Scenario Planning to Envision Potential Futures for Engineering Education

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Abstract—Various technological, economic, and social developments may radically reshape engineering and computer science education in the next 20 to 30 years. Leaders in engineering education, such as IEEE, that play key roles must decide how they will innovate and support initiatives to improve engineering education. The IEEE’s Curriculum and Pedagogical Committee (CPC), which is charged with helping IEEE forecast the future of engineering education and make decisions about IEEE’s roles in preparing for and crafting that future, engaged in a scenario planning exercise to help understand how various influences and trajectories could influence engineering education. Scenario planning methodology has been used by many organizations making long-term investments. After considering influencers in the engineering education environment; important stakeholders and their roles (influencer, purchaser, end-user, decision maker); goals, constraints, and outcomes for key stakeholders; and potential uncertainties, the CPC identified two critical uncertainties over the next five years: (i) How will engineering programs innovate and adapt? (ii) What will be the values and competencies of engineering faculty? Considering two extremes for each of these uncertainties, the CPC crafted four scenarios, which are described in this paper, to characterize potential future trends and how different scenarios will influence the evolution of engineering education.

Keywords—polarity management; scenario planning; strategic planning

I. INTRODUCTION

Undergraduate engineering education will be radically reshaped over the next 20 to 30 years by various technological, economic, and social developments. Although the future of engineering education cannot be predicted, it can be influenced. Leaders in engineering education, such as IEEE, that play key roles must decide how they will innovate and support initiatives to improve engineering education. Decisions must be guided by both historical trends and potential future evolutions of engineering education. Therefore, the IEEE’s Curriculum and Pedagogical Committee (CPC), which is charged with helping IEEE make solid decisions, engaged in a scenario planning exercise to help understand how various influences and trajectories could influence engineering education. Scenario planning methodology has been used by many organizations making long-term investments, to understand how future developments could be taken into account when making key decisions. The approaches used in scenario planning were simultaneously developed by various scholars [1], [2], but it is Schoemaker who is credited with the most rigorous scholarly treatment of the method [3]. Schoemaker notes that scenario planning is distinguished from other planning techniques in that it is qualitative and multivariate [4].

After considering influencers in the engineering education environment; important stakeholders and their roles (influencer, purchaser, end-user, decision maker); goals, constraints, and outcomes for key stakeholders; and potential uncertainties, the CPC, as a crucial step in the process, identified two critical uncertainties: (i) How will engineering programs innovate and adapt? And (ii) What will be the values and competencies of engineering faculty? Considering two extremes for each of these uncertainties, CPC crafted four scenarios to characterize potential future trends and how
different scenarios will influence the evolution of engineering education. Generation of scenarios through consideration of extremes recalls the polarity management approach [5]. The polarity management metaphor is particular helpful in considering the multiple missions of academia that seem in tension with one another, but which are both necessary for the system as a whole to thrive — e.g., teaching vs. research or preserving knowledge vs. generating knowledge.

A criticism of the scenario planning process is that the usefulness of the method is dependent on the development of scenarios that are well-informed. To address this limitation, von der Gracht [6] and others have suggested integrating a Delphi process with scenario planning so that the expertise of the Delphi panelists can ensure the quality of the scenarios generated. Rather than use a Delphi process, the authors propose to establish the validity of the scenarios in two ways — by presenting the results of the scenario planning exercise in a special session at the 2014 Frontiers in Education conference [7] and by informing the scenarios through a globally distributed survey capturing both academic and industry perspectives. The survey will be administered to educators, department heads, and deans at engineering programs across the world as well as to corporate practitioners. Some of the areas addressed by the survey include: enabling technologies; program strengths; markets for engineering graduates; expectations of employers for engineering graduates; characteristics of accreditation systems; approaches for assessment and development of selected student attributes such as engineering design; and faculty experience.

This paper describes the scenario planning process and explores four scenarios for the evolution of the engineering education enterprise. Describing this process both illustrates how the authors produce the reported results and provides a model for other organizations engaged in planning processes.

II. Framing Development of Potential Futures of Engineering Education Programs

As Heath and Heath point out in their book Decisive [8], one of the biggest challenges faced by decision makers is broadening how decisions are framed so that a wide range of potential alternatives are considered. Therefore, the scenario planning exercise includes multiple activities designed to help participants consider a wide range of influential stakeholders, forces, trends, patterns, etc.

