To examine values and competencies of engineering academics, the survey included questions that addressed skills that students have now and those they should have in the future as well as the roles that evaluation of teaching played in evaluating faculty members. The survey was deployed in July - August 2014 to individuals who (1) teach undergraduate students, (2) administer a degree program (i.e., Department Chairs and Heads), (3) serve as a top-level administrator over all engineering degree programs (i.e., Deans), and (4) work professionally in engineering. The results were compiled by IEEE Strategic Research and reported to the CPC for analysis.

RESULTS
This paper describes the demographics of the 2176 survey respondents. In addition, it reports on responses to the survey about teaching and quality versus quantity of engineers. An encouraging finding is that there is agreement among all types of respondents on the strategic priority of quality over quantity of engineers.

CONCLUSIONS
The congruence of our findings with expectations voiced by others, particularly in the area of teaching methods, indicates that the survey has validity and suggests that fields of interest to IEEE match the aggregate behaviour of engineering described in other work. The general congruence of responses across diverse respondents regarding the strategic priority of quality over quantity suggests that the field may be moving towards the more promising future scenarios. Results from the survey provide insight into the extent to which academics and industry professionals are expecting and contributing to the possible futures described in the scenario planning, which in turn provides insight as to how to prepare for whatever the future holds.

KEYWORDS
ECE Education; Scenario planning; strategic planning, survey

Introduction

Technological, economic, and social changes will reshape undergraduate engineering education, but there is little consensus on its future in 10 years. IEEE created a Curricula and Pedagogy Committee (CPC) and charged it to forecast the future of engineering education in general and specifically to make recommendations regarding roles that IEEE will play in preparing for and crafting that future. The IEEE CPC engaged in a scenario planning exercise (Berger, 1964; Kahn& Wiener, 1967; Schoemaker, 1993; Schoemaker, 2002) to consider possible trends in engineering education.

The results of this exercise are described in detail elsewhere (Froyd, et al., 2014a), but are briefly summarised here to provide context for the survey discussed in this work. An important step in the process was the identification of two critical uncertainties: (i) How will engineering programs innovate and adapt? and (ii) What will be the values and competencies of engineering academics?

The dichotomous extremes of each of these uncertainties are combined to anchor four scenarios as summarised in Figure 1. Particularly due to the variability of institutional missions, it is likely that more than one of these scenarios will coexist. The range of operating environments for different institutions will inevitably lead to different outcomes with respect to the key uncertainties.

	Engineering Programs Adapt	Engineering Programs do NOT Adapt
Engineering Academics Value Learning	Scenario 1: “Best of Both Worlds”	Scenario 4: “Life After Tara”
Engineering Academics Value Status Quo	Scenario 3: “Inmates are Running the Asylum”	Scenario 2: “Broken, Don’t Know Why”

Figure 1. Four Potential Futures of Engineering Education

Members of the engineering education community can provide information about likelihood of each of the dichotomous extremes, and their composite responses might be useful in analysing the four scenarios. To examine how engineering programs might innovate and adapt, the survey included questions about current instructional practices, potential future instructional practices, current uses of instructional technologies, and potential future uses of instructional technologies. To examine values and competencies of engineering academics, the survey included questions that addressed skills that students have now and those they should have in the future as well as the roles that evaluation of teaching played in evaluating faculty members. Also, since respondents to the survey included engineering faculty members as well as administrators, such as department heads, and deans, misalignments between those who teach engineering students and those who administer engineering programs will both inform the current trajectory of the field and be presented to both groups to contribute to the development of a shared vision of the future.

Scenario 1, “Best of Both Worlds”. In this scenario, engineering programs adapt well to changing societal, economic and technological developments, and academics prioritise student learning. Analysis of survey results to evaluate evidence in support of this potential trend could be done by evaluating degrees of alignment between faculty and administrators on the value of teaching as well as looking at the degree to which changes in instructional strategies and uses of instructional technologies are forecasted.

