In GCC Universities Which Electrical and Computer Engineering Curricula are Really Needed: Flexible or Specialized?

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***Abstract* — In most of the universities of the Gulf Corporation Council (GCC) countries the electrical and computer engineering curricula have focused on narrow specializations and technical subjects with extensive overlaps between programs and neglected other dimensions like social, economical and ethical issues. Restructuring the electrical and computer engineering education is vital for the prosperity of GCC countries. This paper is an attempt to present guidelines for such process by discussing the pros and cons of the flexible and specialized electrical and computer engineering curricula.**

***Index Terms* — Engineering education, curriculum design**

I. Introduction

For years, industry has complained that new electrical and computer engineering graduates fall short on the practical engineering skills that would make them more productive in the real world. For example, major companies have to spend more than one year in retraining new electrical and computer engineering graduates at very high costs. On the other hand, in today's world, if you have a customer with a problem, he does not really care if it is a physics, computer engineering, or software problem. He just wants it to be fixed. To measure up, electrical and computer engineering graduates must have at least a working knowledge of other technologies. They need to know when the solution to a problem can be found within electro-technology and when they must seek help from another area.

Electrical and computer engineering graduates are needed in many professional areas like marketing, manufacturing, development, and research. The task of an engineering educational system in the GCC universities is, therefore, complicated. On the one hand, it must prepare graduates with sufficient knowledge in basic science and technology, as well as an adequate degree of specialization to handle current technological problems; on the other hand, it must produce open-minded people who can adapt easily to a wide spectrum of jobs available in relatively small markets, and who can respond and progress quickly to new issues faced by society. Meanwhile, they have to be productive, innovative, concerned individuals, capable of bridging science with humanistic well-being. The system must also produce graduates who can define and analyze problems and/or systems, and present solutions in accordance with the logic of the technology and the socio-economic environment in which they live. In fact, the outputs from electrical and computer engineering programs go into a diverse filed of job-situations. For example, if we consider the list of IEEE societies, it is noted that there are around 40 active societies and at least 30 different work descriptions given with at least 20 different principle job functions.

Electrical and computer engineering graduates should help industry to make profits, for without profit industry can not exist and neither can engineers. The continuous growth of knowledge in basic science, which is doubled in less than 5 years, is opening new directions for applications in engineering endeavor. But since it is not possible to encompass all these applications in a university program, it would be better to focus more on the basics than teaching detailed technologies, which are going to change in a short time. Again, education and not training should be the target of any engineering school. The real question awaiting an answer is, therefore, what type of engineer should the university produce? A person with technical competence? A manager? A public policy-maker? Or an all-round personality? Not surprisingly, most academics vote for all the above. Therefore, electrical and computer engineering undergraduates should be exposed to basic science and engineering with a focus on teaching them how to think, in addition to: (a) improvement in their verbal and written communication skills, (b) interpersonal skills-such as empathy with other team members, (c) a knowledge of when to speak out and when to let someone else talk, (d) the ability to defend ideas without generating confrontations-just to do their jobs, (e) self-management, (f) self evaluation and peer evaluation, (g) concurrent engineering, and (h) management of technological innovation.

Equally critical are computing skills. It is not enough for engineers to be computer literate. They must be top-notch. Knowing how to use a computer may be more important than knowing how to use a pencil. However, more emphasis must be placed on practical laboratory work, as against computer simulations.

But is it possible to achieve this? It appears that the electrical and computer engineering education is faced with a near-impossible task. Consider, for example, (a) the four-year baccalaureate program in engineering is full and overflowing, (b) an engineering education leads to a multiplicity of career opportunities, and (c) including more topics in the baccalaureate program increases the stress on the search for excellence in engineering education.

What sort of a curriculum is required which will stand up to these diverse requests? For universities to prepare students in all these areas in a short time; typically four years, is a pretty tall order. But many are forging ahead and revising their electrical and computer engineering curricula to fill the bill. The traditional electrical and computer engineering curriculum, designed to produce people who knew everything about their own fields and nothing else, can not work well in today's environment; see for example [1]-[5]. In fact, most of the faculties, designing electrical and computer engineering curricula in GCC universities, are far removed from engineering as it is practiced. Unfortunately, most of them have never practiced engineering in the field. To produce engineers who fit a new mold, flexible curricula are needed.

II. Restructuring Engineering Education

Today, it is commonly agreed that new engineers are expected not only to be technical experts but also to integrate science and technology into society as a whole. Therefore, new engineering curricula must be broad in order to provide diversity and depth of skills required by constituents. Regardless of the discipline, it should also address: (1) The challenges of globalization, (2) effective communication (written and oral), (3) cultural literacy, (4) social, ethical, environmental, and economic issues, (5) quality, information, and human management, and (6) life-long learning.