The process was led by a Senior Business Strategy Manager at IEEE who had experience leading such workshops. The participants included the five members of the CPC (EE faculty/administrators from across the world), two IEEE staff, and an additional Engineering Dean who is active in IEEE. The participants were divided into two groups. Each group produced an output for each exercise and shared it with the larger group. The membership of the groups was changed in the middle of the day. The entire process took one business day.

The goals of the scenario planning process were stated as:

Part I: Explore the Curriculum and Pedagogy environment and its key components

Part II: Engage the future through a strategic scenario planning exercise that will ultimately help to create a strategic path for the CPC.

A. Part I Explore Environment

Part I was guided by the following 3 goals:

1. Complete three pre-scenario planning exercises to better understand the curriculum and pedagogy environment
2. Funnel down from the disparate views, opinions and data points a common perspective on key audiences to be examined
3. Create a data set that could be used in building out the strategic scenarios

1) Influence Mapping Exercise

The goals of the first exercise were:
- Create an influence map that represents all of the major components of the CPC environment
- Identify and prioritize the critical components we want to keep in mind for today’s workshop

2) Potential Stakeholders

To identify potential stakeholders, the participants performed a “buying center” exercise [9] where they considered the question “Who Buys Into CPC and its Recommendations?” These stakeholders were considered in four categories: Influencer, Purchase, End-User, and Decider. Both groups included Faculty across all categories. One group included students and industry across all categories while the other had IEEE across all categories.

3) Goals, Constraints, Key Outcomes

The third exercise in this part of the process focused on profiling and prioritizing goals, constraints and key outcomes for three of the stakeholders. This was done by completing a “Lost in Translation” exercise [10] for students and a separate one for faculty.

B. Part II Scenario Planning

The assumptions that guided this process were stated as:
- Looking forward 3 to 5 years
- Utilize key trends, critical issues, and uncertainties identified in the pre-workshop survey
- Utilize data set created from pre-scenario planning exercises
- Global scope
- Most importantly, select two important uncertainties that will have maximum impact on the goals and potential stakeholders.

1) Trends

Prior to the meeting, participants had responded to questions about trends and issues in engineering education. These were discussed at this point in the workshop. Trends in engineering education that were identified as increasing included:
- Learning-by-doing
- The need for giving real world examples or application to each and every concept
- Hybrid learning environments
...and potential influential trends and stakeholders, participants generate potential uncertainties. In this workshop, participants generated four uncertainties:

1. How will curricula keep pace with the rate of technological advancement, globalization and workforce issues?
2. How will engineering programs innovate and adapt to include business, communication and societal competence?
3. What will society need from professional engineers in the near future?
4. How will MOOCs, other virtual learning opportunities and social media transform engineering education?

The scenario planning process requires that participants then select the two most significant uncertainties. In this exercise, participants picked these two:

U1: How will engineering programs innovate and adapt?
U2: What will be the values and competencies of engineering faculty?

The first significant uncertainty started with the second potential uncertainty and broadened it beyond competencies in business, communication, and societal contexts. The second emerged from conversations about pivotal roles that faculty members play in an academic institution and how their values and competencies will influence development of programs. Although faculty did not appear explicitly in any of the uncertainties that participants initially generated, they did appear in stakeholder, trends, and issues exercises. Therefore, values and competencies of faculty members were thought to be one of the two most important uncertainties that may influence trajectories of engineering programs.

For each of the two uncertainties, consider two extremes.

A. Uncertainty in the degree to which engineering programs adapt and innovate

For uncertainty surrounding the degree to which engineering programs will innovate and adapt, there are two extremes, characterized by participants as follows:

- Adapt extremely well: Continued Existence, Increased Learning, New Courses, Pathways, Products, Validation by Society, Diverse Community, Personalized Learning, Metrics for Success (convincing)
- Adapt ineffectively, if at all: some engineering institutions go out of business, decreasing enrollment in engineering, engineering graduates face massive unemployment, and enrollment is elitist and non-diverse.

B. Uncertainty in values and competencies of faculty members

For uncertainty surrounding the degree in the values and competencies of engineering faculty members, participants also generated two extremes, characterized as follows:

- Value Student Learning: Technical Literate, Apply Quality Standards same as Research, Teaching is something I can Learn, Teachers think in terms of competencies, Value Student Learning, Teaching Scholarship Counts
. Status Quo: Research is the number one priority; Teaching no longer considered; Teachers think in terms of content

Fig. 1 visually represents the possibilities of an engineering program adapting or not adapting combined with the faculty-member valuing student learning or maintaining a status quo. This leads to four different combinations, and hence four scenarios, each of which has been given an informal title to capture the tone of the challenges it presents.