Scenario 2, “Broken, Don’t Know Why”. This is the negative counterpart to Scenario 1; engineering programs do not adapt to changing societal, economic and technological developments while academics maintain the status quo. Academics sense a problem, but continue to focus on research, as they maintain the status quo. Engineering graduates continue to be technically competent, but lack a variety of professional skills, leaving employers discouraged. Students are left to adapt after graduation and confidence in and funding for higher education erodes. Analysis of survey results for evidence in support of this potential trend would be done by looking at the antitheses of the patterns in Scenario 1.

Scenario 3, "The Inmates Are Running the Asylum". Engineering programs adapt, but those who teach engineering students do not. As the title suggests, this scenario reflects dissonance—a misalignment between academics focused on research and a changing reward system. As a result, many academics feel unable to meet needs of changing curricula. This scenario might include differentiated reward systems that academics do not understand. Engineering academics committed to student-engaged learning environments may do so through non-traditional programs, e.g., new institutions or online educational organizations. Analysis of survey results to evaluate evidence in support of this potential trend could be done by identifying responses indicative of student-engaged learning environments and seeing if there are patterns among these respondents.

Scenario 4, "Life after Tara[1]". Here, engineering programs fail to adapt, but those who teach engineering students prioritise student learning. This scenario is plausible—if those who administer engineering programs are unconcerned with student learning, they are not likely to notice what is going on in the classroom. Academics in this scenario must find professional development opportunities outside their institution. They must at least identify pathways to permanent appointments where those exist, and they must either find ways to succeed in the current reward system in spite of their student focus or draw satisfaction from sources outside the reward system. This scenario could lead to the initiation of new institutions that seek to shift to Scenario 1 thinking by recruiting talent from institutions still stuck in Scenario 4.

Methods

In this section, the survey target population, administration, and response profile are discussed. After the methods section, the paper reports descriptive statistics from the survey.

The Population Targeted

The survey was distributed electronically during July and August of 2014 to academics, department heads, and people in industry in various groups either in or associated with IEEE as well as the Electrical Engineers College of Engineers Australia. A total of 2,176 responses were received with details shown in Table 1.

Table 1: Sample and Response Rate, by List

List	Sample	Responses	Response Rate
IEEE Educational Activities Board	125	32	26%
IEEE-sponsored ABET Program Evaluators	447	107	24%
IEEE members (a random sample)	3702	661	18%
ECETDHA Department Heads	119	18	15%
ECEDHA Department Heads	360	54	15%
European and African department heads	29	4	14%
IEEE Education Society membership	2883	376	13%
Indian department heads	59	4	7%
Electrical Engineers College of Engineers Australia	22,000	920	4%
Total	**29,724**	**2176**	7%

[1] We apologise for this U.S.-centric film reference. It was suggested by an Australian. "Tara" is the ancestral home of the main character in *Gone with the Wind*.

Survey design and administration

The focus of survey design was to develop questions that would probe the four future scenarios described earlier to determine the current trajectory and the field's position on that trajectory. Another objective was to ascertain the role that IEEE might have in supporting that future.

A number of practices in survey design and administration were used to improve response rates, minimise sampling error, and maximise coverage area. Ensuring that the questions are clearly interpretable by participants reduces measurement error (Berdie, Anderson, & Niebuhr, 1986; Dillman, 2007). The survey design team had representation from the United States, India, and Australia, which helped ensure that questions would be correctly interpreted by an international audience with varying educational practices and terminology. The IEEE Strategic Research group reviewed the survey for readability and proper survey practice. Reminder messages were sent to non-respondents to improve response rates (Dillman, 2007; Klapowitz, Hadlock, & Levine, 2004; Deutskens, et al., 2004), and the emails were sent by IEEE, a credible source (Dillman, 2007).

Web surveys should take into account both how computers operate and how people expect questionnaires to operate (Dillman, Tortora, & Bowker, 1999), so survey branching was used to ensure that no respondent was asked a question for which the response was already known from their response to another question. Further, like items were grouped together to decrease survey time (Couper, Traugott, & Lamias, 2001; Deutskens, et al., 2004). Branching to reduce overall survey length and displaying a progress indicator have been found to motivate participants to continue (Couper, et al., 2001; Dillman, et al., 1999).

