A Tale of Interdisciplinary Studies: Communication Systems Engineering

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ABSTRACT

Two decades ago an interdisciplinary undergraduate program for Communication Systems Engineering was planned and suggested by Ben-Gurion University and approved by the Council for Higher Education of the State of Israel. Since then, hundreds of students have enrolled in this program and graduated successfully, and graduate programs in CSE were offered. The interdisciplinary nature of the undergraduate program enabled students to resolve their uncertainties over whether to study hardware- or software-oriented engineering programs. Many considered the CSE program a remarkable success during its early years, as it responded to the Israeli high-tech industry's requirements and the students' expectations. The graduate engineers of this program met the industry's desperate requirements for skilled engineers in networking, communication equipment, and software during the pre- and post-bubble era of the Internet boom. However, a few years after its inception, this undergraduate program, or the department running it, or both, started to decline in many respects, mainly in the demand for this program, to the point where the department even considered closing it down. The decrease in demand stands in contradiction to the satisfaction of both students and graduates. This paper briefly describes this interdisciplinary undergraduate program, and the factors that could have influenced its success or failure.

Keywords: Interdisciplinary, Engineering, Computing, Communication Systems Engineering.

1. INTRODUCTION

Twenty years ago, students began their studies in the newborn Department of Communication Systems Engineering. The curriculum for the B.Sc. degree in Communication Systems Engineering (CSE) was approved by the University's senate, and by Israel's Council for Higher Education (CHE). The curriculum, as well as the justification and the motivation for this study program and the resulting degree are described in [17]. The CSE undergraduate program is interdisciplinary, combining Computer Science (CS), Electrical Engineering (EE), and Information Systems (IS) in its curriculum. It is based on the multidiscipline knowledge required to analyze, design, deploy, implement, operate, administrate, manage, and maintain communications systems and networks. There are many academic and professional journals in CSE, as well as many academic and professional conferences for CSE issues. The communications and Internet industry is blooming if not exploding, and requires the multidisciplinary knowledge of CSE. Despite all of this, departments dedicated to CSE (sometimes called Telecommunications or Network Engineering) are not very common, and traditionally, Electrical Engineering or Computer Science departments usually teach and research CSE.

The Department and the CSE curriculum at Ben-Gurion University in Israel attracted many high-quality students at the beginning, and these students, as well as the graduates and their employers in these years, were satisfied, according to occasionally conducted surveys. However, during the last decade, a decrease in demand for this interdisciplinary program has been recorded, and the quantity and quality of the admitted applicants fell dramatically. This decrease is in contrast to the market demand for CSE graduates and to the communications and Internet market sentiment. There are many possible reasons for this dichotomy, and this paper tries to shed some light on the main factors.

Academic disciplines' success is hard to measure; there is a vast literature on academic success, which is beyond the scope of this paper. Hence, this paper describes one dimension of success or failure of this specific Department of CSE, namely the applicants' demand to learn in this Department. It does not necessarily reflect on the CSE discipline or inter-discipline, and certainly not on other CSE programs. The contrary, however, might be true, i.e., failure of this discipline might affect the demands for this Department and the CSE program it offers.

Factors that can influence the failure of the CSE Department or CSE program include industry trends, applicant quantities and quality, faculty characteristics, curriculum and curriculum updates throughout the years, students' satisfaction during their studies, and graduates' satisfaction in their professional careers. One additional factor is the alleged supportive environment, or, how the University has handled interdisciplinary undergraduate study programs at large. These factors are divided into external ones, which the University has no control over, and internal ones, those factors that the University can control, as discussed below.

Academic management of interdisciplinary programs is more challenging than administrating a single-discipline, established, academic program. It involves, among other things, understanding of the requirements of the usually new interdisciplinary field and the demands for this field's graduates, creating and maintaining a good curriculum, appointing the right mix and number of faculty members, and appropriate budgeting of the program.

