

# Computing Branches Out: On Revitalizing Computing Education

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**Abstract** *Computing professionals are employed in so many different ways that it is difficult to even define the common foundation that all of them should master; however, a single degree program, computer science, is currently providing the training for most of these jobs. Computing education, following the model of engineering, may need to branch out into specialized degree programs to address the diversity of jobs that computing professionals currently hold. In this paper we describe the approach to computing education taken at DePaul University's School of Computer Science, Telecommunications, and Information Systems, an approach that involves both specialized computing degrees and the integration of computing in general education requirements. Both of these efforts have had a positive effect on enrollments at DePaul CTI and hold promise for revitalizing computing education more broadly in the United States.*

*Keywords:* Expanding the audience for CS

## 1 Introduction

In the past decade computing has become crucial in a growing list of professions including such diverse areas as manufacturing, the financial sector, government, medicine, and entertainment. Computing professionals are employed in so many different ways that it is difficult to even define the common foundation that all of them should master. According to the Bureau of Labor Statistics, there were about 2,850,000 computing jobs (occupation codes 15-1011 through 15-1099) in the U.S.[15] A single degree program, computer science, is currently providing the training for most of these jobs, though many computing professionals also come from math, the sciences, or engineering. The same statistics indicate that there are fewer than 1,450,000 engineers in the U.S. This number in-

cludes electrical, chemical, mechanical, aerospace, biomedical, civil, computer, environmental, agricultural, nuclear, petroleum, mining, and marine engineers all of whom are trained in different degree programs. This comparison suggests that computing education, like engineering, may need to branch out into specialized degree programs to address the diversity of jobs that computing professionals currently hold.

Like other computing programs in the U.S., the DePaul University School of Computer Science, Telecommunications, and Information Systems (CTI) has seen a drop in new enrollments in its “traditional” computing programs. With the dot.com bust, many students decided that they were not interested in traditional computer science courses focused on math or programming and typical careers like software development. Female students, especially, left the field en-masse. One hypothesis is that the traditional technical foundations of computing seemed too abstract or too irrelevant to students who grew up using computers and other computing devices like cell phones, PDAs, digital music players, and gaming consoles in their daily lives. Furthermore, many computer science degrees focus on traditional foundation courses, leaving very little time for students to obtain applied problem-solving skills for jobs such as a system, network, or database administrator, a game or computer graphics developer, or a software or security engineer. Faced with taking abstract courses in a degree program that seems divorced from the applications that may have motivated them in the first place, students have decided that computer science is not the right choice for them.

## 2 A different approach

This convergence of phenomena suggests that a new approach to computing education may be war-

ranted. We describe a two-pronged approach, implemented by DePaul CTI faculty, that shows potential to revitalize computing education.

## 2.1 Multi-tracked computing education

The DePaul CTI faculty decided in the 1990s that a single computing curriculum was not sufficient for the needs of our students. Since then, the faculty has continued to identify broad fields within information technology as a whole, and computing in particular, and created degree programs for students interested in pursuing careers in those fields. Ultimately, we think that this process of creating multiple tracks in traditional undergraduate computing programs will prove to be beneficial to the whole computing endeavor in the U.S. We believe that a multi-track model will increase the number of students entering the computing field and graduating and that it will increase the quality of the graduates because they will be better prepared for their chosen profession, whether it is computer graphics, telecommunications, or computer science.

We also believe that traditional computer science programs will benefit from the multiplication of computing programs. If computing education is to be modified to include an array of more professional programs, then traditional computer science will be refocused as the core program that trains students to be computer scientists, i.e. professionals trained in mathematics and problem solving, programming and modeling, and computer systems foundations. As the ACM 2001 B.S. in CS curriculum suggests, they will be the developers and researchers and work on making current computer applications better or developing new applications for computer systems[3].

### 2.1.1 Degree programs

DePaul CTI is a large school with nearly 80 fulltime faculty, 15 bachelors degree programs, and almost 1000 undergraduates. The degree programs at DePaul CTI cover a broad range of information technology from information systems to digital arts, but there are five degree programs that are of particular interest when considering the issue of broadening computing. Computer games development, computer graphics and animation, network technology, and information assurance and security engineering are all highly technical degrees that focus on particular subarea of computing. Along with computer science, they form the backbone of computing at

DePaul CTI[10].