The response rates are generally in line with expected rates for surveys distributed electronically. While Dillman (2007) has reported response rates as high as 58%, much lower response rates are commonly reported. Klapowitz and colleagues (2004) report a 25-30% response rate and Deutskens and colleagues (2004) reported 17-25% response rates. Incentives increase participation in surveys (Bosnjak & Tuten, 2003; Church, 1993; Deutskens, et al., 2004). The primary incentive in this case was the participants' relationship to IEEE, and the findings in Table 1 are clear—the response rates are strongest among those with the strongest relationship with IEEE, those active as volunteers. As would be expected, those with the looser ties to IEEE had lower response rates.

Survey respondents

The survey respondents self-identified into one of the groups below. Those who selected "Other (please specify)" in question 1 (340 respondents, 15.6%) did not continue in the survey. The two largest subgroups of Other self-identified as retired or as students. The responses are divided quite evenly among those who teach engineering students (30.3% of respondents), practitioners in industry and government (28.1%) and management in industry, government, and academia (25.9%). Table 2 shows the breakdown of respondents.

Table 2 - Primary Occupation

Occupation	n	Percent Selected
I teach student engineers at an academic institution (public or private)	659	30%
Department Head/Chair or equivalent position at an academic institution (public or private)	188	9%
Dean or equivalent position at an academic institution (public or private)	80	4%
Industry Practitioner (engineering, technical staff, and so on)	549	25%
Industry Manager (hire, manage and direct an engineering or technical staff)	262	12%
Government Practitioner (engineering, technical staff, and so on)	63	3%
Government Manager (hire, manage and direct an engineering or technical staff)	35	2%
Other (please specify)	340	16%

Gender distribution of respondents. Overall, 12% of respondents were female, which is typical for the discipline, but there were differences by occupation. While the percentage of women in all other categories ranged from 9-11%, those who teach students are more likely to be female (17%), whereas only 5% of industry managers reported as female. This disparity in leadership positions is not found among the leaders in academia (Chairs/Heads and Deans) or among government managers among our survey respondents.

Among those who teach engineering students (659 respondents), it was anticipated that responses might vary based on the level of students the respondent typically teaches. To ensure consistency with an individual's response, to consider possible variation in teaching practices by student level, and to assess the distribution of student level taught by survey respondents, participants specified an undergraduate subject they taught during the previous academic term and anchored their responses to that subject. Since a single subject can enrol students at different levels, the responses add up to more than 100%. As Table 3 shows, the 659 respondents represent subjects that span the undergraduate curriculum.

Table 3 - Level of Students Taught by Respondents

Level	Percent Selected
First year	22%
Second year	34%
Third year	44%
Fourth year	34%
Fifth year	12%
Sixth year or higher	8%

Academic Department heads and chairs comprise 8.6% of all respondents (n=188). Institution size varies in the sample—about 40% of these academic managers came from institutions with 200 or fewer undergraduates, about 40% from institutions with 201-500, and about 20% with more than 500. Department size varied as well; 15% of respondents had a small department (9 or fewer people who teach), 36% between 10 to 20, 18% from 21 to 29, and 31% larger than 30. These administrators indicated a workload, on average, comprised of 47% teaching, 34% research, 15% service, 11% partnership, and 7% other.

On average, administrators reported 23% female and 77% male undergraduates in their programs. We are averaging percentages, so this does not mean that the undergraduates represented are distributed in those percentages. Nevertheless, this ratio is surprisingly high given the lack of diversity in students of EE and CpE internationally (Mills, Ayre, & Gill, 2003; Godfrey, 2007; Lord, et al., 2009; Lord, Layton, & Ohland, 2011; Lord, Layton, & Ohland, 2014; Litzler, 2010; Anderson & Gilbride, 2003; Hazzan, Levy & Tal, 2005; ASEE, 2014). A large, multi-institution study (Lord, et al., 2009) noted only 11% of EE students and only 4% of CpE were women. Godfrey (2007) reported similar percentages of female participation as 16% of EE and 14% of CpE. The question asked was, "What is the gender makeup of your undergraduate students, approximately?" We do not believe department heads or chairs would provide figures for institutional rather than program enrolment, but it is possible.

