Crafting a Hybrid Discipline: Design and Development of a Master of Science Program In Computer Information Technology

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Abstract

This paper guides the reader through the nascent stages of design, development, and implementation of an inter-school, multi-disciplinary Master of Science program in Computer Information Technology. In an effort to provide the academy with an informative resource for those currently planning or contemplating the offering of similar IT programs, it discusses the origins of the program, describes its conceptual framework and curriculum design, and presents challenges encountered in the process of implementation.

Keywords: information technology, interdisciplinary program, computer-related graduate program, curriculum design

1. INTRODUCTION

In March 2001 the State of Connecticut Board of Governors for Higher Education granted Central Connecticut State University permanent licensure and accreditation for its interdisciplinary Master of Science degree program in Computer Information Technology (M.S. CIT). Shortly thereafter in May, degrees were conferred upon the first cohort of M.S. CIT students, nearly sixteen months after the program gained preliminary licensure authorizing the University to begin admitting students.

Initially conceived in Spring 1996, this hybrid program, jointly offered by the Departments of Computer Science, Management Information Systems, and Industrial Technology, was designed to break existing boundaries of related computing disciplines with the purpose of presenting a holistic approach to information technology (IT). The Computer Science component would provide foundations in analysis, design, and implementation of algorithms; Management Information Systems would bring their expertise in business applications of IT for strategic advantage in organizations; Industrial Technology would focus on the implementation aspects of hands-on networking, communications, and industrial applications of computer-based systems.

Witnessed by its steadily increasing enrollment, the program has served to answer employers' as well as students' needs for education in the emerging field of information technology. CIT has experienced a surprisingly impressive growth rate since January 2000 with the number of students increasing from 0 to 60 in 4.5 months, reaching 150 by the end of its first year (January 2001), with the most recent enrollment statistics reporting 224 students.

The process of shepherding the CIT program from initial idea to final implementation has been a rewarding and memorable learning experience; however, success has not come without a price. This has been witnessed particularly in the greater than expected faculty workload demands within the founding department and the increased advising responsibilities on the part of both CIT faculty and director. These and other program-related issues will be discussed in this paper, beginning with a description of the program and a brief history of its development, followed by the resulting curriculum design and implementation issues encountered in the process from licensure to accreditation.

2. PROGRAM DESCRIPTION AND EARLY DEVELOPMENT

The uniqueness of the program stems from its computing-related multi-school, multi-disciplinary iden-

tity, known on campus as an Interdisciplinary Program (IDP), formed as a virtual department composed of appointed and affiliate faculty persons. Appointed faculty persons include two from each of the three core departments, Computer Science, Management Information Systems, and Computer Electronics and Graphics Technology, and a Director initially from Computer Science to carry out the program's decision-making responsibilities. With the increased demand for new courses in networking and communications technology, a new faculty member was hired with expertise in these areas. In July 2001 the Department of Industrial Technology was divided into two departments, one of which is the Department of Computer Electronics and Graphics Technology, which will now become the Technology arm of the program. Affiliate faculty, both full and part-time, are identified as persons from departments who either currently teach courses or plan to offer courses in the program such as Mathematics and Physics.

The program has attracted an extremely heterogeneous audience including mechanical engineers, horticulturalists, IT workers seeking formal study and credentials for promotion, social workers and health care professionals, primary and secondary school educators, and biologists and pharmaceutical experts. Increasingly students are working in parallel on the M.S. CIT degree along with other computing-related advanced degrees elsewhere. (For instance, one student is working on a doctorate in Chemistry at a nearby private university while building a Beowulf cluster for a capstone project in high performance computing and communications within the M.S. CIT program.)

With the conception of this program nearly six years ago, CCSU began to carve its niche in the emerging field of information technology. The time was ripe for inventing a new way of packaging and presenting a holistic approach to the study of computer-based systems under the umbrella of information technology.

Motivation for its design came from students, faculty, and the growing pervasiveness of computing in society along with external corporate practitioner influences. As students inquired about the availability of a graduate program in computer science, it soon become clear that in fact a research-oriented computer science degree was not what they were really asking for, but for the kinds of tasks that they were describing, they needed a broad background knowledge and skill set in a variety of areas including software engineering, project management, business computing applications, networking and database management and administration.