The purpose of this paper is to contribute to understanding how to organize and operate an interdisciplinary undergraduate program, in order to avoid the fate of this particular program.

The paper is organized as follows: The first section presents the interdisciplinary nature of CSE in the context of computing disciplines, as defined by the joint Association for Computing Machinery and the Computing Society of the Institute of Electrical and Electronics Engineering (ACM/IEEE-CS) task force, and in the context of engineering disciplines in general. In the next section, the decreased demand for this specific undergraduate program, or for studying in this specific department, is demonstrated by the reduction in the number of admitted applicants and their quality. Next, the development of the curriculum over time is described and compared to the trends in the communications and Internet sectors, which dominate the Israeli high-tech industry. Finally, the contribution of the young faculty and the way the University handles interdisciplinary undergraduate programs add additional perspective to the factors affecting the interdisciplinary undergraduate programs. The last section summarizes and concludes this paper.

2. COMPUTING DISCIPLINES

A short description of the evolution of academic disciplines, especially computing disciplines, is given in the following in order to better understand the CSE curriculum and its rationale. There is vast literature on disciplines and on multi-, hybrid-, inter-, cross-, and trans-disciplines in academia, science, arts, and industry. From the pre-disciplines era to the four academic disciplines of early universities in the 11th-13th centuries (Theology, Medicine, Law, and Arts/Philosophy), through the 17th century when science was first introduced into universities, we have today many hundreds of academic disciplines [7, 11]. Although engineering has existed since ancient times, it became a profession in the late 18th century (following the industrial revolution) and was only acknowledged as an academic discipline in the 20th century. The main engineering disciplines were civil (in contrast to military engineers), mechanical, electrical, and chemical [24]. However, engineering disciplines are rapidly evolving, and currently we are witnessing tens of categories of engineering disciplines [1, 2, 18].

These engineering disciplines developed through evolutionary processes, e.g., natural selection, mutation, speciation, extinction, and heterosis, according to evolution theory [13]. The main evolution processes of engineering discipline development are contrasting: the first is specification, when a discipline gets too broad or complex, and sub-disciplines emerge and become disciplines of their own; and the other is heterosis, when several hybrid disciplines join to form a new discipline.

The way the hybrid engineering disciplines are combined determines the development and success of the outcome engineering disciplines. In short, hybrid engineering disciplines can be categorized and distinguished as follows: Multidisciplinary is the weakest way of creating new disciplines, in which different fields of knowledge (disciplines) join and collaborate to solve a particular question [22] by addition and not integration of the disciplines' fundamentals (concepts, methodologies, etc.; [16]). Multidisciplinary can refer to generalists, who possess knowledge in several disciplines, and make use of this in solving a question, without integrating the disciplines, or creating new ones. Interdisciplinary is a better path towards new disciplines, integrating different disciplines in solving a particular question [22], resulting in mutual enrichment [16]. Transdisciplinary is the best way to create new disciplines, as it integrates and transcends the disciplines' fundamentals [13. 16, 22]

Digital computers appeared in the middle of the 20th century (following World War II) and created additional academic disciplines, from theoretical computer science to practical computer engineering. They all started as multidisciplinary engineering, and continued to integrate until some of them became disciplines of their own, as described in the following. All these additional disciplines seem to belong to the hard, applied, nonlife characteristics of Biglan's academic discipline taxonomy [10], together with computer science and the other engineering disciplines that Biglan studied.

The dispute on whether Computer Science is a discipline is well-documented in Curriculum 68 [8], noting that it might even be offered "as options in such fields as mathematics or electrical engineering", and then later again [15]. Computer Science was described as an integrated field based on mathematics, science, and engineering [15, 21], i.e., of a transdisciplinary nature that matured into a discipline of its own. It seems that this dispute continues in all emerging computing disciplines.

