Abstract - This paper describes a new four-year Bachelor of Electrical Engineering program being introduced in British Columbia (BC), Canada at the BC Institute of Technology (BCIT). The program addresses the need in industry for engineering graduates that have a solid practical focus as well as the expected theoretical depth and topical breadth of knowledge. The program works in tandem with a nationally accredited two-year Diploma of Electrical and Computer Engineering Technology. The program structure allows both the existing Diploma program and the Degree program to be optimized based on their respective priorities and market needs, i.e., there is no need to impose major changes on the Diploma program in order to accommodate the Degree program. The result is a pair of programs that allow students to graduate with either a diploma or a degree, and also to return after receiving their diploma to complete their degree later. This structure provides, in effect, a two-stage entrance evaluation process which allows the program to draw from a broader pool of prospective engineers, thereby providing a path to the profession to people that may otherwise have missed the opportunity. The program’s curriculum uses a contextual or spiral approach, where applications are introduced prior to theory, and then revisited once the theory is developed. While the program described here is designed to help address the shortage of electrical engineers in Canada, similar conditions prevail in the United States and elsewhere, and similar programs may be useful in addressing these shortages.

Index Terms – Contextual Curriculum, Spiral Pedagogy, Bachelors Electrical Engineering Program Structure, Diploma Interaction.

INTRODUCTION

While events around the turn of the century in the telecommunications marketplace (or more generally the "high technology" marketplace) had a well-publicized chilling effect on the electrical engineering sector, data now indicate that the effect was transient in nature and that the industry is strong and growing. For example, in the Province of British Columbia, the GDP for the high technology sector started to rebound in 2003 [1][2], and is predicted to continue to grow [3]. Similar such trends are apparent throughout the continent.

Although it is comforting to be in a healthy and growing industry sector, there is considerable concern in North America that the local capacity to meet the need for new engineers is inadequate. Large numbers of "baby-boomers" will retire from the profession over the next decade. In order to replace these experienced engineers, Industry needs a strong sustained supply of new engineering graduates, and the time for these graduates to acquire the maturity and experience needed in senior engineering positions. In the broad sense, Industry refers to any social, academic or industrial activity that employs electrical engineering expertise, though for the present program the emphasis is more towards engineers in industrial contexts. We are at a particularly critical time now, as the impending retirements leave behind a void in mentorship. Unfortunately, birthrates in North America have declined over the past few decades, so the pool of prospective engineers is uncomfortably small. Many good candidates are drawn away to various other noble academic pursuits. Others are unable or unwilling to go through a minimum of four years of intensive study with high tuition fees and personal income that is far less than their counterparts that have full-time jobs. In any case, the natural response of Industry to this shortfall is to export engineering activities to other countries or to import foreign trained engineers as immigrants. Undue reliance on these strategies ultimately undermines the educational advantage that has contributed to the productivity and standards of living enjoyed by industrialized nations through the past century.

These concerns, and their connection to economic well-being and competitiveness, are well known. For example, Augustine [4] and Lucky [5] described the findings of a US National Academies committee that examined the issue in 2005. An alarming decline was noted in the number of students graduating with engineering bachelor's degrees, both in absolute number terms and in proportion to other degrees. Their main call to action was to improve the K-12 education system and to provide increased funding for basic research. Clearly, means are needed to make the pathway through school to an engineering career more effective, attractive, productive and accessible.

Engineering programs focused on the education of students destined for engineering practice, such as the one being introduced at BCIT, can be an important adjunct to traditional programs, as they can increase the pool of prospective engineers. Not every aspiring engineer “fits” well within traditional programs, even though many of these people could make very good engineering practitioners. Good candidates may take an indirect path to engineering and enter the programs with widely varying backgrounds in trades and other areas, or they may be “late bloomers” that
have not yet shown their academic potential. In any case, new programs that have a deliberate practitioner focus may be an effective means of drawing good people into the profession who might otherwise have missed the opportunity.