The majority of administrators (55%) indicated that their institution was research-focused, some in many fields (42%), some in only technical fields (13%). The primarily undergraduate-focused institutions were similarly divided between comprehensive institutions (25%) and technically focused institutions (17%). Recognizing that an institution's mission to serve a particular population can shape its approach to engineering education, we asked participants to indicate if their institution had a special mission to serve one or more underrepresented populations, and 45 (26%) reported a mission focused on serving such a special population. This was higher than expected, and a quick review of respondent performance indicating what population is served revealed an astounding diversity of institutional missions and also indications that our question was misinterpreted. Of the 45, 27 respondents described a commitment to diversity rather than a special mission. The remaining 18 identified a variety of underrepresented populations, including first-generation college students, ethnic and religious minorities, and various native populations disadvantaged by colonialism. It is likely that some respondents are referring to scholarships or other recruiting programs that target those students or that those students receive special consideration in admissions.

Academic administrators (n=268), which adds Deans to the previous group, were split regarding curricular focus, with 43% claiming their "curriculum emphasises theory-based courses; students apply what they learn in one or two design courses" while 44% claimed their "curriculum emphasises extensive engineering practice".

Industry and government managers and practitioners (n=909) make up the remaining responses. The primary job function of these respondents was frequently engineering and technical design (24%) and management in those fields (19%). Those in consulting, retired, or unemployed, made up 14% of respondents, and are not represented in the findings below. The detailed data regarding job function are shown in Table 4.

Table 4 – Primary Job Function	
Percent Selected	**Job**
24%	Engineering/Technical Design
19%	Management: Engineering/Scientific/Technical
12%	Engineering/Technical Applications
11%	Consulting
8%	Management: Corporate/Government
6%	Engineering Testing, Reliability, Quality Control or Standards
4%	Engineering/Technical Research
4%	Management: Software/IT
4%	Engineering Production (Processing or Manufacturing)
3%	Management: Other (please specify)
2%	Software Development
6%	Retired, Unemployed, Other

While 27% of non-academic respondents worked at small organizations (1 to 25 engineers), nearly twice as many (48%) worked at organizations with 201 or more engineers. The remaining non-academic respondents were evenly divided among companies employing 26-50, 51-100, and 101-200 engineers. The respondents tended to have a considerable amount of experience – only 9% of respondents had fewer than five years' experience, whereas a majority (58%) had more than 20 years' experience. For reasons unknown, those working in power, energy, and industry applications dominated the respondents—see Table 5. It is unclear whether or how overrepresentation of this sector influences the survey results.

Table 5 – Organizations Primary Sector or Technology Area	
Resources	**Percent Selected**
Power, Energy and Industry Applications	42%
Aerospace/Defense	9%
Communication, Networking and Broadcasting	8%
Computing and Processing (Hardware/Software)	6%
Transportation	6%
Other (including categories w/ less than 3% each)	29%

Where the sample composition is relevant to our findings, it will enter into our discussion—particularly when it is appropriate to compare the responses of multiple types of respondents.

The usefulness of scenario planning is dependent on the development of scenarios that are well-informed. To address this limitation, the IEEE CPC is establishing the validity of the scenarios by presenting the results of the scenario planning exercise in a special session at the 2014 Frontiers in Education conference (Froyd, et al., 2014b) and through this work – informing the scenarios through a globally distributed survey capturing both academic and industry perspectives. Sharing those results publicly at the 2014 AAEE meeting provides further opportunity for the larger engineering education community to improve the scenarios and how we interpret them.

Responses about Teaching

Results are presented describing expected future teaching methods and curriculum approaches, which directly inform one of the critical uncertainties – the values and competencies of academics. Responses forecasting the use of various teaching resources also help determine the trajectory of student learning. Finally, we report the prevalence and acceptance of online courses and Massive Open Online Courses (MOOCs), because it is timely and speaks to the uncertainty in institutional adaptability.