The first attempt to describe a common, acceptable computing curriculum seems to be the 1965 preliminary recommendations for an undergraduate program in Computer Science, by the Association for Computing Machinery (ACM) curriculum committee [4]. Following the preliminary recommendations, the ACM published the Curriculum 68 recommendations for academic programs (undergraduate and graduate) in Computer Science [8]. Curriculum 68 [8] was updated by Curriculum 78 [9], which in turn was superseded by Computing Curricula 1991 [20, 25, 26, 27] by the ACM/IEEE-CS Joint Curriculum Task Force.

The uncertainties regarding the computing discipline disappeared at the beginning of the 21st century, and Computing Curricula 2001 announced a family of independent computing-related disciplines emerging from the broadening computing and information technology disciplines: Computer Science (CS), Computer Engineering (CE), Software Engineering (SE), and Information Systems (IS) [5, 21]. It was clear that new computing disciplines would emerge over time, and indeed, Computing Curricula 2005 added the information technology (IT) curriculum, and left space for mixed disciplinary majors [3, 6, 19, 23]. Just recently, additional Cybersecurity Curricula have been offered at the post-secondary level, in order to structure the cybersecurity discipline [19].

3. COMMUNICATION SYSTEM ENGINEERING

In all the above-mentioned ACM/IEEE-CS committees and reports, the term computing or computer systems included network and communication systems. In the offered curricula, some communication and networking areas and courses were described, but in a very limited way and definitely not as a separate discipline. Computing Curricula 2001 acknowledged (in chapter 3) that networking was marginalized, while networking became the underpinning for the economic and critical foundation of computing [5]. Nevertheless, Computing Curricula 2001 and its following recommendations did not offer a separate discipline for communications and networking, as it did for the other declared disciplines, and despite the dozens of computing programs around the world [6], some of them were specifically communication and networking oriented. The need for the communication engineering discipline was clear [12, 14]. The Engineering Technology Accreditation Commission (ABET) published program criteria for Communications Engineering and similarly named programs [1, 2], according to which few US programs were accredited. The UK's Institute of Engineering and Technology (IET) accredited dozens of full engineering programs of communications, telecommunications, and networking to 13 UK universities as of 2017 [18], 11 of them offer chartered engineer degrees, the highest engineering degree. There are many other European, Far Eastern, and Australian programs for CSE (or similarly named programs).

In all CSE curricula, including the one offered by the Department of CSE that is described in this paper, it is emphasized that the program is of an interdisciplinary nature. This program combines electrical engineering, computer engineering, computer science, and information systems and technology, in different weights. Sometimes electrical engineering is emphasized, when the focus of the program is transmission channels, e.g., radio, fiber, or wires, and sometimes software when dealing with applications, control, or management. CSE can be regarded therefore as of an interdisciplinary nature, despite the main roles of networking and communications taking place in the computing arena.

Demands for the Department and by the Industry

In 1996, at about the same time ACM/IEEE-CS started to define the various computing disciplines in Computing Curricula 2001, the CSE program was offered in Israel as a response to the Israeli industry demands [17]. The program was very successful during early years according to students' surveys, enrollment, and industry reaction, but it sank later, in terms of students' demand, as described in the following. This decline can be attributed to many factors, external to the University and to the program (e.g., number and quality of applicants and faculty members, industry sentiment), or it can be caused by internal factors that are under University control, i.e., treatment of the students and faculty members, budgeting, students' satisfaction, curriculum, or running an interdisciplinary program.
Currently, the main problem of the Department of CSE is the low applicant demand for the Department or its CSE curriculum. This demand is a function of the number of admitted applicants to the Department and of the admission criteria, so that the higher the demand, the higher the admission criteria and the number admitted. The psychometric evaluation of the applicants reflects the admission criteria or the quality of the admitted students. The average psychometric evaluation is 540, and the maximal evaluation is 800. In order to neutralize some of the external factors that might influence the demand for the Department, a comparison to a similar computing department was performed. This comparison rolls out factors like demand for learning, engineering and computing in particular, or in this University in general, number of potential applicants, etc.
Figure 1 shows the number of admitted applicants to the Department of CSE and to a similar department during the last 20 years, relative to the number of admitted applicants in 2001 (solid lines), and their quality in terms of psychometric evaluation (dashed line; that of the CSE admitted applicants is shown with the standard deviation).