OBJECTIVES

As with any engineering undergraduate program, the general aim is to provide the student with an appropriate mix of mathematics, basic science, engineering science, engineering design and complementary studies to enter a career in electrical engineering, as well as the confidence and problem solving skills to quickly and independently develop a working level of competence in unfamiliar areas when needed. Within this general aim, the program has the following objectives:

1. A distinctive emphasis of the program is on meeting the needs of Industry for engineering practitioners. The curriculum and the faculty need to be aligned with this emphasis.

2. The graduates need to be recognized in Industry as being at the same “level” as graduates from traditional university-based program. This doesn’t necessarily mean that they are the same, rather, it means that they can meaningfully compete for the same entry-level jobs and command the same entry-level salaries as their university counterparts, and that they achieve comparable levels of success in engineering careers.

3. Accreditation of the program through the Canadian Engineering Accreditation Board (CEAB) is seen as being important. Accreditation is sometimes used by Industry as an indicator of legitimacy, and is also used by the provincial engineering associations as an academic quality control measure to streamline the process of acquiring licensure as a professional engineer. Although the accreditation process is often misunderstood by prospective students, accreditation status is often used as an indicator of the quality when they are choosing an engineering program.

4. The program is to operate in concert with BCIT’s existing Diploma of Electrical and Computer Engineering Technology (Diploma) program to provide accessible and flexible educational paths towards successful professional careers either as electrical engineers or as technologists. This co-operation is an efficient way to draw in a broader catchment of students and allow them to “find their level” within the Institute’s programs. This co-operation also allows the engineering program to derive significant benefit in sharing of institutional resources and providing a strong hands-on practical emphasis.

PROGRAM STRUCTURE

The program structure is illustrated in Figure 1. Key attributes of this structure are as follows:

- **Shared first year:** The first year of the new engineering program is shared with the existing Diploma program. It effectively identifies students with the specific aptitude and work ethic needed for the remainder of the program.

- **Two-stage entrance requirements:** Entrance to the first year is the same as for the Diploma, which is lower than is usual for first-year entrance to an engineering program. Entrance to the second year is competitive, with a minimum requirement that students have a GPA of greater than 70%. Those that do not meet this threshold can continue and complete their Diploma, and apply again later if they so choose.

- **Three year engineering continuation with a parallel one-year Diploma completion:** The remaining three years of the engineering program were built to provide students a straight-through four-year path to a Bachelor’s degree.

![Diagram of program structure](image-url)
possible to obtain a Bachelor’s degree in 4 years, or both a Diploma and a Bachelor’s degree in 5 years. In future, it may be possible through course scheduling to shorten the program length by one term for diploma graduates, thereby providing an attractive 4½ year educational path that includes both a diploma and an engineering degree.

- **Co-operative education:** The program includes a mandatory co-op component: at least one summer must be spent on a co-op work placement. Additional co-op placements are encouraged. The Co-op component reinforces the emphasis of practitioner focus and industry relevance, and provides students with the many well-known advantages of a co-op program. However, the practitioner emphasis of the program is only achieved in part through co-op education: the structure and curriculum of the program, and the background and approach of the faculty, are also prominent means of achieving this emphasis.

**PROGRAM CHARACTERISTICS**

The aim of the program is ambitious: We aim to consistently produce graduates that compare favourably with their university-based counterparts, even though on entry to the program some students will not have demonstrated their academic potential for engineering studies through traditional measures. The program has the following characteristics to accomplish this aim:

- **Demanding program with high contact hours:** The intensity of the program is an important means of ensuring that graduates meet a high standard. The shared first year of the program contains approximately 30 hours per week of contact, and the terms are 17 weeks long. This first year is recognized by current students of all abilities to be highly demanding. The term length remains the same throughout the program. The contact hours in later years drop to about 25 hours per week, in part to allow more time for self-directed independent exploration and thought. Nonetheless, the total contact hours for the students over the course of the program are higher than usual, and the demands of the program will be high in all years.

- **Faculty with industrial experience dedicated to undergraduate teaching:** Most faculty are primarily active in, and motivated by, teaching. Faculty participate in both lectures and labs at all levels of the program, and are consistently available outside of designated contact hours for interaction with students. When hiring faculty, a PhD is viewed as an asset but the emphasis is on industry experience, as relevant industry experience among faculty is essential for the practitioner focus of the program.

