A Model IT Curriculum for the UAE University

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August 4, 2000

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Objective

The University of the United Arab Emirates (UAEU) is establishing a college of information technology, which they intend to be among the best in the world. To accomplish this, they have requested assistance in designing a forward-looking, innovative curriculum, and approaches to engaging with IT research and with professional and entrepreneurial practice.

The IT curriculum task force is charged to produce an innovative model curriculum to serve as a model for the new IT college and to recommend ways of integrating curriculum with research and with professional practice. The curriculum model should incorporate innovations and best practices but need not be constrained by traditions that no longer make sense. The curricula of degree programs for which there is a duly constituted accreditation body should be accreditable. The College will set up external advisory panels to assist in the ongoing review of the other degree programs.

This report consists of an overview, a matrix representation of the IT body of knowledge, an IT core curriculum, program descriptions for each of the degrees, and a catalog of courses.

The IT Field

The IT field has been maturing rapidly from a set of technology-oriented, autonomous disciplines into a profession. The IT profession comprises all the professionals who make a living helping other people with the concerns, breakdowns, and opportunities that IT causes for them. The specialties of the profession are many (over three dozen) and diverse. They can be grouped into three sets. The IT specialties are concerned with aspects of computing and

networking technology itself; the IT-Intensive disciplines have other concerns that they pursue with a heavy dependence and investment in IT; and the IT infrastructure areas are staffed by professionals who implement, maintain, operate, and repair IT.

IT Specialties	IT-Intensive Disciplines	IT Infrastructure
Artificial intelligence Computer science Computer engineering Computational science Database engineering Graphics Human computer interaction Network engineering Operating systems Performance engineering Robotics Scientific computing Software architecture Software engineering System security	Bioinformatics Cognitive science Digital library science E-commerce Genetic engineering Information science Information systems InfoSec and Privacy Instructional design Knowledge engineering Mgt information systems Multimedia design Telecommunications	Computer technician Help desk technician Network technician Professional IT trainer System administrator Web services designer Web identity designer

The IT field is thus much more complex in character than computer science and presents major new challenges to educators. It can no longer be served by a single university department. The smallest organizational unit that can accommodate it is a school. But an IT school cannot be neatly segregated into autonomous departments like many other schools because the professional areas share significant bodies of knowledge. The degree programs offered by the school are best designed through a coordinated effort.

Because the IT field is dominated by professional specialties, not just intellectual disciplines, its students need to be immersed in practice as much as in a study of concepts and principles. They need to learn to be professionals, which means they need to learn and embody their specialty's body of knowledge, its standards of practice, and its ethical codes of conduct.

Designing a curriculum for a set of related IT professional degrees is not the only challenge. Because the half-life of technical knowledge is so short -- and with "Internet time" continues to get shorter -- an IT school must pay special attention to fostering in its graduates the ability to continue learning new technologies and new practices throughout their careers. The capacity to continue learning must be embodied through practice. The curriculum must present students with many opportunities to practice mobilizing their resources and creativity, such as incompletely specified projects, fickle and demanding customers for project teams, and midstream changes of direction. Students need to develop a tolerance for uncertainty and a facility to recover from breakdowns it causes.

In addition to being fast-paced, the IT market features a model of innovation that is quite different in character from the research model most familiar in universities. The market model emphases fast time-to-market; it funds projects with venture capital; it fosters innovation by rewarding entrepreneurs who specialize in transforming people's practices to become more productive with the help of new technology. The university research model emphases careful development of ideas and principles; it funds projects by federal and state grants; it achieves innovation only after ideas have gone through a long "pipeline" that distills out the best and brings them into practice (over 15-20 years). The dichotomy between market and idea-pipeline models presents great challenges to educators. Graduates of IT programs need to understand the market model as well as the idea-pipeline model. Most faculty have not experienced the market model first hand. Intensive market involvement of undergraduates can be accomplished by involving them in industry through internship programs and by offering courses that teach them entrepreneurship.

In summary, the design of an IT curriculum is complicated by factors in the IT market and by the structure of the IT profession -- a plethora of interrelated professional specialties, the need for graduates to be professionals, the need for graduates to continuously learn on their own, and the need for graduates to be skilled entrepreneurs.

UAEU's Degree Programs

Effective in September 2000, UAEU proposes to combine three existing degree programs into a new College of Information Technology. One year later, they propose to add up to six new degrees program in other important fields of information technology. The degree programs for the proposed college are listed below.

UAEU INITIAL PLAN

Existing	CS	computer science
	CE	computer engineering (nascent)
	MIS	management information systems
New	SWE	software engineering
	IS	information systems
	NE	network engineering
	EC	e-commerce
	SEC	information security
	ET	educational technology

Students currently enrolled in the CS, CE, and MIS programs will complete their studies within their current colleges. Students entering in September, 2000, and later will enroll in the new college.