Another factor which influenced the development of the CIT program was the blossoming of demand for computing resources by all of the University's schools, particularly by the departments that later formed the program. It seemed reasonable to attempt to bring together these departments in an effort to share resources, so that this joint program could accommodate the growing computing curriculum activity and encourage interdepartmental collaboration in a more cost-effective and productive way. (While this has not occurred as yet, it was also hoped that on an undergraduate level, resource sharing would minimize duplication of effort through the consolidation of General Education courses taught in the different departments.) At the same time as these internal influences were at work, corporate and industrial infrastructures were beginning to show clear and undeniable signs of the infusion of computing-dependent processes. This signaled the growing demand for knowledge worker support for data communication, storage, management, development, and software engineering needs. Soon the term, "information technology", began to be used extensively and evolved to reflect the holistic use of computing in the Information Age. The title of the program, Computer Information Technology, which was initially conceived in an attempt to represent each founding department's equal claim stake in participation and responsibility, became quite relevant.

All of these factors worked together to help identify a shared vision of a need for a program that would bring together, in a synergistic way, the expertise of the three founding departments. Actual progress began when, early in the spring of 1996, after a number of informal brainstorming sessions, consensus was reached that a collaborative interdisciplinary program in Computer Information Technology would be developed. In an effort to establish an autonomous and equally balanced basis upon which to build the program from the outset, a title was chosen with one word representing each participating department; thereafter, the program came to be referred to as the "Computer Information Technology" program. The design of the CIT program with the combining of talents, computing facilities, curricular strengths, and varied (academic) cultural perspectives was clearly an idea whose time had come since it took precious little convincing, at least in the beginning!

As explained by Daniel Rowley, Herman Lujan, and Michael Dolence, the central tenet of strategic planning is to align the organization with its environment; the institution needs to respond in a forward-thinking, proactive manner by designing programs, among other things, that serve to connect with external forces on the institution (Rowley 1997). To this end and initiated by the University President, a group of CIT faculty and deans was called together with the charge of investigating CIT connections through potential models for student internship positions at local corporations to fulfill the required capstone project culmi-

nating experience. While remaining responsive to external constituents and individual stakeholders it is the careful mission of CIT never to lose site of the absolutely critical value in the study of fundamental principles and modes of thought of each of its founding disciplines.

3. CONCEPTUAL FRAMEWORK AND THE ALCHEMY OF INTERDISCIPLINARITY

Discussions with employers and recent graduates hired by corporate IT firms revealed the importance placed on the acquisition of firm foundations in a wide range of computing-related knowledge and skill areas including

- programming substantially large systems in C++ or Java,
- information architecture, including system analysis and design,
- project management experience with the software development lifecycle, and,
- database and network administration.

Employers also emphasized that students need to be proficient in one object-oriented language while also able to learn new software packages quickly; oral and written communication skills are critical; the ability to work independently and in small group settings a must. It is the mission of the CIT program to prepare information technologists with these skills together with a firm foundation in the fundamentals of each component discipline. This is validated by Freeman and Aspray's NSF-sponsored report on the supply of and demand for IT workers in the United States released in 1999, in which they explain that, while there may be as many as twenty academic specialties that study various aspects of information technology, the three most popular IT-related disciplines are computer science, computer engineering, and information systems. According to Freeman and Aspray, all three of these disciplines capture some aspects of what we regard to be information technology, but none of them covers all aspects (Freeman 1999).

Given that the study of information technology is inherently interdisciplinary, any such program should take a breadth-first approach and be designed with flexibility in mind to incorporate IT-related disciplines; it should resist the urge to compartmentalize its curricula into specific areas as computer science has traditionally been predisposed to do by designing courses around its artifacts such as compilers, assemblers, and operating systems.

With this in mind, the structure of the CIT program was designed and the component courses were organized into a set of required core courses, a choice of specialization, and a capstone practicum as culminating experience. Prerequisite knowledge was identified for both the core and individual specializations along with courses suitable for obtaining this necessary background.