- **Well equipped laboratories for programs that put time and emphasis on laboratory skills:** Most technical courses in the program have a heavy emphasis on laboratory activity, with the number of lab hours often being the same as the number of lecture hours, and with substantial requirements being placed on students for lab preparation and in-lab activities. The provisioning of such laboratories, and the Institute in general, is driven largely by program needs, and not research needs. Students are generally provided with fully-equipped individual workspaces for independent work. Group work in laboratories is undertaken for pedagogical reasons, not purely economic ones. A passing grade is needed in both the lecture component and the lab component in order to pass most technical courses.

- **Customized mathematics, science and communication support courses:** The mathematics and science courses are presented with specific reference to relevant electrical engineering applications and subject matter. For example, the first year mathematics courses are introduced in tandem with circuit analysis courses, and draw strongly on circuit analogies. The communication courses are tied closely with project reports, proposals, documentation, presentations and other such communication activities found in the technical courses of the program.

- **Contextual curriculum:** Practical applications are presented, as much as possible, before the underlying theory so that the theory can be learned in context. The applications are subsequently revisited and explored in greater depth given the benefit of the newly introduced theory. This contextual approach is in contrast with a more conventional approach, where theory tends to be more fully developed before applications are introduced.

- **Ample non-technical material:** Broad and thorough exposure to non-technical aspects of engineering is an important aspect of establishing a full and mature context for the technical aspects of the curriculum. A larger than usual proportion of the program is devoted to relevant non-technical material. Examples include inclusion of a marketing course prior to much of the advanced technical material, interweaving of an emphasis on technical communication through specially designed communication courses, insistence on good documentation and reporting practices in laboratory work, an appropriate selection of liberal arts electives, and exposure to financial, management, social, legal, ethical and professional responsibilities of engineers prior to, or in tandem with, the capstone design project.

- **Heavy emphasis on a capstone project:** The capstone project spans the entirety of the final year and is a significant multi-faceted engineering design experience. It serves to tie together the various topical threads within the program. This project is expected to be a key focal point for achieving and maintaining the distinctive emphasis for the program: students, faculty and sponsors from Industry will be deeply involved. The benefits to students and Industry are readily apparent: students get much needed realistic experience and contacts, and industrial sponsors get good work done at low cost by people that they may wish to hire. The
benefits to faculty are also substantial as the projects can serve in part to provide an outlet for their industrial expertise and ensure that they remain current in the practice of engineering.

**Program Pedagogy**

The program’s characteristics reflect good pedagogy for the design of a practitioner-focused undergraduate engineering program. Elements such as the two-stage entrance requirement, high levels of instructor contact and a contextual curriculum create a strong basis for learning that meets the needs of students and ensures a solid foundational understanding of the discipline.

As mentioned above, the traditional approach to undergraduate education has been to build up a foundation of necessary pre-requisite knowledge in mathematics and sciences, and then use this basis to inform theory and analysis of practical and relevant applications. For many students, however, engineering programs of this design are like mystery novels: you gather a whole bunch of seemingly disconnected facts and knowledge only to find out at the end how they all fit together in a useful way. While it all does finally come together in the end, it can be a frustrating and de-motivating experience while you are in the middle of the program. This undermines learning for some students.

An essential ingredient needed to learn in engineering programs is founded on the learner’s willingness, or motivation, to engage in deep levels of thinking for extended periods of time in order to achieve understanding. Motivation suggests that learners are “active and curious searchers for information to solve personally relevant problems” [6]. It is important that students see the relevance and practicality of what they are learning in order to be motivated. To this end, the program utilizes a contextual curriculum where practical applications are presented before, or in tandem with, the underlying theory. This provides an applied context for the theory at the outset, which ultimately becomes the theoretical framework for the more advanced engineering subject matter. The applications are subsequently revisited and explored in greater depth, with the learner benefiting from earlier experiences. In so doing, students are able to quickly establish the connection between theory and practice and have immediate opportunities to apply their newly acquired knowledge in realistic situations.