Teaching methods

Respondents reported that lecture will still be the most commonly used teaching strategy in the next five years, although it is worth noting that 4% of respondents indicated that they never plan to lecture again. The only other responses used at least once per week by a majority of respondents were having individual students conduct activities beyond listening and taking notes and having individual students do homework to prepare for class. The former finding is consistent with recent findings (Borrego, Froyd, & Hall, 2010).

Strategies using teams were more likely to be projects and were expected to be used least often. Please see Table 6 for more details.

Table 6 - How Often Do You Plan to Use Each Strategy?

Strategy	Never	Once to a few times per term	Once or more times per week	Every class
Instructor lecture	4%	12%	50%	34%
Individual students conduct activities beyond listening and taking notes	12%	42%	33%	14%
Individual students do homework to prepare for class	18%	31%	41%	10%
Teams of students conduct activities beyond listening and taking notes	19%	49%	22%	10%
Individual students do homework after class for evaluation	14%	41%	37%	8%
Students work on projects that last the entire term	31%	52%	10%	7%
Teams of students working on projects lasting multiple days and are taught the skills to complete the project as it proceeds	22%	58%	14%	6%
Teams of students do homework to prepare for class	36%	36%	22 %	5%
Individual students working on projects lasting multiple days and are taught the skills to complete the project as it proceeds	27%	54%	14%	5%
Teams of students do homework after class for evaluation	34%	42%	20%	4%

Curricular approaches

In addition to considering approaches used in the classroom, there is value in exploring other aspects of curricular design—the prevalence of synchronous meetings, distance education, undergraduate research, service learning, work-integrated learning, and MOOCs.

Lectures were by far the most likely educational practice to be used in nearly or every class (52% for once to multiple times per week and 40% for every class). Labs were also likely to be used often (55% said they would use them once to multiple times a week). Service learning and distance education were the least likely to be used. The lower incidence of service learning was expected based on the findings of Borrego, Froyd, and Hall (2010)—the aggregated response of all those who use some service learning nearly matches their findings, even though the populations in our studies were very different. See Table 7.

Table 7 - How Frequently Did You Use Each Educational Practice?

Practice	Never	Once to a few times per term	Once to multiple times per week	Every class
Lectures	1%	7%	52%	40%
Labs	15%	21%	55%	9%
Distance education	73%	17%	7%	4%
Undergraduate research	42%	47%	8%	2%
Service learning	77%	17%	4%	2%
Work placements alternating with academic enrolment	73%	20%	6%	2%
MOOCs	87%	9%	3%	1%

Consistent with observations that topics are more commonly added and less frequently removed—at both the scale of an individual academic subject and at the curricular scale (Black, 1994; Martin, et al., 2005)—the "Never" response declines for all options in Table 8 (next 5 years) vs. Table 7 (current practice). Considerably more respondents expect to use distance education, MOOCs, undergraduate research, service learning, and work placements in the next 5 years than did during their previous semester. However, lecture and labs will still be used more frequently. See Table 8 for more details.

Table 8 - How Frequently Do You Plan to Use Each Educational Practice in the next 5 years?

Strategy	Never	Percent change	Once to a few times per term	Percent change	Once to multiple times per week	Percent change	Every class	Percent change
Lectures	1%	-1%	9%	2%	54%	2%	36%	-3%
Labs	8%	-8%	24%	4%	59%	4%	10%	1%
Distance education	52%	-22%	33%	16%	12%	6%	4%	0%
Undergraduate research	27%	-16%	59%	11%	13%	4%	2%	0%
Service learning	63%	-14%	27%	10%	7%	3%	3%	1%
Work placements alternating with academic enrolment	59%	-14%	30%	10%	9%	3%	2%	1%
MOOCs	68%	-20%	23%	14%	7%	4%	2%	1%

In the aggregate, there are institutions that teach design in all parts of the curriculum. The prevalence of design content grows to a maximum in the fourth year to 71%. About a third (32%) of institutions places a strong emphasis on internships, a quarter (25%) on alternating school and work experiences, and a fifth (22%) on industry partnerships in the classroom. Nearly all respondents said their programs are accredited (90%).