The program in computer games development is interdisciplinary and includes courses in mathematics, programming, game design, physics, and animation[10]. Graduates are prepared to take a variety of positions within the gaming industry, as well as at more traditional companies interested in using games for advertising and promotion. The computer graphics and animation program has two tracks, one for students interested in careers as graphics software developers and one for those who wish to facilitate the visual aspects of graphics lighting setup and scene layout[10]. The network technology program is designed for students who want to select, justify, configure, and manage network technologies in a variety of business settings. Course topics include the foundations of networking, local area network design and management, Internet access technologies, routing, and interconnection technologies[10]. The security engineering degree is designed to teach students foundations of information assurance technology, techniques, and processes in order to prepare graduates for employment in an information security team or in any technology position where information security is an important part of the work function[10]. In contrast with each of these degrees, the computer science program provides students with a comprehensive foundation that permits them to adapt to as well as create new technologies, new paradigms, and new ideas in computing[10].

Each specialized degree program has some broad foundations courses. However, as focused degree programs, they also provide courses designed to prepare students for the particular area in which they are specializing. Table 1 lists some of the broad and more specialized courses that can be found in each of the non-traditional computing programs discussed in this section.

**Table 1: Sample computing courses**

Degree Program	Foundations Courses	Specialized Courses
Computer Games Development	C/C++ Programming I & II; Calculus I & II; Linear Algebra; Data Structures in C++; Computer Systems I & II	Game Development I & II; Artifact, Level, and Terrain Design; 3d Modeling for Animation and Gaming, Physics for Game Developers, Game Modification Workshop

Computer Graphics and Animation	C/C++ Programming I; Data Structures in C++; Discrete Mathematics; Calculus I & II; Design and Analysis of Algorithms	Computer Graphics Development; Advanced Rendering Techniques; Principles of Computer Animation
Network Technology	C/C++ Programming I & II or Java Programming I & II; Introduction to Desktop Databases; Discrete Mathematics	Applied Networks and Security; Principles of Data Communications; Introduction to Local Area Networks; Voice Communications Technologies
Information Assurance and Security Engineering	C/C++ Programming I & II or Java Programming I & II; Introduction to Desktop Databases; Discrete Mathematics	Applied Networks and Security; Fundamentals of Information Assurance; Principles of Data Communications; Computer Forensic and Incident Response; Information Systems Security Engineering I & II

### 2.1.1.2 The DePaul multi-track model as compared to other institutions

In the past 10 years there has been a tremendous effort, within the United States and elsewhere, to develop innovative computing programs. Schools with specialized undergraduate degree programs in bio-informatics, gaming, or software engineering, for example, are too numerous to list, although they include the University of Denver's B.S. program in animation and game development[16], Carnegie Mellon's B.S. programs in computational biology[1] and in computational finance[2], and the University of Victoria's Bachelor in Software Engineering[17]. In addition to the specialized programs, innovative approaches to organizing computer science education, such as Georgia Tech's Threads[12], are being developed as well.

While it is not uncommon for computing schools and departments to offer a few specialized under-

graduate programs, not even the largest schools have committed themselves to a really broad palette of applied, specialized computing programs. We are not aware of any school that has come close to DePaul CTI's model that includes more than a dozen undergraduate computing degree programs. Furthermore, while some of the programs offered at DePaul CTI are traditional (such as computer science) and some are increasingly found elsewhere (such as computer game development), DePaul CTI is also offering programs that few have.

One example is the B.S. program in computer graphics and animation that has been offered since 2001[10]. Few similar programs exist. It is one of only 10 programs listed in the ImageWorks Professional Academic Excellence program (a Sony Picture ImageWorks Inc. program)[14], along with Pratt, USC, Carnegie Mellon, MIT, Stanford, and others. In fact, most schools in the ImageWorks Professional Academic Excellence program do not offer a specialized technical (i.e. focused on math and systems) degree in computer graphics and animation, just concentrations or courses.

Another example is DePaul CTI's undergraduate degree program in information assurance and security engineering[10]. This program is one of the reasons DePaul CTI was designated a National Center of Academic Excellence in Information Assurance Education by the National Security Agency and the Department of Homeland Security[13]. There are only 64 such centers in the United States. Among these 64 schools, very few offer an undergraduate security degree. A look at a sample of about 20 of the 64 schools yielded only one program at Dakota State University[11].

Because many of our specialized degree programs are new, we do not yet have data that shows the effectiveness of our programs. For example, the first gaming and security degree cohorts will graduate in June 2007. Thus no employment statistics for a number of degrees exist. Graduates from our more established programs like network technologies and graphics are employed in a variety of companies. Employers for networking technology program graduates include carriers such as AT&T, Sprint, Verizon Wireless, Cingular, and Comcast, manufacturers such as Motorola, Lucent, Rockwell, Cisco, and Westell, Internet service providers such as Earthlink, Covad, and Charter Communications, network consultants such as D&D Net services, and network-dependent industries such as the Chicago Mercantile Exchange, Chase, and Blue Cross Blue Shield of Illinois.