For clarity the CIT curriculum is described in the following tabular format:

Table 1: CIT Curriculum

COMPUTER INFORMATION TECHNOLOGY (36 credits)		
Core Courses (18 credits)		
Computer Science: Foundations of Computer Science (3 credits) Computer and Communications Technology (3 credits)		
Management Information Systems: Foundations of MIS (3 credits) eBusiness and Information Technology (3 credits)		
Technology: Applied Networking Technology (3 credits) Industrial Applications of Computers (3 credits)		
Specialization Electives: (12 credits)		
Computer Science	MIS	Technology
Topics in Soft Engineering	Data Communications and Networking	Advanced Networking Technology
Topics in Human Computer Interaction	Distributed Processing, Networking and Telecommunications	Robotics
Topics in Artificial Intelligence: Building Problem-Solvers, Knowledge Discovery and Data Mining, Image Processing, Visualization and Pattern Recognition	Data Management	Research in Technology
Topics in Database Design and Applications: Bioinformatics, Advanced Database Design, Medical Informatics	Database Program Development	Digital Telecommunications
Topics in High Performance Computing and Communications: Computer Networks and Security, Robotics and Automation, Signal Processing and Telecommunications	Emerging Technologies for Business: Advanced Networking Structured Systems Analysis and Design	Transmission Systems
Culminating Experience (6 credits)		
Research Methods in IT (3 credits) Capstone Practicum (3 credits)		

In addition, courses in Statistical Data Mining, Computer Electronics and Lasers and Optics are currently

being developed in conjunction with the Departments of Mathematical Sciences and Physics respectively.

Core

The core of the CIT program incorporates two graduate level courses in Computer Science, Management Information Systems and Computer Electronics and Graphics Technology respectively. Together with the six core courses, a four-course specialization, a research methods course and a final capstone project complete the program for a total of 36 credits.

Core computer science courses focus on principles of software engineering, networking and distributed processing while the management information systems component addresses strategies and technologies for e-Commerce, along with study of Harvard cases and mechanisms for information flow within organizational IT infrastructures. From its implementation perspective the Technology component focuses on industrial applications of computing along with practical design, construction and maintenance of networks. In summary, with each of the three components, analysis and design, business applications, and actual physical implementation of computer-based systems, combine to form a broad-based foundation necessary for the formation and specialization of the IT professional.

Specializations: Computer Science, Management Information Systems, Technology

Providing an example of Michael Dolence and Donald Norris' inverted, truncated cone metaphor for education in the Information Age, the hybrid CIT program uses the term, "specialization", to connote a spiraling upward while broadening and strengthening rather than narrowing the problem domain and foundation for IT education. According to Dolence and Norris, "The Information Age will continue to need highly focused specialists who perpetually upgrade their specialties… Specialists will need to support more effectively applied and multidisciplinary work…What the Information Age needs in much greater numbers are broadly educated problem solvers who can acquire and apply knowledge in a wide range of ever-changing hybrid disciplines…the physical metaphor for these professionals is not a pyramid, but an inverted, truncated cone, beginning with a broad base of critical thinking skills and expanding upward within the cone, driven by the analytic and problem-solving needs of a rapidly evolving environment" (Dolence 1995).

Formally, there are three discipline-specific specializations in the program: computer science, management information systems, and technology, however, with feedback and suggestions form students, the program is slowly evolving toward offering specializations or course packages in various information technology themes such as bioinformatics, database design and development, information network security, information technology education, systems analysis and design, and software engineering. These specializations would span disciplinary boundaries to include, for example, database-related courses from computer science, management information systems, and technology as well.

Each four-course specialization, taken after completion of core requirements, provides the student with an opportunity to build a conceptual framework in chosen areas such as software engineering, networking, databases, data mining, or biomedical informatics. Flexible, modular specializations allow students to choose courses entirely within one of the three component disciplines or a combination of courses from any of the three disciplines, leveraging the hybrid nature of the program.