Use of teaching resources

Respondents currently use or expect to use several electronic resources in the next five years; electronic notes, course management systems, online tutorials, downloadable software, eBooks, and virtual and simulated labs were the most frequently selected items for future use – each selected by more than 45%. However, most online collaborative or social resources scored low including collaborative annotation tools (20.4%), shared note taking (16.7%), Google group (16.1%), Google hangout or Skype (14.8%), collaborative sketching (8.5%). Please see Table 9 for more details.

Table 9 - Resources Used or Planned to Use

Resources	Percent Selected
Electronic lecture notes	63%
Course management system / Learning management system (for example, Moodle or Blackboard)	61%
Online tutorials	60%
Downloadable instructional software	53%
eBooks	51%
Virtual / Simulated labs	46%
Instructional materials developed at another institution	45%
Video Lectures (recorded remote lectures)	43%
Plagiarism checker	43%
Discussion forums (online)	42%
Web platforms (for posting questions during lecture)	42%
Computer-aided design and drawing	40%
Instructional materials developed outside of academia	35%
Wikipedia (or other wikis)	31%
Mobile platform applications (for example, smartphones and tablets)	28%
Automated grading systems	24%
MOOCs through Coursera, EdX, and so on	22%
Video conferencing (live remote lectures)	20%
Collaborative annotation tools	20%
Remote labs (actual laboratory hardware located at a different physical location and accessed via a computer by a student)	20%
Shared notes taking	17%
Google group	16%
Blogs	15%
Google hangout / Skype	15%
Collaborative sketching	9%

Unfortunately, the most popular uses of technology are those that simulate the most passive approaches to learning. It is difficult to interpret this finding, however. If less engaging approaches are being implemented using technology out of convenience, that is unhelpful. On the other hand, if these methods are seen as necessary, these methods might be used to move less-engaging activities out of class to maximise the time for discussion and other interaction during class time, and that is a good strategy.

Prevalence and acceptance of online courses and MOOCs

Respondents were much more likely to teach courses in-person than online; in the last academic term, 88% had taught at least one in-person class versus just 13% who had taught at least one online. Most (46%) taught one or two classes in-person, while 28% taught three or four. Please see Table 10 for more details.

Table 10 – In-person vs. Online Teaching		
Courses Taught	**In-person**	**Online**
0	12%	87%
1 to 2	46%	8%
3 to 4	28%	3%
5 or more	14%	2%

Administrators appear to be adapting to the availability of curricular resources. The majority of administrators were likely to encourage the use of teaching materials developed by another academic institution (51%). However, just 26% would encourage the use of materials from a non-university provider.

In curriculum design, administrators seem to want to maintain control locally—just 36% said they would model a new degree program after an existing degree program at another institution. The administrators seem more trusting of IEEE, however; nearly half (46%) would use an IEEE model curriculum for developing or revising a degree program. Most respondents are at institutions that have not yet begun awarding credit for student participation in MOOCs (83%) while just 5% have and 12% did not know. Respondents believe that their institution is more likely to award credit for MOOCs as time passes, with about equal numbers expecting their institution to award credit as those who believe that outcome unlikely 15 years in the future.