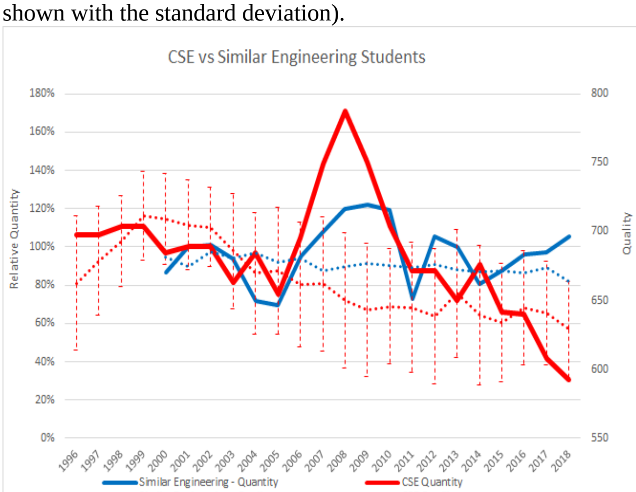

Figure 1: Number of admitted applicants and their quality in CSE and in a similar department (source: Academic Secretary).

Among the other external factors that influence the demand for the Department, the market sentiment is probably the dominant one. The communications and Internet sectors of the high-tech Israeli industry are the market sentiment that is relevant to the Department, which creates a demand for graduates of this Department, and causes a demand for the Department. There are several indicators that can be used to reflect the market sentiment, e.g., number of active companies in the sector, number of employees, and sectors' revenues, but each has its drawbacks, especially in terms of demand for skilled graduates. Figure 2 represents the number of new start-up companies annually over the past 20 years in Israel in the Communications and Internet sectors. This number indicates market sentiment and demand for graduates, reflects the interest that entrepreneurs and investors have in the sector, and is based on objective measure. Figure 2 also shows the year-to-year (Y2Y) growth rate in the number of new start-ups. In this figure, the Communications sector includes Broadband Access, Broadcast, Enterprise Networking, Mobile Applications, Mobile Infrastructure, Optical Networking, VoIP & IP Telephony, Wireless Infrastructure, Telecom Applications, Wireless Applications, NGN & Convergence, and Home Networking subsectors. The Internet sector includes Content Delivery Platforms, e-Commerce, Internet Applications, Internet Infrastructure, Online Advertising, Online Entertainment, Search Engines, Content Management, E-Learning, Social Networks, and Other Internet subsectors.

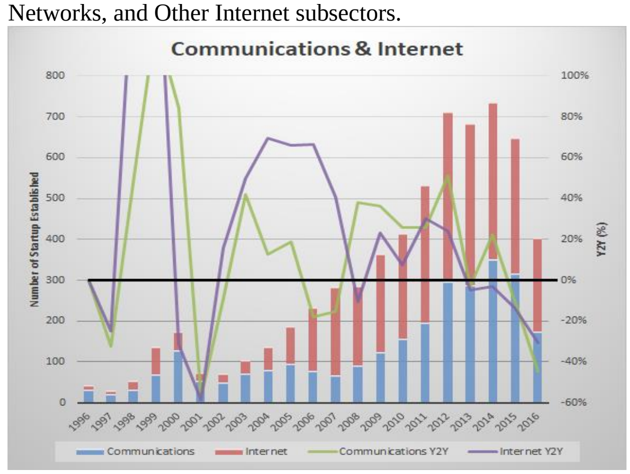

Figure 2: Number of new start-up companies opened annually in Communications and Internet and Y2Y growth rate (source: IVC-ONLINE).

