AC 2009-566: INTEGRATION OF AN INNOVATIVE ENGINEERING PROGRAM IN A SUNY COLLEGE

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Integration of an Innovative Engineering Program in a SUNY College

Abstract:

The development of a new engineering program in an existing and well-established institution presents several challenges, including the creation of a sound curriculum that satisfies some of the local and national engineering workforce needs. However, besides curricular issues, the new program must also satisfy all accreditation requirements and incorporate modern and innovative teaching methods, equipment, and facilities. Due consideration must be given to the already established educational tenets of the university as the engineering program must be inserted within the university's existing curricular infrastructure, including the general education requirements and the existing support courses in the sciences and mathematics.

There is a strong desire to develop a program that is competitive within the engineering education field and that responds to expected needs in the engineering profession. Several specific ideas are considered to achieve this goal. The curriculum will be largely project-based and will rely on active-learning methods and multidisciplinary teaching using proven methods as described and already implemented in other successful engineering schools.

Engineering education is a recognized important factor in economic development and several new programs are already or will likely be developed in many educational institutions. The results of this work concerning the early development and planning of a new engineering program provide valuable referential experience for future engineering program development efforts.

Introduction

Engineering is recognized as an important factor in the economic well-being of society. In the current global market, engineering programs are gaining in importance with the realization in the USA and elsewhere that future economic prospects depend on the availability of skilled and competent engineers. In response to the increasing demand for engineering professionals, several institutions of higher learning that traditionally offered degree programs in the liberal arts have started or are now planning to offer engineering degree programs[1]. This paper discusses the development of a new Electrical and Computer Engineering program within a long established university.

The establishment of a new program in any area demands consideration of several options and leads to choices on many different issues. Accreditation of the new program in due time is a primary concern; therefore, some guidance is drawn from various requirements for accreditation as provided by the Accreditation Board for Engineering and Technology (ABET). It can be argued that implementing a suitable accreditation processes is more effective during the development phase of a degree program rather than if inserted through changes in an already established program.

In this work, the implementation of the new ECE program is divided into five closely interrelated categories: curriculum, personnel, facilities, budget, and institutional support. Each of these issues is addressed and discussed in a separate section.

Curriculum

The curriculum under consideration allows students to graduate as engineers after taking a total of 128 semester credit hours distributed into core courses, cognate courses, electives, and general education requirements. Engineering education has been the subject of extensive research which shows that engineers should be educated and trained to be professionally competent in a global economy with constantly changing opportunities and challenges. The characteristics of 21st-century engineering professionals are well-addressed in reference 2.

Degree programs

One of the primary decisions in the start-up of a degree program in engineering is the choice of discipline and its scope. Electrical and Computer Engineering is a global field that includes different important and widely needed branches, such as Energy and Power Systems, Electronics, Controls, Communications, Electromagnetics, Semiconductors, Computer Systems, Digital Design, Mechatronics and Robotics, and more. A start-up program will typically lack the capability to offer a long list of courses within the global discipline and must choose which areas to cover beyond the basic content of the curriculum. The choice of disciplines should be based on the regional constituencies and the existing strengths of the university. Most university graduates tend to seek employment locally, when available. This places the needs of local engineering employers as an important factor in the design of the curriculum.

The State University of New York (SUNY) at Oswego has a successful and thriving computer science department, which led to the decision to include computer engineering in the degree program rather than offer an electrical engineering degree. The objective is to use existing computer science courses, faculty, and facilities to complement the computer hardware courses in the engineering degree. Due to curriculum content limitations taking into consideration general education requirements to insure a broad grounding in the arts, social and natural sciences, and humanities, the curriculum is implemented with different tracks that ECE majors can choose to follow in the completion of their own degree program. Figure 1 shows the envisioned organization of the core courses and the two EE and CE tracks.

Teaching methods

It stands to reason to seek modern and effective teaching methods for a new program. Studies have shown that project-based and hands-on teaching is more effective that theoretical teaching, particularly at the undergraduate level. Consequently, the main teaching method adopted is studio-based[3,4] to combine hands-on experimenting with lecturing rather than the traditional separate lectures and lab sessions. The studio format increases interactivity between instructor and students in the classroom and engages students in active learning.