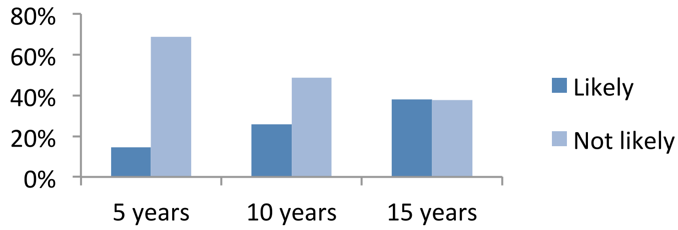

Figure 1 – Likelihood to Award Credit for MOOCs

Responses about quantity vs. quality of engineers

The dominant rhetoric worldwide in engineering is that more engineers are needed. Reports from Australia (Engineers Australia, 2012), the United States (NAE, 2006; Jackson, 2004, JEC, 2012, PCAST, 2012), Britain (Bowen, et al., 2007; Harrison, 2012), Sub-Saharan Africa (Matthews, et al., 2012), and others describe a shortage of graduates in engineering or in technical fields more broadly. While others have argued that there is no evidence of a shortage (Wadhwa, et al., 2007; Smith & Gorard, 2011), the rhetoric persists. Meanwhile, other reports and accrediting bodies described earlier in this paper call for the development of more engineering competencies. Quality and quantity are in principle independent, yet compete at some level as institutions make decisions about scale and strategy.
To explore the sense of the profession regarding these choices, we asked, “Some have expressed concern over the number of engineering graduates. Others are more concerned with improving the skill set of engineering graduates, even if it reduces the number of graduates. Which of the following do you think is more important?” The response choices and the rates at which each population chose them are shown in Table 12. All populations surveyed indicated an overwhelming preference for better-trained engineers rather than more engineers (65.2% versus 3.5%), while 31.3% saw them as equally important.

The columns in Table 12 correspond to the rows in Table 2—ranging from those who teach engineering students (**Acad**), academic chairs (**Chair**), deans (**Dean**), industry practitioners (**IndP**), industry managers (**IndM**), government practitioners (**GovP**), and government managers (**GovM**).

Table 12 – Does the profession need more or better trained engineers?							
Resources	**Acad**	**Chair**	**Dean**	**IndP**	**IndM**	**GovP**	**GovM**
Having better trained engineers is much more important	44%	46%	32%	46%	44%	42%	50%
Having better trained engineers is somewhat more important	19%	22%	19%	22%	27%	13%	32%
Both are equally important	35%	30%	37%	29%	24%	39%	9%
Making sure we have more engineers is somewhat important	2%	0%	2%	1%	1%	5%	9%
Making sure we have more engineers is much more important	1%	3%	11%	1%	4%	0%	0%

The congruence of the various respondents is notable. Although both industry and government respondents should have some interest in a larger supply of engineering graduates—making it easier to recruit engineers to fill vacant positions and driving down salaries—those respondents clearly indicate a preference for better-trained engineers rather than more engineers. This may explain why 9% of government managers indicated that "Making sure we have more engineers is somewhat important." Similarly, industry managers were more likely to choose that response than industry practitioners. Some Deans would have an incentive to increase the number of engineers so that they have higher enrolments and revenues, which may explain the fact that Deans have a higher response rate for "Making sure we have more engineers is much more important."

As one of our survey respondents described in an open comment on the survey, forcing respondents to choose between better-trained engineers and more engineers is something a false dichotomy. As noted, however, these priorities may affect strategic directions. The polarization of the responses to this question suggests that there is some truth to this dichotomy, and that there is surprising clarity in which choice is preferred.

Conclusions

The congruence of our findings with expectations voiced by others is indication that the survey has validity. Even more encouraging are findings regarding the prevalence of certain teaching methods that agree with those published by others. This latter agreement is an indication not only of the validity of the IEEE CPC survey, but also suggests that fields of interest to IEEE match the aggregate behaviour of engineering described in other work where there was no disaggregation by discipline.

Returning to the scenarios described earlier in the paper, the general congruence of responses regarding the strategic priority of quality over quantity is very encouraging. The congruence of responses across diverse respondents suggests that we may be able to avoid **Scenario 3** and **Scenario 4**, the scenarios in which engineering programs and those who teach engineering students are working at cross-purposes. The focus of all populations on the quality of engineering graduates gives hope that respondents are generally trying to chart a path to **Scenario 1**. Noting that 4% of academic respondents indicated that they never plan to lecture again, we are particularly encouraged that academics plan to avoid **Scenario 3**.

We find further evidence that engineering programs are adapting in the expectation that more institutions will award credit for MOOCs as time passes, with about half of respondents believing their institution will award credit for MOOCs within 15 years. If this strategy is critical to success but not adopted by all, some programs may go the way of **Scenario 4**.

As analysis of the survey results continues, particularly analysis of responses from practitioners, a deeper understanding of the future of engineering education will emerge. The results of the IEEE CPC survey and the survey itself will be shared with other professional associations in hopes that it will be possible to validate our findings in other disciplines.

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