In the following, we offer an integrated model for the IT school curriculum encompassing seven degree programs and one certificate program, all based on a common IT core curriculum. Our recommendation has several differences with the proposal summarized above. Because MIS is traditionally regarded as a specialization of business, we recommend against an MIS degree program in the IT College; instead, we propose an MIS specialization within Information Systems. We recommend that the emphasis of the computer engineering program be on systems; we propose naming it Computer Systems Design to avoid confusion with programs in the College of Engineering. Finally, we recommend that Education Technology be established as a certificate program rather than as a degree; the College can encourage students who want to help bring information technology into the national school system to obtain this certificate. The ET certificate can also be available to students outside the IT school.

RECOMMENDED PLAN

Existing	CS	computer science
	CSE	computer systems engineering
New	SWE	software engineering
	IS	information systems (with MIS specialization)
	NE	network engineering
	EC	e-commerce
	SEC	information security
	ET	educational technology (certificate)

Matrix Representation of Body of Knowledge

Following the model of the ACM/IEEE-CS report, *Computing as a Discipline*, we depict the body of descriptive knowledge of Information Technology as a matrix, of the form shown below.

	Theory	**Abstraction**	**Design**	**Technology**
Area 1				
Area 2				
Area 3				
…				

The rows of this matrix correspond to knowledge areas such as algorithms, programming languages, or network protocols. The granularity of these areas is just broad enough to correspond to professional specialties that have their own identity, recognized literature, and communities of practice. Each of these areas hosts one or more courses in the curriculum. Except for survey courses, no course cuts through multiple areas.

The columns of this matrix correspond to major practices of the field, which can be interpreted as follows:

- **Theory** is the process of creating abstract mathematical objects to represent aspects of the world, define basic relationships among the objects, and deduce consequences and properties of objects and of systems of objects through proof.
- **Abstraction** is the process of creating models (hypotheses) about the world, gathering data to validate the models, and refining the models after comparing their predictions to observations. This is in effect the familiar scientific method.
- **Design** is the engineering process of creating specifications for a system, building a version, and testing the version to see if it meets the specifications within the given cost constraints. This cycle is repeated until the system is acceptable.
- **Technology** is the process of creating tools, equipment, instruments, and systems that enable people to engage in new practices that were not available to them without the technology. The artifacts of technology are often short-lived, being replaced by more advanced artifacts through continuous improvement.

A cell in the matrix contains a description of how the process (of the column) shows up in the given area (of the row).

In our website the matrix is implemented with a set of hot links:

- Clicking on a row name brings up a page listing the scope of that knowledge area and its major topics in theory, abstraction, design, and technology.
- Clicking on a cell brings up the portion of the row page corresponding to the cell's column.

In addition to the body-of-knowledge matrix, we offer a cross-reference matrix that shows which knowledge areas contribute to each of the degree programs. It appears like this:

	CS	**CSD**	**SWE**	**NE**	**SEC**	**IS**	**EC**	**ET**
Area 1	X			X			X	X
Area 2	X	X	X		X			X
Area 3		X		X		X		X
…								

Levels of Competence

Because we are designing a curriculum for professionals, we need to add a third dimension to the body of knowledge. Professionals are judged (by others in their profession) at a number of different levels of competence. The basic set of levels is

Beginner
Advanced beginner
Entry-level professional
Proficient professional
Expert
Virtuoso
Master

Each of these levels has its own standards of performance set by the community. Since these are levels of *embodied competence* -- i.e., performance in action -- it takes time and practice for a person to attain each level. In fact, one's professional career can be interpreted as a journey on a path to mastery.

In the four or five years a student is an undergraduate in college, we cannot realistically aspire that they attain competence higher than entry-level professional. Even that level is a challenge not often met by most IT undergraduate programs.

Exhibitions and Their Management

We offer a design that leads the students from the beginner stage to the entry-level professional stage by the time of their graduation. At the end of each stage there is a major milestone, which we call an *exhibition*, at which the student demonstrates his or her knowledge by performing tasks demonstrating the knowledge. Exhibitions will be the primary means of assessment to determine whether a student has attained the next level of competence. In brief:

- **Sophomore exhibition:** demonstration of beginner level competence in IT core subjects.
- **Junior exhibition:** demonstration of knowledge of major area at advanced beginner level; includes components that will be needed in senior project.
- **Senior exhibition:** demonstration of ability to put together a complex system in the major area that satisfies a customer.

Although it is possible to make enrollment in the next year be contingent on passing the current exhibition, we do not recommend this approach. Using exhibitions as gateways would create a significant management overhead to provide non-passing students with additional practice and an opportunity to

retake the exhibition when ready. We do recommend that faculty advisors work closely with students who do not pass exhibitions to help them prepare for the courses in the next year of study. The exhibitions are not only a valuable experience for the students, they are a valuable assessment tool for the faculty.