The use of projects wherever possible in the curriculum provides motivation and focus for learning and facilitates student understanding of class material[5]. Class projects must be well-related to class material in both topic and scope to be truly effective. However, larger, possibly multi-term and multi-disciplinary projects can be determined, preferably in partnership with local employers, that engage students in realistic and "real world" applications of their knowledge and training. Multidisciplinary team projects are useful for accreditation as well and should be used as part of the overall teaching.

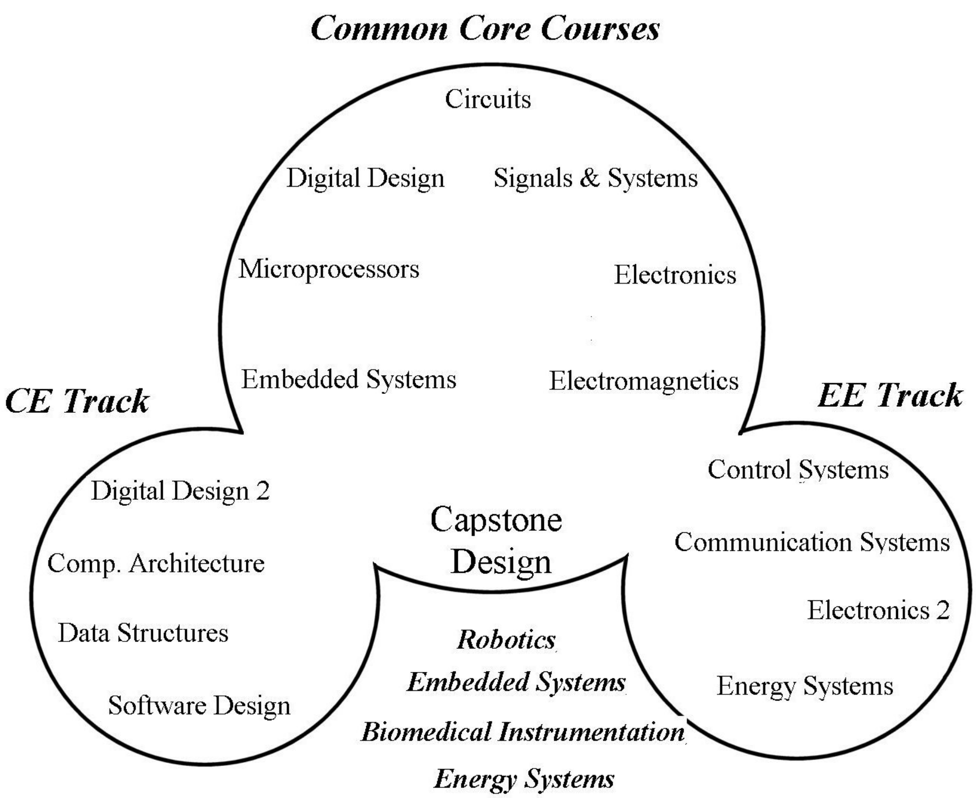

Figure 1. Core ECE courses

Another effective educational method is multidisciplinary teaching. Traditional curricula break down engineering programs into a set of seemingly unrelated courses partitioned in different disciplines. While the whole program constitutes a coherent and effective body of knowledge, the interrelation between disciplines and courses is not obvious. Multidisciplinary teaching helps bridge the gap and illustrates the interrelation between courses. Many topics combine well in multidisciplinary courses such as physics, mathematics, and engineering. Outside of the sciences, topics like writing, ethics, economics, and entrepreneurship relate well to engineering as well.

Rethinking Mathematics and the Sciences for Engineering

Most engineering schools in the nation require a minimum level of proficiency in Mathematics, Physics, and other sciences[6-9]. Four courses in mathematics consisting of a series of three calculus courses and a differential equations course are considered a minimum in an engineering program and most engineering students are advised to take courses in linear algebra, numerical analysis, and discrete mathematics, to name a few. A minimum of one year of Physics and one semester in chemistry or biology are also typically required. However, due to curriculum crowding and regulatory limits on total degree credits, it has become quite difficult to adequately educate engineers in a four-academic-years period and only the most talented of students manage to do so. Optimization of preparatory courses in mathematics, physics, and the sciences and a better integration into the engineering curriculum can help improve its efficiency by replacing non-important content with essential material. This approach has been taken at newly established engineering schools such as the Franklin W. Olin College in Needham, Massachusetts[10].