Therefore, the traditional electrical and computer engineering curricula, designed to produce people who knew everything about their own fields and nothing else, can not work well in today's environment. We need to restructure electrical and computer engineering education to produce engineers who fit a new mold. Engineering schools around the world are changing, upgrading or adapting their curricula to make them more practical and responsive to industry. In some institutions mathematics and science are taught within the engineering course rather than as separate courses in the first and second years. This ensures a 'just-in-time' approach and students get a much clearer picture of where the different mathematical, science or chemistry modules fit into their curriculum. Many universities in U.S.A. are reconsidering the desirability or reduction of certain basic courses such as, for example, chemistry, strength of materials, and, dare one say it, even physics; see for example [6]-[7]. Some of the basic courses provide the essential foundation for education in electrical/electronic engineering and must be carefully reviewed. No consideration should be given to the reduction of current mathematical content of engineering courses. The reason for this is that mathematics will continue to be an essential skill in engineering education.

Statistics show that the majority of GCC countries electrical and computer engineers are employed by the private sector as employees or as consultants, or even running their own small, private consulting and/or manufacturing and construction firms. A fewer enter applied research, and even fewer end up in fundamental research. In the GCC countries industry is essentially an applied one in which little basic research takes place. In fact in the GCC countries more than 80% of electrical and computer engineering graduates are employed as technologists. Therefore, demand for highly specialized engineers and researchers is limited. Nonetheless, a number of people have to be prepared for research and development programs.

For GCC countries to survive in today's fiercely competitive and technologically oriented world, let alone to boost their industrial and economic standing, drastic and immediate measures have to be taken to improve their higher education. This can be achieved by the following:
1. Less expansion of universities and the establishment of higher technical institutes or introducing technology programs to current universities.
2. The status of technologists should be boosted by awarding them engineer status in the form of a B.Sc. degree. This is the case today in Britain and Germany.
3. Employers should hire 'engineers' or 'technologists' according to the skills required and there should be no discrimination between the two types in terms of salary. Job opportunities will be much better for the latter than the former. This should reduce the pressure on universities, increase enrollment in technical institutes and decrease structural unemployment.
4. New textbooks specially dedicated for technological education are strongly needed. Currently, most textbooks are written for use in research universities.
5. What is expected of the faculty in traditional university engineering degree programs differs from what is expected in a university that provides a bachelor's in engineering technology. The difference is illustrated by the background of faculty members. Appointment as a

professor of engineering typically requires a doctorate, a publication history, and the ability to attract grants. Often, people with these credentials have no industrial experience. On the other hand, to be an engineering technology faculty member, one either has to have a master's in the discipline or a master's degree plus professional registration and at least four years of recent industrial experience. These criteria are fixed by the ABET. Differing faculty requirements affect the curriculum predictably.

III. Generalized or Specialized Curriculum?

Over the years large industries have pressured academia to maintain a general and broadly based introductory course structure. At the same time young graduates and small industries have agitated for earlier specialization to make graduates more directly useful when leaving the university. This last pressure was enhanced by academics pushing their own interests into undergraduate programs.

To satisfy both the general and the technical requirements, one has to consider parallel streams of courses. One stream would provide a general program, with a sound base on which students can build in a rapidly changing engineering environment with a rapidly increasing obsolescence rate. The other stream could lead into early specialization at different levels for students who are not interested in a broader base and those who cannot cope with the more academically advanced levels. However, the latter would require industry to provide facilities for updating their staff as technology moves on.

On the other hand many universities, faculty members, and accrediting agencies are becoming entrepreneurial in their approach to developing electrical and computer engineering curricula by appealing to the perceived needs of the worldwide industry that, in turn, is being driven by accelerated advancements in technology and market opportunity. Increasingly faced with the problem of trying to keep up with the rapid advances in technology without adding material to overburdened four-year engineering curricula, engineering departments began to develop more specialized curricula. Examples of this curricular entrepreneurship can be seen in the number of new engineering degrees beginning to appear; see for example [8]-[9].

The emergence of specializations at the undergraduate level provides an interesting and yet-to-be proven opportunity to attract the attention of prospective students and specific sectors of government and industry. This approach essentially seeks to define curricula based on "market" opportunity, thereby focusing on the needs of industry and government. While this approach may be attractive in securing the financial health of educational institutions, it was noted previously that the long-term ramifications of a whole-scale paradigm shift in that direction is not well understood. Clearly, there are issues and down sides and, perhaps, ethical concerns. The extent to which undergraduate specialization narrows the scope of undergraduate knowledge is of primary concern. Technology is rapidly evolving. Care must be exercised to ensure that undergraduates have a sufficiently broad educational experience to deal with and adapt to the evolution, even to the extent that their specialization may be obviated. Furthermore, educational institutions must assume some responsibility to ensure the long-term value of a chosen specialization, especially if the curriculum does not prepare students to think outside the field of specialization. Specializations should build solidly upon foundational courses in engineering and computer science with virtually no dilution of the basics. It should be sufficiently broad in scope-an extension rather than a deviation or departure from core engineering knowledge and theory. The panning of a specialized undergraduate curriculum must also account for the limits, if any; it might impose on graduate level education. In contrast, a general undergraduate education provides a proven path for students who wish to specialize at the graduate level.