This contextual approach to learning leads to a curriculum structure that has been described in the literature as a “spiral” curriculum [7-9], wherein course material is presented multiple times in ascending degrees of depth and complexity, and from several different points of view. According to Bruner, who coined the term spiral curriculum, “a curriculum as it develops should revisit basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them” [10]. It has been suggested in the literature that spiral approaches result in greater motivation for students, and increased student satisfaction and confidence throughout the program [11][12].

An example of the contextual approach is the introduction of students to operational amplifiers (op-amps) in the program. A conventional approach would be to first cover mathematics, physics and semi-conductor theory, and then use this knowledge for a sophisticated treatment of op-amps. The new program operates differently. Op-amps are introduced very early in the program, i.e., before covering the usual mathematics, physics and semi-conductor theory. Clearly the treatment of op-amps at this point is not the same as for the conventional approach. However, as we subsequently introduce the other subjects, we revisit the topic of op-amps at increasingly sophisticated levels. At the end of the program we will have fully covered the required material for op-amps. The important benefit, however, is that we will have covered the foundational material in the context of its ultimate application.

The contextual curriculum and spiral approach serve another important pedagogical role. Driscoll describes work done by Ausubel in the area of learning processes where the importance of making learning meaningful to learners was emphasized. To ensure meaningful takes place, three conditions are required to be present: the learner must engage with the material in a meaningful way (linked to motivation); the material itself must be appropriate and meaningful to the learner (relevance of material); and, most importantly, the relationship between the learner’s existing knowledge and the material being learned must be linked [13]. While the first two conditions are often readily addressed, it is the third condition that is particularly well-served by the contextual approach. Specifically, the advantage of the contextual approach is that it ensures important conceptual links are present in the learner so that when more abstract theories, concepts and mathematical principles are introduced later there are “anchor points” available from previous learning upon which new knowledge can be built.

A high level of instructor contact with students is another hallmark of the program’s pedagogy. Interaction and active involvement of instructors with student learning provides opportunity for prompt feedback to students on their understanding of new material. Timely feedback is important to deal with what Marchese calls “scary” consequences of prior learning that are based on early childhood formations of how the world works, and that have since become entrenched [14]. Prompt feedback on a student’s understanding of a subject is therefore critical to the early identification of these misconceptions and the necessary correction.

**Challenges**

Introduction of programs such as this presents several significant challenges. The host institution needs to commit to an expensive program, with well-provisioned labs, low teacher-to-student ratios, heavy course loads, experienced senior faculty and specialized courses that are not easily shared with other programs. Existing faculty need to see the inclusion of the engineering program as being constructive
for the diploma program and its students. New faculty with extensive industry experience need to be hired into a teaching environment that has different constraints, demands and culture. Attracting good new people into an environment where compensation is lower than in industry can be difficult. Work loading and other aspects of faculty responsibilities need to be revisited in consideration of the inherent differences in a four-year degree program as compared with a two-year diploma program.

Acceptance of the program within the engineering educational community represents a challenge. Engineering program accreditation guidelines are built up around educational community represents a challenge. Engineering program accreditation guidelines are built up around the concrete reality of a four-year degree program as compared with a two-year diploma program. Work loading and other aspects of faculty responsibilities need to be revisited in consideration of the inherent differences in a four-year degree program as compared with a two-year diploma program. Recognition for graduate studies at other institutions is an unknown: an appreciation needs to be developed at these other institutions that practitioner emphasis does not imply deficits in theory.

Built-in mechanisms for ensuring the currency of faculty are needed. This includes generous provisions for professional development and lower teaching loads than is typical for two-year diploma programs. Continued activity in industry among faculty members will be an important element, and the capstone project will be a focal point for such activity, to the benefit of both the faculty and the students. Given the nature of the program and its faculty, and the absence of graduate degrees, publication and research activity will be less prominent. Finally, with an emphasis on hiring of faculty that have substantial industrial experience, the average tenure of faculty will be lower and hiring will be more frequent. A benefit of this last point is that the experience of the new hires will serve to replenish currency in engineering practice among faculty.