## 2.2 Computing and the Liberal Arts

With the belief that students with majors outside computing must be informed about computing and information technologies in general, the DePaul CTI faculty also worked to integrate computing and information technology into the general education requirements at DePaul University. As a liberal arts university, DePaul places a strong emphasis on general education, and students are required to take approximately half of the credits required for graduation in the Liberal Studies Program. The Liberal Studies Program has a common core of classes that are required of (nearly) all DePaul students as well as courses in specific domains, in particular, Arts and Literature, Philosophical Inquiry, Religious Dimensions, Scientific Inquiry, Self, Society, and the Modern World, and Understanding the Past[4]. The DePaul CTI faculty believe strongly that computing courses are crucial in the Liberal Studies Program and have worked to include over 30 courses in all but one of the domains and over a dozen CTI courses in various parts of the common core. A large number of DePaul students who do not major in computing take computing courses as a part of their general education.

### 2.2.1 The DePaul Liberal Studies Program

The Liberal Studies Program is the general education portion of almost every undergraduate education at DePaul University[4]. The exact number and mix of courses taken in the program varies by College within the University[6], but the requirements are separated into two major types: the common core and the domains.

Common core courses are the ones required of nearly every undergraduate. The majority of the course are taken during the first year as a part of the First Year Program in the Liberal Studies Program[5]. First Year Program courses include a Discover or Explore Chicago course, which introduces students to the urban and Vincentian aspects of the University, a Focal Point Seminar, which emphasizes active learning in a seminar situation, two courses in composition and rhetoric, and up to two courses in mathematical and technological literacy. During each of the remaining three years in an undergraduate degree, students take a sophomore seminar in multiculturalism, a junior year experiential learning course, which can be fulfilled with an internship, research course, or study abroad, and a capstone course, which is usually taught by the student's home unit[4].

The domain courses in the Liberal Studies Program are the conventional breadth courses that are found in many general education programs. Students take courses in six learning domains, which are Arts and Literature, Philosophical Inquiry, Religious Dimensions, Scientific Inquiry, Self, Society, and the Modern World, and Understanding the Past[4]. Each domain has a set of learning goals specific to the domain, and any course that is approved for the domain is reviewed by a faculty committee that ensures the course meets the required learning goals.

As mentioned above, students are required to take a varying number and mix of Liberal Studies courses depending on their home College and major. As a liberal arts university, however, DePaul students in general take a large number of Liberal Studies courses, with as many of 45% of their credit hours in the Liberal Studies Program[6].

### 2.2.2 CTI courses in the Liberal Studies Program

In the past 5 years, the DePaul CTI faculty have made a significant effort to expand the breadth of technical courses offered in the Liberal Studies Program. The first efforts focused on increasing the number of CTI courses in the domains in the Liberal Studies Program. DePaul CTI currently offers 10 courses in the Arts and Literature Domain, 1 course in the Philosophical Inquiry Domain, 19 courses in Scientific Inquiry Domain, 3 courses in the Self, Society, and the Modern World Domain, and 2 courses in the Understanding the Past Domain. DePaul CTI does not currently have any courses approved for credit in the Religious Dimensions Domain. Some of these courses are quite popular and account for very steady enrollments for DePaul CTI. For example, there are a large number of DePaul CTI Liberal Studies courses that are scheduled for the upcoming Spring 2007 quarter, including three sections of ANI 101: Animation (Arts and Literature), two full sections of CSC 208: The Computer and Social Responsibility (Philosophical Inquiry), one full section of CSC 239: Personal Computing (Scientific Inquiry), one full section of CSC 250: Computers and Human Intelligence (Scientific Inquiry), three sections of GAM 224: Introduction to Game Design (Arts and Literature), three full sections of GPH 211: Perceptual Principles for Digital Environments I, eight sections (seven of which are full) of HCI 201: Multimedia and the World Wide Web (Scientific Inquiry), and seven full sections of IT 130: The Internet and the Web (Scien-

tific Inquiry). All of the courses mentioned above are offered every quarter with the number of sections indicated above, and the courses usually reach the DePaul enrollment cap (30 or 40 depending on the course).