Two apparently opposing views have emerged with a multitude of specialized curricula on one end and generalized generic curricula on the other. Each of these approaches provides value in different ways. Both should be measured by the breadth and depth of knowledge they develop in emerging graduates and the degree to which they prepare graduates to make professional contributions. Either approach appears capable of fulfilling the long-term needs of industry and developing economics. The value of a general curriculum is linked to the **breadth or scope** of technical contribution that emerging graduates are prepared to deliver. In contrast, the value of specialized curricula is linked more to the **depth** of technical contribution that graduates are prepared to deliver. Clearly, there may be profound value in both approaches, but there are also down sides.

Each approach seeks to handle the conflicting constraints imposed by the accelerating pace of technological advancement versus realistic limitations of the scope of content that an undergraduate curriculum can realistically deliver. While specialized curricula may provide sufficient depth of content to allow entry-level engineers to make more immediate contributions, their benefits must be afforded by eliminating one or more fundamental courses, possibly limiting the ability of emerging specialists to grow and evolve with disjoint technological advances. An increased rate of technical obsolescence may indeed be a by-product of a curriculum that is too narrow or specialized. Educational institutions must also be careful to ensure the long-term relevancy of proposed specializations taken as a whole, as well as the constituent courses. Furthermore, the emergence of new specializations will introduce new challenges in accreditation and standards for entry into advanced degree programs.

Clearly, undergraduate specializations may have strong appeal and value to industries engaged in technical disciplines that require a substantial degree of specialized knowledge beyond that provided by traditional engineering curricula. Well-developed specializations may indeed reduce the costs of corporate training at the entry level. However, one must consider that the savings at the entry level may be offset by an increase in costs to replace or retain an experienced professional workforce as technological advances continue.

The greatest advantages of a generalized undergraduate curriculum are aimed at providing entry-level graduates with a profound understanding of broad and universally important principles, as well as abilities to learn and adapt to technological advances. However, practical limitations on the volume and scope of curriculum content have not kept pace with the specialized knowledge required to make relevant technical contributions at the entry level. Specialized knowledge is often gained at corporate expenses through "on-the-job" training or financial support for graduate studies. Furthermore, corporate support for training and graduate studies has become increasingly risky. Industries experiencing a professional workforce shortage are often forced to compete for the services of the very people they trained.

While the author suggests that both approaches may be necessary to support the needs of the global community taken as a whole, the ramifications of a large-scale paradigm shift toward undergraduate specializations are not well understood. The author understands the benefit of undergraduate specializations in certain areas, he does not, however, support their widespread proliferation as encompassing the general character of mainstream undergraduate programs. A curriculum that attempts to optimize the conflicting attributes of generality and specialization will have the strongest appeal.

In light of this situation and the down sides discussed previously, the author favours a more general engineering curriculum as the predominant mode of undergraduate engineering study in addition to a limited number of specialized curricula running for specific periods depending on the local industry needs. In other words, although the author foresee the need for both undergraduate specialists and generalists, he believes that specializations must be driven by the long-term universal needs of the engineering communities of interest and profound insight in developing curricula that serve the long-term career interests of their graduates. The author further believes that the needs of the engineering community will continue to diversify, and a general curriculum that attempts to optimize over the conflicting attributes of generality and specialization will also be of great value and may indeed have the strongest appeal.

As a first step in this direction, the author strongly believes that it is time to merge the electrical engineering and computer engineering degree programs in a single integrated bachelor's degree in electrical and computer engineering. The courses offered can be grouped into five or more technical areas ranging from traditional electrical engineering to computer software. The computer software courses may be taught by the computer science department but counted toward a degree in electrical and computer engineering. With courses arranged thus, the new curriculum can stress a balance of breadth and depth among five or more technical areas, rather than demand a specific set of courses. The main principles around which the new curriculum can be designed, may be summarized as follows: (a) teach engineering early, concurrent with fundamentals, (b) base curriculum requirements more on area, less on specific courses, (c) increase flexibility through elective courses, (d) manage the workload, (e) offer one B.Sc. degree in electrical and computer engineering, not two, (f) tructure curriculum to accommodate change.