A program of study in mathematics that satisfies the educational objectives of a modern and innovative engineering program is needed in order to achieve adequate integration of mathematics components in the curriculum and to satisfy four broad conditions:

1. Students receive all the mathematics skills needed within the engineering curriculum;
2. The mathematics content must adequately support the engineering program's objectives;
3. Mathematics knowledge and skills must be embedded within the curriculum so as to enhance and facilitate learning in engineering;
4. Students gain the ability to use modern computing tools to enhance their learning in mathematics and engineering.

The engineering discipline evolves and progresses fast and so do the mathematics needs of the engineering students. While more mathematics can never be detrimental to engineering, one should take into account both students' initial background and the limited time available for covering math and engineering topics. The imbalance between taught and needed topics greatly hinders student learning and complicates engineering education. For instance, complex numbers and their representations, complex arithmetic, and functions of complex variables are not covered well in the math requirements of traditional engineering curricula. On the other hand, much time is spent in the calculus series covering topics such as integral, area, and volume computation and various mathematical proofing methods, usually quickly forgotten by students and hardly ever seen again in their engineering careers. However, implementing engineering-targeted preparatory courses is easier done in a new school dedicated to engineering than in a program that must be integrated within an already existing regional university. Embedding a new program with redesigned courses for engineering in an already established curricular infrastructure is difficult, if not impossible, due to limited resources.

Embedding Communication Skills

The importance of efficient communication skills in engineering is now widely recognized and has become one of the tenets of engineering education as well as an important requirement for accreditation. The development of a new educational program offers a unique opportunity for curricular innovations and for the design of courses where communication skills are incorporated into the curriculum.

In modern days, communication has exceeded its traditional dual aspects of verbal and written. Computers, the rise of the internet and new wireless technologies have allowed communication to incorporate presentation, technical, graphical, electronic media, and artistic concepts as well as communication techniques targeting different audiences. It is important to teach students not only to express their ideas, thoughts, and concepts clearly but also to be able to do so as individuals, while working in small teams, or when participating in large audience events.

Advances in technology have brought several tools for communication including computer graphics, visualization, and modeling software, all of which allow the integration of advanced imagery and animations in computer documents and presentations. Engineers must often describe complex systems with moving parts. Therefore, they can greatly benefit from the inclusion of these modern communication techniques in their program of study. A modern curriculum must therefore emphasize communication skills in its content, offering, and delivery. Such skills are introduced in the curriculum through

- Technical writing and composition courses
- Seminar presentations
- Written reports on their assignments and projects
- Participation in discussions and debates supported by PowerPoint presentations
- Team work and team reporting

The engineering profession has evolved during the latter half the last century to require that engineers communicate with diverse audiences, including upper managers and administrators, colleagues from various disciplines, co-workers, students, and the public at large. The means of communication have also multiplied from oral and written to presentations with visualization, audio-visual, simulation, and internet content. As a result, the communication skills that engineers need in the practice of their profession now include:

a. Good technical writing techniques and general composition;
b. Oral communication and presentation techniques;
c. Incorporation of technical graphics, figures, graphs, and other visual content in live presentations as well as in written reports and assignments;
d. Development of effective and expressive web content.
e. Communication techniques targeted to different audiences.

Concentration tracks

A starting program must select a few areas of concentration within its discipline to offer some focus and character to the program. Theses concentration areas are best chosen in accordance with local employers' interests to generate industry support, provide educational partnerships, and insure increased local employment opportunities for graduates. In the case at hand, four areas of concentration were chosen based on local industries and institution strengths:

1. Robotics
2. Embedded Systems
3. Biomedical Engineering

4. Sustainable Energy Systems

These areas were also chosen because of their estimated future growth and employment prospects. Once selected, these choices help determine the areas of expertise sought in hiring faculty for the program as well as the necessary facilities and equipment, and the relevant required and elective courses to be offered in the curriculum.