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<thead>
<tr>
<th>Faculty</th>
<th>Engineering Program</th>
<th>Adapt</th>
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<tr>
<td>Value Learning</td>
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<td>Value Status Quo</td>
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<td>Scenario-4</td>
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Fig. 1. Overview of Four Potential Futures of Engineering Education

It is possible for more than one of these scenarios to happen as a final result; the range of operating environments for different institutions will inevitably lead to different outcomes with respect to the key uncertainties. These scenarios will each provide different dimensions for key challenges such as faculty professional development and mobility, and the nature of industry demands for and of graduates; the next sections deal with each scenario in turn.

IV. SCENARIO 1: “BEST OF BOTH WORLDS”

In Scenario One, engineering programs adapt well to changing societal, economic and technological developments, and faculty members prioritize student learning.

In this scenario, students are more mobile because their engineering education has focused on development of skills, such as lifelong learning, technological innovation, communication, and leadership that help them to be more adaptable to changing landscapes. This has occurred because faculty focus on student learning has led to curriculum development focused on assessment and development of in-demand skills. Concurrently, faculty members have become less mobile, because their development has allowed them to be very productive in their institutions, focused on development and assessment of specific skills. For example, one faculty member may have developed extraordinary capabilities and learning activities to facilitate development of technological innovation and leadership. However, demand for this niche may be limited to a small number of institutions that have chosen to focus on these skills or have demand for student skill development in these areas. Institutions and/or engineering programs have become more differentiated in terms of the skills on which they focus, in their assessment of these skills, and in activities through which these skills are developed. Almost every electrical engineering program teaches introductory courses in circuits that are very similar; however, skills such as communication and lifelong learning are often assessed and developed in different ways. Differentiation has made accreditation/quality assurance much more challenging, and professional societies, such as IEEE have taken more proactive roles in quality assurance processes. Differentiation has also introduced more chaos and raised questions about the extent to which electrical/computer engineering education across the world is a system. Concurrently, institutions seek more community with institutions whose curricular emphases, assessment processes, and learning/development activities are similar to theirs so that faculty members can share and exchange ideas and materials. As engineering programs differentiate, need for community rises as institutions need grounding and cooperation from similar programs. Online institutions have proliferated, but they are not elitist. Also, as engineering programs differentiate, professional societies, such as IEEE, are needed to help industry identify ways to transform expectations for engineering graduates, program identification, student recruitment, and hiring practices. Also, students need more help and advice to choose programs since there is more variation across the choices. The participants suggested that a new position might emerge such as a coordinator of an educational seminar for Engineering for my “place” (Town, Region, etc.) This person might help high school students identify best sources of information, consultants, education planners, serving as navigators for groups of students.

V. SCENARIO 2: “BROKEN, DON’T KNOW WHY”

In Scenario Two, engineering programs do not adapt to changing societal, economic and technological developments, and faculty members maintain the status quo.

In this scenario, the antithesis of the first scenario, faculty can sense that the undergraduate engineering education system is broken, but because they are focused on research as the sole activity for which they are rewarded they are not sure why they are concerned. Since engineering programs have changed along timelines and trajectories that are similar to the ones during the past 30 to 50 years, engineering graduates continue to have sound technical competencies, but significant improvements in skills sets that have differentiated engineering graduates during their careers: communication, teamwork, innovation, leadership, moral/ethical decision making, and contextual analysis (ABET Outcome h, the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context) have not occurred. Therefore, employers have lost confidence that higher education will provide engineering graduates they need to remain competitive and frequently turn to other alternatives to prepare their engineers. However, engineering programs continue to be accredited and accreditation organizations continue to function. Career paths of engineering graduates change as they find they must develop needed skill sets to command desired salaries. Undergraduate enrollment remains flat or decreases as other alternatives to developing desired engineering outcomes and skills sets become available, but graduate enrollment continues to increase. Given decreases in employer confidence in higher education, government funding for higher education drops.
VI. SCENARIO 3: “THE INMATES ARE RUNNING THE ASYLUM”

In Scenario Three, engineering programs adapt to changing societal, economic and technological developments, however faculty members maintain the status quo.