In parallel with the changes in the electrical and computer engineering program, the engineering college must consider redesigning the entire freshman year. Each department, including the electrical and computer engineering, must develop an introductory course with substantial engineering content and laboratory work. The purpose of this course is to give students a sense of what electrical and computer engineering is all about, and help them understand the importance of all the physics and mathematics classes that they take. Students must take another engineering course, one in the area in which they plan to specialize, and one in another engineering area. This setup lets them explore engineering disciplines other than electrical and computer engineering. A new sophomore mathematics class, the Mathematical Foundation of Electrical Engineering, can be introduced. Such a course must be designed to fill crucial gaps in the mathematical preparation of the engineering students and to improve the integration of mathematics and engineering teaching.

Courses should be offered in an atmosphere of collaborative learning that stresses the interrelationships among various topics; proficiency with computers; and such non-technical skills as oral and written communication and teamwork. The goal is to develop the student's identities as engineers, making them problem solvers, giving them technical and communication skills that they need to function as engineers.

Sophomore electrical and computer engineering majors will take an engineering science, and mathematics curriculum that coordinates such subjects as conservation laws, statistics, mechanical and electrical engineering, and thermal and fluid sciences. Juniors will broaden their grasp of their field by studying subjects ranging from power transmission to communication, to microelectronic circuit design. Senior year may focus on a year-long design project involving real engineering problems supplied by clients from industry if possible. Students will work either individually or in groups of up to five or six. The projects will include interim presentations to the client and a report documenting the results.

Such a curriculum is expected to arm students with the knowledge and skills that industry seeks. When students really believe that what they are doing in the classroom prepares them for what they will be doing when they graduate, then we have their attention.

IV. Graduate Programs

The advanced degrees are degrees of specialization; they apply more to countries with highly industrialized societies and front-line industry. In smaller countries with less highly developed industry, specialization courses should be designed carefully and after thorough study of the market to which they are addressed, so that they will not lead to graduate unemployment.

Generally, two stages of engineering education may be distinguished in GCC countries. The first focuses on education in basic science and technology with little specialization, and leads to a university graduate engineer. The second trains the graduate engineer in industry and/or in a university to become a specialist. This stage is based on training in specialized topics.

It should be pointed out that narrow specialization may be necessary in some large industrialized countries, such as the U.S.A., China, India and U.K. but may well be an unnecessary luxury in smaller ones, such as GCC countries. Therefore, the establishment of graduate studies in GCC universities must be carefully considered. The direction, the depth and the number of graduate programs should reflect the capacity and trends of the domestic market and the country’s research needs. To adopt effective education programs from good technical universities of large, highly industrialized countries, without modification and adaptation to local conditions, may prove to be a great mistake. It may lead to unemployment and an unjustified waste of money.

V. Conclusion

Traditionally, students GCC countries joining electrical and computer engineering programs have excellent skills of memorization, but they have never completed an independent assignment. They have not learnt to study outside the classroom. What they have learnt is to memorize what the teacher tells them to and that, in an academic environment, one is not required to use any of the analytical and problem solving skills that he/she has learnt. These are the students whom we have to train to be competent engineers. Obviously, this task requires special measures to be taken by universities to upgrade, adapt or restructure their educational systems. Basically, to restructure electrical and computer engineering education we must first and foremost change educator’s attitudes. Only then can engineering schools produce the open-minded and versatile modern engineers capable of making improvements to our quality of life. The possibility of redesigning the curriculum to increase its flexibility, to encourage technology education, to merge the electrical and computer engineering and to reconsider our graduate programs are among the other measures that can be considered to restructure electrical and computer engineering education in the GCC countries. The idea is to graduate an engineer who can serve the needs of the local industry. This would reduce the structural unemployment and stop the brain drain of overqualified graduates.

Moreover, the establishment of new departments and/or narrow specialized programs was discussed and it is believed that this trend is not generally healthy. It is recommended to restructure the existing electrical and computer engineering departments, in many universities in the GCC countries, in order to minimize the overlap among these departments and to train new graduates to serve the local industries needs. Moreover, it is proposed to minimize the narrow specialization programs to a very limited number running for specific periods depending on the local industries needs. In general, the needs of engineering community will continue to diversify, and a general, rather than specialized, curriculum will be of great value and may indeed have the strongest appeal.

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References

[1] http://www.kfupm.edu.sa
[2] http://aus.edu
[3] http://uob.edu.bh
[4] http://www.ksu.edu.sa
[5] http://www.kaau.edu.sa
[6] http://www.cm.edu
[7] http://www.rose-hulman.edu
[8] http://www.ulb.ac.be
[9] http://www.brunel.ac.uk