DePaul CTI faculty also worked to expand the common core of the Liberal Studies Program to include more technologically-oriented courses. The most dramatic change in the past five years has been the addition of a technological literacy course in the common core. ISP 121: Mathematical and Technological Literacy II "provides more advanced mathematical and computational methods in the analysis and interpretation of quantitative information. Topics include databases, descriptive statistics, measures of association and their interpretation, elementary probability theory, and an introduction to algorithms and computer programming" [8]. DePaul CTI is charged with staffing ISP 121, and there were 9 sections in the Winter quarter 2007, and there are currently 11 sections in the Spring quarter 2007.

DePaul CTI also contributes to the rest of the common core of the Liberal Studies Program by offering junior experiential learning courses, including Global CTI courses that involve brief international study opportunities for students, and senior capstone courses for each degree program within CTI. DePaul faculty also increasingly teach Discover and Explore Chicago courses and Focal Point Seminars.

Overall DePaul CTI's participation in the Liberal Studies Program has changed the way that CTI faculty view general education at DePaul. It is now common for faculty curriculum committees to consider what introductory courses can serve both majors and non-majors and to develop service courses purely for the Liberal Studies Program.

### 2.3 Impact on enrollments

Although DePaul CTI has suffered undergraduate enrollment declines as other computing-focused institutions have, the multi-track curricular model at CTI and the broad integration of CTI courses in the Liberal Studies Program at DePaul has mitigated some of the losses. During 2002-2004, total undergraduate enrollments at DePaul CTI decreased 22% [9]. However, as the DePaul CTI NCA report states: "In 2005-2006 we began to see a reversal of these trends. First year undergraduate headcount for Fall 2005 increased 55% over the previous fall. Total CTI enrollments for Fall and Winter 2005-2006 were within 1% of the respective enrollments

in 2004-2005. This is in contrast to reported trends nationally that showed a continued decline in incoming freshmen. In Fall 2006-2007 we are seeing a 7% enrollment increase over Fall 2005-2006" [9].

The impact of the computing degrees in the multi-track model at DePaul CTI can be seen more clearly if we consider enrollment history for each of the computing degree programs. While the undergraduate computer science program has gone from 739 students in Fall 2002 to 169 students in Fall 2006, other computing degree programs have remained steady or even grown. The peak for the computer graphics and animation program was 144 students in Fall 2004, but the decline in that program has not been as dramatic as computer science, with 89 students in the program in Fall 2006. The network technology degree has remained remarkably steady, varying between 185 students at its peak to the current count of 131 students. The gaming degree has shown the most dramatic growth among the computing degree programs, with an increase from 22 students at its inception in the Fall 2005 to the current total of 133 students. The security engineering degree is very new, but it is also promising, growing from 20 students in the Fall 2005 to 32 students in the Fall 2006.

The NCA report also discusses the impact of the Liberal Studies Program courses, noting that the overall undergraduate enrollment decrease was less than the decrease in courses taken by majors "due to aggressive development of CTI courses for the Liberal Studies curriculum, courses that enrolled a significant number of non-CTI students." [9] A year-by-year breakdown of non-CTI enrollments in CTI courses makes this contribution very clear. During the fall quarters of 2001-2003, non-CTI students in CTI courses numbered less than 500. In the fall quarter of 2004-2005 these numbers jumped to 683, in the fall 2005-2006 to 973, and in the fall of 2006-2007 non-CTI enrollments reached 1209. The inclusion of CTI courses in the Liberal Studies Program has not only changed general education at DePaul. It has also changed the way that DePaul CTI understands its role in the university.

## 3 Conclusions and future work

Like other computing programs in the U.S., the DePaul University School of Computer Science, Telecommunications, and Information Systems (CTI) has seen a drop in enrollments in its "traditional" computing programs. However, the

two-pronged approach to broad curriculum development that has been developed by the DePaul CTI faculty has mitigated some of the loss of enrollments. By adopting a multi-track curricular model for computing at CTI and the broadly integrating CTI courses in the Liberal Studies Program at DePaul, the faculty have produced a more robust model for computing than can be found at other technically-focused institutions. We believe that this model shows potential to revitalize computing education, making it better able to prepare students for the increasingly diverse field of computing and creating a set of programs that are appealing to a broader audience.

We would like to do more work to evaluate the effectiveness of our programs. Employer satisfaction statistics and surveys of our students several years after graduation will provide some initial data. We believe that our model, or parts of it, can be replicated at many institutions, large or small. We have already applied for funding to produce, in collaboration with a host of institutions and organizations, a new multi-tracked model for computing education and an implementation and assessment strategy. It is our hope that the kind of model used successfully at DePaul CTI can help to revitalize computing in the U.S. on a broader scale.

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