Exhibitions are an uncommon practice within a university and will present some new management challenges. The challenges should not be a reason to abandon exhibitions. But the program must be carefully planned and executed if is to succeed.

The exhibition can be organized within the regular course model. A group of approximately 30 students is assigned to an exhibition section. The instructor can organize them into 10 three-person teams. The instructor's time during the semester will be devoted primarily to managing the teams, which will consist of reviewing weekly progress reports and meeting individually with each team to assess and guide them. A few group meetings will be required; in them, the instructor can go over common rules, constraints, and knowledge, and conduct dry runs of project presentations to enable the students to learn from each other. At the end of the exhibition course, all the teams will present their projects in a final exposition to an audience consisting of the students in the section, the industry customers of the project teams, and a few faculty. This exposition meeting is an opportunity for students to show professional presentations and for everyone to celebrate their accomplishment.

Staff support will be needed to help link student teams with industry customers, place the students into sections according to common themes, obtain the meeting and exhibition space, and generally keeping the exhibition program moving smoothly.

Curriculum Structure

The UAEU has a standard freshman year for all students covering 26 hours of language, culture, humanities, mathematics, and technology. The professional degrees each need a total of 132 credit hours for graduation. This means we must allocate 106 credit hours to the three stages of beginner, advanced beginner, and entry-level professional. We designed a common IT core of 42 credit hours including an exhibition that majors of all IT degree programs will take; on successful completion of the IT core, students will be beginner IT professionals. A disciplined, full-time student should be able to complete each stage in one year.

> **Beginner (sophomore year)** -- aware of the structure of the IT field and the nature of the work in the various specialties; able to develop algorithms, data structures, and simple circuits to solve well-defined problems; able to program and test those algorithms and circuits. Not expected to see the connections and interrelations among all the components that make up typical computing systems, but is expected to understand the purpose of

each component. This stage consists of the IT core and its exhibition (42 credit hours).

Advanced Beginner (junior year) -- familiar with the terminology and concepts of the specialty; sees many of the connections among components of computing systems; able to design algorithms (and possibly circuits) of moderate complexity (several dozen modules), program them, and test them. Able to carry out tasks for a customer but needs supervision to avoid common pitfalls and breakdowns. Able to communicate effectively in speaking and in writing. This stage consists of the first year of the degree major and its exhibition (33 credit hours).

Entry-level Professional (senior year) -- thoroughly familiar with the specialty; understands systems and can diagnose system problems; able to design systems of moderately large complexity (hundreds of modules), program them, test them, document them, and present them. Can carry out standard professional tasks for customers in application domains without supervision. Understands professional ethics and acts ethically. This stage consists of the second year of the degree major and its exhibition (33 credit hours). The exhibition is focused on a senior design project with a customer.

Students begin to specialize into their major degree programs in their junior year. They move on to the advanced courses in their major in their senior year.

For each degree program, we offer a description that maps out courses in junior and senior years, ending each year with an exhibition. The program descriptions include course catalog descriptions for each course proposed.

Time to Completion

The UAEU standard student load is 15 credit hours (5 three-credit courses) per semester. Students who take courses in only the fall and spring semesters will thus accumulate 30 credits per year and 120 credits in four years.

In addition to the 132 credit hours required for the major, all students in the IT College will be required to complete a semester of internship with a company for which another 15 credit hours will be awarded.

With these requirements, the student who takes the summers off will require five years to complete the degree. It is possible that students who do their internships and take some courses in the summers can complete the program in four years.

There is precedent in UAEU for degree programs that require five or more years to complete. We recommend that the leadership of the IT College provide

adequate advising and student assistance so that the majority of majors will complete in four years.

The IT Core

One of the novel aspects of our curriculum model is its IT core curriculum. The sophomore year is organized to permit all IT students, regardless of major, to achieve the beginner level in IT. The core consists of 42 credit hours distributed in the Sophomore, Junior, and Senior years as shown in the table below. In addition to this core, we recommend that all students intending to major in the IT College substitute the first course in programming for the "computer literacy" course in the freshman year.

Two parts of the core extend into the junior and senior years. Instead of a 3-credit ethics and professionalism course, we recommend three one-credit professional responsibility workshops conducted 1 hour per week for one semester in each of the sophomore, junior and senior years. We also recommend that a course on speaking and writing be required in the junior year; this course can be taught by a humanities department after the IT College has approved its content.