**DISCUSSION**

The structure and characteristics of a new electrical engineering undergraduate program have been described. We believe that the resulting program structure and characteristics can be generalized as an effective path to an engineering career for a broader selection of aspirants. The attributes of the program are as follows:

- **Superior Entrance Evaluation:** Sharing of the first year with the Diploma minimizes reliance on first-year entrance requirements. It is well known that comparison of marks obtained in various school districts and colleges can be problematic: an A student from one school may be the same as a B student from another school. This problem is made worse when you include immigrants or people that have spent time in the workforce. The shared first year is, in effect, a one-year on-site topical entrance evaluation. This allows us to safely bring in a broader catchment of students in the first year, and identify capable people who otherwise may have been denied the opportunity to try. It allows us to identify students that have the aptitude, work ethic and commitment needed to succeed in a demanding program of study, regardless of their apparent academic qualifications on entry. It also allows us to design the final three years of the program with a more solid, specific and reliable understanding of the background and capabilities of the students.

- **Practical Foundation started in the First Year:** The first year lays down a foundation for the strong practical hands-on skills that are developed throughout the program. There are significant advantages to sharing a first year with a diploma program, as compared with the alternatives of having a common first year among various engineering disciplines or having a second-year entry point for students that have completed one year of general science. The Diploma is very discipline-specific and quickly introduces relevant applications in tandem with theory. It has a substantial practical hands-on emphasis, with students immersed in significant laboratory activities right from the start. It is also very demanding, as much material needs to be covered in the two-years of the Diploma program.

- **Diploma or Degree Exit:** Engineering programs are notorious for high levels of attrition. An important advantage in the present program structure is that students who might otherwise drop out have the option of working towards a role in industry as Technologists, rather than being lost to the industry altogether. Both Industry and students benefit.

- **Built-in Bridge for Degree Completion:** Some engineering programs allow diploma graduates to bridge into their third year by taking a package of mathematics, science and other courses. This is burdensome for the students, and often requires articulation of courses among several institutions. In the present program, such bridging is not needed for graduates from diploma programs that have similar attributes as our Diploma: it is built into the program. The built-in bridge allows our students a second chance at entry: if they do not get a seat in the competition for entry after their first year, they can proceed to complete their Diploma and try again later.

- **Three-year sequencing:** In a discipline that is as broad and complex as electrical engineering, it is very useful, perhaps necessary, to have three years after a shared first year in which to set out an appropriate sequencing of material. The alternative, which is attractive from an institutional and a marketing perspective, is to build a two-year degree completion program on top of an existing diploma. After considering such an approach, we concluded that the desired sequencing for the degree would necessitate a significant restructuring of the diploma, and the result would be a compromise that would not serve either program well. Moreover, the advantages of having a single shared first year would be lost.

- **Minimum disruption of the Diploma program:** The Diploma program has been operating for more than 30 years: It has an enviable reputation and a solid market for its graduates. Major changes to this Diploma
program, driven by the needs of the new engineering program, are not justifiable. In fact, continuation of a strong diploma program which is optimized based on its own priorities and market requirements is critical to the ultimate success of the engineering program. We believe, therefore, that an important advantage of the proposed Degree program structure is that there is no required coupling with the Diploma after the first year, and that the first year can be left largely unaltered.

A pivotal question related to programs such as the one described here is whether they will reliably produce graduates destined for Industry that are at the same “level” as those coming from traditional programs. The graduates need to contribute in Industry at least as successfully as their counterparts. Falling short in this regard would greatly diminish the usefulness of such programs in addressing the deficit in engineers. We believe that the program model adopted at BCIT can produce the desired results.

REFERENCES


AUTHOR INFORMATION

Neil Cox, Instructor, BEng Program Champion, British Columbia Institute of Technology, neil_cox@bcit.ca
Glenn Pellegrin, Instructor, British Columbia Institute of Technology, glenn_pellegrin@bcit.ca

Acknowledgement: The authors gratefully acknowledge the contributions of the members of the Electrical Engineering Faculty Engagement Team, which presently includes Craig Cowan, Bob Gill, Ron Jones, Enrico Murru and Rod Randall as well as the authors.