Analysis

Figure 1 shows that over the years, there is a slight increase in the number of applicant admissions in a similar department (except for a substantial increase during 2006-2008 that later decreased), coupled with a slight drop in the quality of the admitted applicants. Contrary to that, there is a significant decrease in the quality of the admitted applicants to the Department of CSE (except in the early years), along with an ongoing decline in the number of applicant admissions (with the exception of a significant increase during 2006-2008 that disappeared later). Figure 1 also shows that although in 2008 the number of applicant admissions almost doubled, it was accompanied by a substantial drop in the quality of the admitted applicants to the Department of CSE, a decrease that has continued.
The comparison in Figure 1 of a similar department in the computing discipline shows that the weight of external factors

related to the demand for learning in the University, for engineering or high-tech in general, or the number of potential applicants, is meaningless in explaining the drop in the demand for the Department of CSE. This bad admission policy falls among the University responsibilities.

Other external factors that relate solely to the Department are those concerned with the sentiment of Communications and Internet industry sectors. Figure 2 shows that these external factors should have escalated the demands for the Department; Communications and Internet sectors grew and advanced with a very positive sentiment during the last two decades. The “2000 bubble” is well reflected in this figure, although it must be noted that the number of new startups annually post-bubble are more than the number of new startups pre-bubble. Since the bubble and until 2014 there was a steady growth in the Communications and Internet sectors, and then, from 2014, a slowdown in all the high-tech market (Communications, Internet, and Information Systems, as can be seen in Figures 2 and 3) can be observed, despite the impressive number of new startups annually.

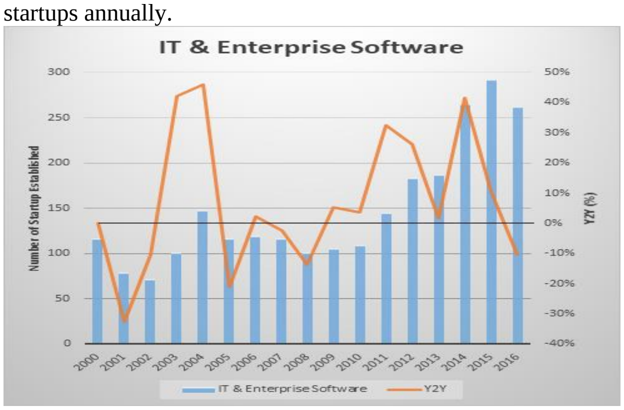

Figure 3: Number of new start-up companies opened annually in IT and Enterprise Software and Y2Y growth rate (source: IVC-ONLINE).

To better identify the employment market that is relevant to the graduates of CSE, Communications and Internet subsectors were reordered into core Communications, e.g., infrastructure, equipment, and systems of communication networks, and Internet and communication software, e.g., Communications and Internet applications, software that is not for infrastructure, etc. This reordering is somehow superfluous, since the CSE program covers Internet subjects as well, e.g., social networks, on-line entertainment, and many other software and application domains. Core Communications includes Broadband Access, Broadcast, Enterprise Infrastructure, Enterprise Networking, Home Networking, Internet Infrastructure, Mobile Infrastructure, Network Processors, NGN & Convergence, Optical Networking, VoIP & IP Telephony, Wireless Communication, Wireless Infrastructure, and Wireline & Home Networking subsectors. Core Internet and Communications' software includes Content Delivery Platforms, e-Commerce, E-Learning, Internet Applications, Mobile Applications, Online Advertising, Online Entertainment, Search Engines, Social Networks, Telecom Applications, and Wireless Applications subsectors. The resulting reordering of Communications and Internet Sectors is depicted in Figure 4, and shows a stable sector of startup companies that deal with the core communications issues (except for the bubble years), and an increase in the number of startups that deal with Internet and communications software (until 2014, as noted above).