Initially the specialization component required a choice of four courses in one of the three component specializations; however, at the request of students, more flexibility has been built in to allow for laterally chosen courses that cut across the three discipline boundaries rather than longitudinally along one chosen discipline. This requires careful advising to ensure that students focus on one area such as database design and applications as opposed to taking a possibly unrelated set of courses that would leave their backgrounds fractured and weak. Specialization courses are often favorites of participating faculty since they are opportunities to teach in their areas of interest and expertise. For example, an Biomedical Informatics specialization consisting of courses in bioinformatics, medical informatics (legal and ethical issues), health informatics, and one of neural networks and pattern recognition, image processing, advanced database design and applications or data mining is offered to students in advising sessions as a specialization "package." This particular specialization relies upon part-time professors including a neurosurgeon, a pediatrician, an attorney, and a biochemist "borrowed" from the Biology Department; with the academy chorus in unison relating the dearth of potential candidates for full-time tenure track positions in Computer Science and related disciplines, reliance on part-time instructors will no doubt become an important contributing factor in the development of new specializations.

Capstone Project as Unique Culminating Experience

The CIT program is marked by its unique capstone requirement. Unlike all other graduate programs on campus, this program currently does not offer a thesis or comprehensive examination option. Rather, the capstone project is the required culminating experience. Capstone projects are carried out in groups of three students (with ideally one student from each component specialization) and must demonstrate inte-

gration and use of knowledge in each of the three component disciplines of CIT. When students form teams, a major capstone advisor is assigned, along with one faculty person from each of the other two areas who serves as an advisor to her or his discipline, however, in a more peripheral role. Students must present a written document describing and documenting the lifecycle of their project, including its purpose, design, functionality, testing and evaluation, as well as the actual deliverable. Finally, an oral presentation is scheduled and videotaped for website archival. Given the steady growth of the program, sustaining the capstone project is fast becoming a significant resource drain. Happily, in response to requests by students, the CIT faculty persons are currently designing two additional options for culminating experience, a thesis option and a cumulative examination option as alternatives to the capstone project.

Critical Foundations and Bridge Courses

Although this program is designed as a nontraditional Master of Science degree that welcomes students who have not formally studied computer science or management information systems, a certain minimal conceptual and skill-based foundation must be guaranteed. With the heterogeneous nature of the student audience, prerequisite knowledge is critical so that professors teaching core courses can assume a certain level of mathematical maturity as well as computer-related foundational knowledge. For without such a tangible base, how could faculty possibly design and build their courses?

As the new curriculum began to take shape, it was decided that, along with the many (fifteen and counting) new core and specialization courses, a foundational course that extracted essential informatics concepts and software engineering skills from existing undergraduate curriculum was of critical importance. This became the catalyst for much heated discussion as we asked ourselves, "what is computer science?" and "what should students who study computer science in this program know?"

Given that students are anxious to begin taking core courses as soon as possible, it soon became clear that a non-traditional approach to providing foundational knowledge needed to be designed. During advising sessions, the following was typical of many students' comments: "I'm not getting any younger, I work full time, I want to change my career, I have a family, and I don't have time to go back and study four years for a degree or take lots of prerequisite courses. I want to start as soon as possible on this degree." Normally for graduate programs in any one of these three disciplines an entire undergraduate degree in a related field would be required, if not assumed; however, the CIT program is not a master's degree in any one of these fields but rather a heterogeneous mix of the three, including concepts, ways of knowing, modes of discovery, all complicated by the pluralism of this interplay of academic cultures.

It was eventually decided that the minimal knowledge base would include differential and integral calculus, data structures design, analysis, and programming in an object-oriented language such as Java or C++, and basic knowledge of computer organization and architecture. In addition, specialization prerequisites were identified as discrete mathematics for Computer Science, digital systems design for Technology, and no additional specialization prerequisites for MIS.

4. IMPLEMENTATION CHALLENGES AND RESPONSES

The qualities that contribute to the CIT program uniqueness are precisely those that have made it challenging to effect. Bringing together students and faculty persons from three related yet separate disciplines, representing two professional schools and one liberal arts school, has not been without its academic culture clashes; the beginnings of a significant acculturation process of mutual understanding and acceptance are appearing amidst faculty disinclined toward and naturally fearful of change.

Whereas the CIT program gains its strength from the balance of theory and practice in the design, analysis, application and implementation of computer-based systems, intellectual sensitivities and attitudes about traditional education versus just-in-time skills training have generated lengthy and heated discussions. Most recognize the necessity for both however, some find it difficult to acquiesce and accommodate both in the same program.