In essence, the ECE program curriculum will have the following characteristics:

- Hands-on teaching. Most courses are offered in studio format
- Project-based. Projects will be offered as possible at the course, semester, or year level and in partnership with industry (capstone)
- Multidisciplinary courses. Many engineering courses will include math and physics material where needed.
- Streamlined math and sciences support courses. Where possible, the pre-requisite math and physics courses are revised to include material that directly and more effectively impacts engineering education.

Faculty and Staff

The initial planning for the new ECE program calls for five tenure-track faculty members including the chairperson, one secretary, and at least one technician. The faculty is able to support a curriculum that includes the concentration areas discussed above, teach all core courses, and participate actively in the governance of the program. The program should be able to support an enrollment of 80 to 100 students. The hiring of the faculty is progressive according to the roll-out period of the program development which is assumed to take three years. As such, an engineering program can be started the first year with as few as two faculty members, with one faculty added every year thereafter as the curriculum offering increases from entry level courses only to the full curriculum offering. New courses are progressively introduced as faculty members are hired.

Facilities

Facilities must be available to offer adequate support for teaching the curriculum including laboratories, classrooms, project labs and offices for faculty, staff, and support personnel as needed. Most, although not all, courses in the engineering core curriculum and electives are better taught with laboratory sessions or in studio format with hands-on activities. To this end, the following list provides examples of required facilities:

1. Circuits and Electronics studio
   This laboratory and its equipment can support several courses such as circuits, analog electronics, signals and systems, instrumentation and related elective courses.

2. Digital Systems Studio
   Several courses in the digital electronics and computer systems areas can be served by this laboratory if equipped properly. Some of the courses served by this

facility are introduction to digital systems, microprocessors and microcontrollers, digital design, and computer architecture, among others.

3. Control, Communication, and Digital Signal Processing Studio
   This lab will service the areas of linear control systems, communication, and signal processing courses or electives.

4. Robotics and embedded systems
   This room is useful in order to support the concentration areas of robotics and embedded systems, as well as related projects.

5. Senior Design Project laboratory
   Students are expected to run independent experiments and construct projects in all areas of interest to the field of electrical and computer engineering in this laboratory.

6. Support Facilities
   A modern engineering program practicing project-based education requires support facilities such as
   - Machine shop for project construction and materials handling
   - Circuit fabrication to allow students to finalize circuits on PCB.
   - General purpose computer lab with computational, simulation, and design software to allow students to perform all design tasks as well as to produce reports and presentations.

The first three rooms listed above are designed to function as studios and are equipped with modern lecture aids, including projector, projection screen, networked computers with an instructor console, as well as lab stations arranged so that students can easily alternate between experimenting on their benches and following lectures and instructor directions.

The robotics laboratory combines practice and training support for robotics and embedded systems courses but also serves as a project construction room in those areas. This helps satisfy minimum usage requirements in effect in some higher education institutions and provides efficient use of the teaching space.

The institution will need to provide these facilities and their corresponding equipment for the engineering program. It is a common complaint that in many academic institutions teaching laboratories are often underutilized. The list above indicates three multi-course teaching laboratories designed to serve the needs of 3 or more core engineering courses each.

Equipment

Technological progress in instrumentation has greatly reduced the cost of typical ECE laboratory equipment. In fact, most laboratory instruments are now available as computer attachments at a small fraction of the price of stand-alone equipment. At the same time the computer has become a widely used low cost tool not only for computing but also for the analysis, design, simulation, and testing of engineering systems. In many cases now, the computer is one of the least expensive components in a typical electrical and computer engineering laboratory station. It has also become possible for students to own portable versions of a laboratory station in the form of computer attachments small enough to carry in their backpacks[11]. However, at the same time, equipment manufacturers are still making and marketing sophisticated and expensive computerized stand-alone instrument for lab stations. Therefore, there are three options as to the equipment selection task in the development of a new program:

1. Use traditional laboratory stations with stand-alone instruments such as oscilloscopes, multi-meters, signal generators, and power supplies.