In some ways engineering programs adapting to societal, economic, and technological developments and faculty members valuing learning might appear to fit together. If this fit is accepted, then scenarios 1 and 2 are potential futures where extremes of the two uncertainties fit. Then, scenarios 3 and 4 are potential futures in which extremes of the uncertainties are to some degree misaligned. In particular, scenario 3 was developed for two extremes of the key uncertainties: (a) engineering programs adapt well to changing societal, economic, and technological developments and (b) values of faculty members remain focused on research. Misalignment was reflected in the informal names workshop participants attached to this scenario, such as “Welcome to the Hotel California” or “Inmates Are Running the Asylum”. In this scenario, workshop participants identified issues such as:

- If engineering programs are adapting, but engineering faculty members continue to value and focus on research, who is doing the work involved in adaptation?
- Are faculty reward systems differentiated, one system for the faculty members focusing on research and another system for faculty focused on the work of program adaptation? Workshop participants thought that differentiated reward systems at the same institutions was a distinct possibility, accompanied by uncertainty and confusion that typically exists in such contexts.
- Given potential for numerous misalignments, how do faculty members view the reward system, the administration, and their colleagues?

Faculty members that are supporting adaptation of the engineering program might be doing so through increased emphasis on non-traditional learning environments, such learning environments in which students participate through synchronous and asynchronous communication technologies. That is, developments in alternative learning environments supported by developments in instructional technologies may allow engineering education to develop in this misalignment of uncertainties. With growth in alternative learning environments as well as engineering courses taught by faculty members principally focused on research, workshop participants thought student satisfaction would be bimodal, that is, some students would really enjoy the bifurcated learning environments while others would be extremely dissatisfied.

VII. SCENARIO 4: “LIFE AFTER TARA”

In Scenario Four, engineering programs do not adapt to changing societal, economic and technological developments, however faculty members prioritize student learning.

Scenario 4 considers the other combinations of two extremes of the key uncertainties that do not seem to fit: (a) engineering programs do not adapt to changing societal, economic, and technological developments but (b) faculty members value student learning. Faculty members that value student learning are working for engineering programs that continue to emphasize traditional engineering programs. Given that institutional contexts are likely unsupportive, faculty members depend on professional societies (IEEE, ASEE, ASCE, ASME, etc.) for community. IEEE and other professional organizations may be the only source of professional development and support in this scenario for faculty members focused on student learning. Therefore, faculty development could become a much higher priority for professional societies. Alternatively, since institutions are not adapting in ways that are responsive to external developments, faculty members might move to positions in industry continuing education organizations, publishers, or startups involving education, social media, and multimedia. If the situation has geographic variation, faculty might move to other countries in which institutions are more committed to the priorities in which faculty members focused on student learning are interested. Whether they stay in institutions of higher education or move to alternative organizations, faculty members will need to be willing to be more mobile, more collaborative, and seek networks for mentoring, professional support, and professional development.

Given that existing institutions are not adapting to societal, economic, and technological developments, workshop participants thought it likely that new institutions/structures/organizations would emerge that focus on faculty development and creating learning environments that promote development of engineering graduates with respect to attributes sought by employers and graduate schools. Scenario 4 is the only scenario in which numerous new institutions/organizations/structures were likely to emerge. These new structures/institutions/organizations could include online engineering institutions, for-profit engineering institutions, communities of practice, and combinations of these three. Further, workshop participants thought it was likely that specific engineering programs would die off spawning department and institutional consolidation. Since institutions making significant consolidations would experience considerable turmoil and require support, a new role for professional societies might emerge. In this role, professional societies would offer support to departments and/or institutions making significant consolidations. In summary, scenario 4 might be the potential future in which professional societies need to make the biggest change in their priorities.

VIII. CONCLUSIONS

We have described a scenario planning process and its outputs for considering the future of higher education in electrical and computer engineering. The four scenarios that emerged from this show a range of possible evolutions and indicate different roles for professional societies such as IEEE. Others interested in such planning processes might benefit from this work.

These scenarios have since been further operationalized through the development of a survey capturing both academic and industry perspectives. The survey will be administered to individual faculty members, department heads, and deans at engineering programs across the world. Areas addressed by the
survey include: enabling technologies; program strengths; markets for engineering graduates; expectations of employers for engineering graduates; characteristics of accreditation systems; approaches for assessment and development of selected student attributes, such as engineering design; and faculty experience.

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