Student Challenges

The main challenges with respect to students have been bringing them all to a common knowledge base in mathematics and computer science. While most students have acquired expertise in various fields including engineering, chemistry, biology, education, and insurance, their skills in mathematics are generally rusty and their experience in data structures programming in Java or C++ generally quite minimal. Conditional acceptance based on earned grades of "B" or better in bridge courses is currently be considered as a standard for formal admittance to the program where students do not have an undergraduate foundation in computer science, management information systems, or in computing-related technology fields. In addition, surprisingly poor written communication skills on the part of many international students have raised the issue of requiring writing samples in the admissions materials. As a result of these early observations, the CIT faculty persons working with the graduate studies coordinator are currently considering requiring a portfolio of materials that represent a stu-

dent's analytical and creative computing-related expertise rather than requiring GREs and GMATS.

In an effort to gain valuable evaluative feedback from students and encourage student-faculty interaction, monthly socials featuring guest speakers from various local corporations and universities have proven to be quite successful and welcomed by all, particularly when pizza is provided. The intent is to foster development of cohorts and a sense of CIT community, particularly difficult with the high percentage of part-time evening students. A convenient and readily accessible twelve workstation CIT laboratory designed to facilitate small group as well as individual collaborative work provides a setting conducive to building learning communities. Regular semester and summer mailings and website information to keep students tuned-in and connected.

Curriculum Challenges

Challenges with respect to curriculum design have come largely with student feedback that they were learning the same concepts and similar material was being presented in multiple courses offered by each of the three areas. In theory, looking holistically at computer-based systems with a lens from each of three different disciplinary perspectives correctly aligns the program with its mission; however, in practice we have found that this has resulted in an overlapping of content issues serving to blur disciplinary boundaries. In response to this, a learning objectives, outcomes-based assessment is currently performed by professors who teach core CIT courses in order to identify curriculum redundancies and review approaches and perspectives.

Core knowledge has proven lacking in system analysis and design as well as research methods and design; as a consequence, one of the core MIS courses will be redesigned to include substantially more system design and analysis material and an additional research methods-based course requirement will be added to the core. In fulfillment of this research requirement, students will be given the opportunity to choose among a variety of research methods courses currently offered across the three schools in Departments of Industrial Technology, MIS, Psychology and Communications as well as in the School of Education. Students will also be given the opportunity to transfer-in two courses taken at other institutions, whether on-ground or online.

In many cases students enter with preconceived notions and incomplete or even erroneous information pertaining to each of the three component CIT areas. In an effort to provide an overview of these areas to incoming students, new in Fall 2001 will be a required (initially non-credit) Colloquium Series for incoming students that will consist of three sessions designed to introduce students to the purpose and organization of the program, the particular culture and academic focus of each component discipline, and the main important legal and ethical issues such as intellectual property, privacy, and information security.

Finally, for planning purposes as well as for maintenance of currency in course offerings, an Advisory Board is currently being formed with membership from local corporate representatives in insurance, engineering, and pharmaceutical companies, together with representatives from local community colleges and universities.

Faculty and Administration Challenges

The major challenge with respect to faculty and administration lies in the inevitable faculty resource sharing issues, notwithstanding the additional faculty lines allocated to support the program. Hiring new faculty has not proven to be the panacea that many had hoped for; the entire solution involves many layers of the onion including careful and coordinated scheduling, allowing thesis and comprehensive examination options to help offset the resources drain for sustaining capstone projects. Recognizing that the laws of physics apply, in particular that we may be called upon to sacrifice speed for power as further limiting of enrollment is considered, along with efforts to balance students' courses of study in each of the current specializations. Additionally, the CIT faculty and director are currently developing a sustainability plan complete with projected personnel and budgetary requirements in order to ensure the continued success and quality of teaching and curriculum.