2. Use a set of computer-based measurement equipment such as the National Instrument Ultiboard with LabView Software.

3. Use both of the above.

The difference between the first and second categories lies in price/performance ratios. Stand-alone equipment typically provides far superior performance in terms of precision, range, and speed of operation. As an example, a stand-alone function generator can deliver frequencies of a few GHz as compared to a computer running at a clock of 2 GHz, limited to generated signal frequencies in the few MHz at best due to computational and operating system overhead. However, computer-based performance is still more than adequate for an undergraduate electrical and computer engineering program. The third option allows for the use of computer-based equipment in some labs where high performance equipment is not needed and of stand-alone equipment in senior level labs. The advantage of this hybrid choice is that it makes some high performance equipment available for projects, student or faculty research when needed, while reducing overall equipment cost. In the list of facilities above, an optimal choice would be to use stand alone equipment only in the Control, Communication, and Digital Signal Processing Studio, a room that supports senior level courses, and in the project laboratory. The hybrid solution also allows student exposure to a variety of laboratory equipment and therefore increases their ability to utilize such tools in their early professional careers.

Institutional support

In order for a new program to be added to an existing institution, it is very important to secure wide-spread institutional support. New programs are often imposed by university administrators and perceived by many as a diversion of resources from already existing programs. This is especially true among faculty and programs farther removed from engineering such as the social sciences, humanities, or the arts. Programs in the natural sciences and mathematics tend to be more welcoming. The new program must be able to function as an integral part of the institution and participate in the governance and social life of the institution. A major factor in achieving general institutional approval for the new program is to secure extra budget allocations through dedicated grants or donations for its development rather than through budgetary cuts in other sectors of the institution.

Engineering programs carry many advantages as well that can be provided to the academic community. Engineering students tend to be better prepared in mathematics and science and take several courses outside of the major core thereby increasing enrollment in several departments. The economic impact of a new engineering program comes in the form of additional departmental and institutional funding through faculty grants for disciplinary and educational research. Finally, a new program increases the diversity of the university and opens new avenues for multidisciplinary cooperation.

Accreditation

The development of all aspects of the new engineering program must be conducted with accreditation as a major guiding factor to insure a successful accreditation with minimum effort when due. The introduction of the ABET criteria in 2000 caused much turmoil in many engineering departments, as they scrambled to satisfy new and more stringent requirements. A new program should be developed with all the required components and with continuous improvement processes in place. An inclusive external advisory board composed of stake-holders should be established to provide continuous guidance in the development and improvement of the program's mission and objectives and the curriculum must provide students with all stated skills and knowledge to function as engineering professionals in the rapidly changing global market. The faculty and staff, the facilities and equipment, and the institution's continuous support of the program must be sufficient to insure that the mission of the program can be achieved.

Conclusion

This paper discusses several aspects of the development of a new electrical and computer engineering program and its insertion in an existing university.

The development and insertion of a new program in an institution of higher learning faces challenges and provides opportunities. The difficulties lie in the procurement of all the resources required for the establishment of a quality program. The challenges include securing sufficient administrative, institutional, space, equipment, and personnel support. The opportunities lie in the possibility to create an efficient, modern, and attractive program for engineering education based on proven innovative teaching methods, state of the art equipment, and a new student-centered curriculum.

One of the first questions that immediately arise is "what is the best curriculum for a new program in Electrical and Computer Engineering?" In attempting to answer this simple question, many possibilities come to mind and a review of several expert opinions and an analysis of a few curricula from leading engineering schools lead to useful conclusions that are described in this paper. Some of these lie in the choice of courses for the curriculum, others in the teaching methods to be used, and yet others concern how the new program should interface with the host institution. The program under discussion adopts hands-on, project based teaching methods and tools, encourages multidisciplinary teaching and projects, and embeds communication skills in its curriculum.

One major objective for a new engineering program at a public university is to achieve accreditation as early as possible. Therefore, accreditation requirements offer guidance on several development issues. A new program should be implemented with all the requirements for accreditation built in.

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