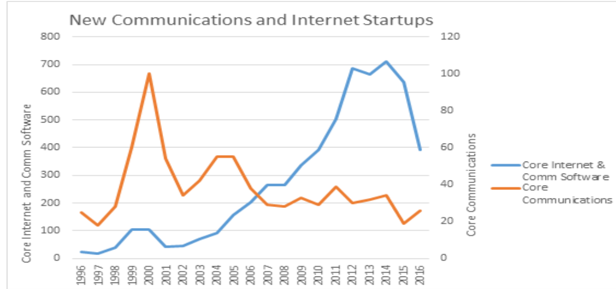

Figure 4: New start-ups in the core fields of Communications and in Internet and communication software (source: IVC-ONLINE).

The demonstrated change of emphasis in communications infrastructure, Internet, and communications software and applications called for changes in the CSE curriculum. The Department of CSE changed its curriculum over the years, as depicted in Figure 5, taken from the department's report to the Council for Higher Education of the State of Israel (CHE).

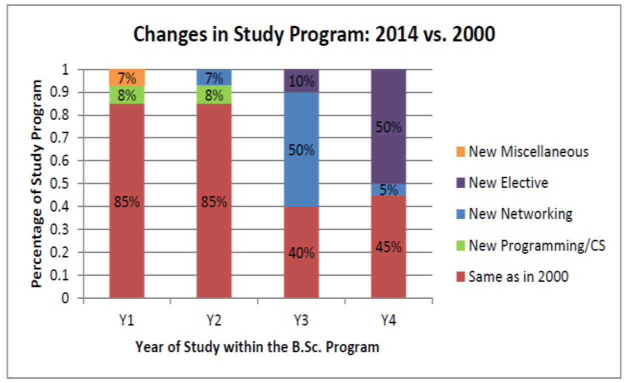

Figure 5: Changes in the curriculum of CSE 2014 in relation to 2000 (source: the Department's report to the CHE).

It is not clear from Figure 5 whether the changes are adequate and match the requirements of the industry. It is also unclear whether young faculty members, multidisciplinary in nature, were capable of coping with a subject matter that is unfamiliar to most of them, as more than 80% of their publications (until 2013) were not in CSE-related journals. This indicates that the Department has more of a multidisciplinary nature, rather than interdisciplinary, not to say transdisciplinary, nature. It emphasizes the need for a real transdisciplinary concept in such a program, where a good understanding and match to the industry's requirements can be achieved. Bad faculty recruitment, promotion, and leadership policies also fall among the University's responsibilities.

Outcome

The graduates of the CSE departments are satisfied with their studies, are employed quickly, and the industry accepts them warmly, as industry and graduate surveys show. The most recent survey, done in 2014, reveals that 89% of the graduates work in the communications industry in a range of roles from CEOs to system architects, VLSI designers, real time and mobile software programmers, and more. A previous survey among the graduates, done in 2005, also shows that 88% of them worked in communications roles, 27% doing software, 8% hardware, and the rest indicated communications; they worked for companies, 67% of which were mainly communications companies.

4. SUMMARY AND CONCLUSIONS

Communication Systems Engineering (CSE) is an inter-discipline of computing and electrical engineering disciplines, and there are many undergraduate and graduate programs for CSE. The inter-discipline program at Ben-Gurion University declined in terms of applicant demand, contrary to market demands for graduates, and the satisfaction the graduates have from their studies and the industry's reaction to these graduates. This paper discusses the place of the communication engineering inter-discipline in academia, in the communications industry, and the industry's requirements, as well as other external factors that are beyond the University's influence. Although this kind of program is quite common in Europe, the Far East, and Australia, it is not as common as other computing disciplines, particularly in the United States. It seems that every country has its unique industry sectors and unique industry requirements, which dictate the nature of its academic disciplines, CSE among them.

It is clear that the Israeli high-tech industry justifies, and in fact demands, CSE discipline, in light of the obvious dominance of this sector in the Israeli industry. It seems that only internal factors, such as faculty composition, lack of trans-discipline components, lack of University management's attention, and bad admission policy led to this decrease in demand for CSE. This finding emphasizes the critical role the University has in the success or failure of interdisciplinary academic programs.

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