Challenges for faculty and administration have also surfaced as a direct result of the lengthy interim between initial creation and approval of the CIT program by relevant university committees, President and Board of Trustees, and the licensure and accreditation at the State Department of Higher Education. Changes in faculty and administration during the five-year development required frequent briefings and updates using anecdotal evidence surrounding the "history" of the emerging program; with new faculty came new ideas and insights that needed to be continually incorporated into the design. Further, the spanning nature of school boundaries as the signature of CIT compounded the already challenging collaborative efforts, often arousing tensions between loyalty and responsibility to school programs versus the CIT program.

In order to support future growth and diversity of the program, as well as to ensure the continued success of the program, the CIT faculty persons are currently considering the possibility of forming an Institute or a Center for Computer Information Technology. It is anticipated that this Center would allow for joint appointments and provide a vehicle for securing external support for the program.

5. PROGRAM ADOPTION CONSIDERATIONS

Students, faculty, the University, and area employers are all benefiting greatly from experiences related to this program. Since the structure of CIT reflects the interdisciplinary nature of the IT profession itself, students gain a wide-ranging background and are well prepared yet flexible for a variety of different tasks which employers will most likely expect them to perform. Students not only learn specific software engineering skills, but are also experienced in the ways in which IT is used in corporate and industrial settings. This knowledge surpasses what any one of the component disciplines can offer. While they have in-depth knowledge of object-oriented design and programming in Java, they also understand how IT is used in businesses for strategic problem solving and competitive edge, as well as knowledge of network design and can easily manage their own computer from operating system issues to peripherals and device drivers to wireless technology issues. We are finding that the holistic program produces holistic, well-rounded IT graduates, likened to a program that provides "general education" as well as content-specific depth in IT artifacts such software applications, digital libraries, databases, and networks.

The CIT faculty persons have also benefited from this experience. They have become more productive as each person's talents and particular interests become known by the group. It has taken some time, but we all agree the process has been worthwhile.

As far as the University, this program has grown in a very short time to be the largest graduate program outside of the School of Education. Certainly this program was unique (at least on the East coast) when first conceived close to seven years ago. It remained unique until relatively recently, which may have been the reason for the many delays on its journey to implementation. In fact, at the time that this program was conceived on the graduate level, the only other IT-related program that the Director found was an undergraduate program under construction at James Madison University. While this program remains unique in the Connecticut and perhaps still in New England (for its stage of development), similar programs are being successfully developed such as the one at Rensselaer Polytechnic Institute. As knowledge in the IT realm converges and as new advancements in Internet technologies and in exciting research areas such as quantum computing arise, it seems natural that universities with an entrepreneurial spirit and significant investment in computing infrastructure and resources would look to offering similar programs.

6. DIRECTOR'S REFLECTIONS

For the director of the CIT program, the biggest challenges have come administratively in trying to develop a CIT identity with mutual ownership by all members. Maintaining a cohesive CIT faculty team largely unfamiliar with each other and thus with a tendency to fracture, has required continual and ongoing vigilance, encouraging open communication channels. Much time and effort has also been directed toward establishing CIT connections with local area employers through the development of a virtual technology park model contributed by the most recent addition to the CIT faculty team. A policy and procedures manual is also being compiled and will be the main topic of discussion, along with the Colloquium Series, at the CIT faculty retreat in late August. Walking the fine line between champion and change agent often requires switching back and forth between the two roles; learning to be enthusiastic, persistent and determined yet in an actively patient, "less is more" way.

Learning to recognize and subsequently letting go of preexisting academic culture biases while at the same time trying to facilitate and encourage faculty to envision the future of CIT has been a difficult yet rewarding learning experience. Now that the program is successfully underway, a top priority is to allow a CIT identity to take shape and substance as its niche in the marketplace continues to be fashioned. The CIT faculty needs to maintain an inclusive posture, welcoming participation from faculty in other departments and schools. Given the pervasiveness of IT and increasing number IT-related disciplines, undoubtedly the future growth and development of the CIT program will depend heavily on new contributions from these areas.

Envisioning its next steps, will CIT appropriate certain concepts of each of its founding three disciplines and proceed to evolve into its own distinct discipline leaving CS, MIS and Technology intact and separate? Or, will CIT incorporate the "gene pools" of all three of its founding disciplines and evolve into a new manifestation of these three combined? In every sense of the word, this program is truly a work-in-progress!

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