AREA	F	SOPHOMORE			J & S
Math		Calculus concepts (derivative, integral, simple diff eq, linear algebra)	Probability and statistics	Discrete math	
Systems		Digital hardware and communication	Computing Systems (OS, networks, architecture)	Information Systems (Web, database, security)	
Programming	Prog I	Prog II			
Business			Business basics	Enterprise basics	
Science			Biology Concepts	Physics Concepts	
Communication					Speaking and writing
Professional responsibility		Professional responsibility workshop			J & S Professional responsibility workshops
Exhibition				Core exhibition	

Industry Experience

In addition to the 132 credit hours to attain a professional IT degree, we recommend that each student be required to participate in an industry internship for one semester (15 credit hours). This work is best done in one or more of the summers. In other words, the requirement to graduate is 132 hours for coursework plus 15 credit hours for industry involvement.

Accreditation and Program Review

The UAEU intends that each program for which there is an accrediting authority be accredited. Accreditation implies program review. The remaining programs will be reviewed regularly by external panels of experts.

Because the Computer Science Accreditation Board (CSAB) has recently become part of the Accreditation Board for Engineering and Technology (ABET), Computer Science accreditation will eventually be conducted under the ABET guidelines. These guidelines give considerable latitude to individual institutions by requiring them to be explicit on four key points:

- **Outcomes.** The program has clearly defined objectives for student achievement with clearly defined standards of performance.
- **Process.** The program has a process to achieve the outcomes.
- **Assessment.** The program contains measures and methods to evaluate whether individual students are achieving the targeted outcomes and whether the program as a whole is meeting its objectives.
- **Feedback.** The program contains planning and administrative structures that act on the feedback and make adjustments in outcome statements, process, and assessment as needed to achieve the program goals.

The program proposed here associates outcomes with professional levels of competence in each of the major specialities; its process consists of courses, exhibitions, and internships to achieve the outcomes; its assessments come from course grades and exhibitions; and its feedback will be implemented by the IT College's management structure. Although the dean and faculty of the IT College have a lot more work to do to fill in the details, they can do so with the assurance that the program framework we recommend meets the basic accreditation principles.

Other Important Recommendations

In addition to the curriculum model, we offer recommendations about infrastructure and support.

- **Course websites.** Because of the high turnover rate of faculty, it will be essential to preserve the "corporate memory" of each course on a course website. Each new teacher can use the website for syllabus, book recommendations, and learning resources, and can modify and revise as needed. The IT College's infrastructure will have to be designed to support and maintain websites for every course.
- **Facilities.** Many of the goals of the College cannot be met without a first-class facilities staff and state-of-the-art equipment. It is important that the facility support state-of-the-art wireless networking -- among other things this would allow students to bring laptops to class and have them all instantly connected to the instructor's local network. It is also important for the IT College to establish a strong, service-oriented IT facilities group. These people will be responsible to design, establish, operate, maintain, and repair the extensive computing and network facilities that will be needed in the college. They will be needed to assist students and faculty learn to use IT tools such as Web sites, databases, graphics, and spreadsheets in their course work. They will be called on for a lot of troubleshooting and configuration questions. It is easy to underestimate the costs of facilities and facilities management.
- **Staffing.** Finding qualified teaching staff has been a difficult quest in many countries because the booming IT industry has created a shortage of IT workers. The problem is exacerbated at UAEU because about one-third of the faculty turn over every year. The IT College needs to give a high priority to establishing an extensive network of contacts so that it can obtain the instruction faculty it needs to implement the program.
- **Training of new Instructors.** Since many aspects of the curriculum are innovative and cover leading-edge technologies, it may be necessary to offer training for instructors who are being assigned to new courses. GMU and the other universities participating in the Advisory Committee are willing to assist in this.
- **Distance Instruction.** Many of the courses can be taught within new Internet-assisted paradigms such as ActiveClass in which Mark Pullen is involved. These technologies can reduce the need for in-person "face time" in the classroom, and can extend the reach of the UAEU curriculum to people who want to take the courses on a part-time basis. We recommend that planning for distance instruction be part of the IT infrastructure planning from the start, and that training of the faculty in the use of these advanced technologies be part of the services provided by the College.
- **Team teaching.** The College of Engineering has had excellent experience with the "Drexel model" that features team teaching. For example, in a mathematics course, the math faculty member can emphasize the math concepts and methods, while the engineering faculty member can point out

the engineering applications. Team teaching recognizes the interdisciplinary nature of many subjects by bringing the domain experts to stand together before the students. The IT College contains many courses shared among degree programs; these courses are prime candidates for teaching teams from within the College. We recommend that the IT College experiment with team teaching extensively.

- **Sunset clause.** We recommend that the College charter all courses for 5 years and conduct a thorough program review before rechartering any of them. The IT field changes constantly and its curricula need to be reviewed regularly and changed often.

Summary

Our curriculum recommendation is attuned to the structure of the emerging IT profession and is designed to help graduates be effective as IT professionals. We have considered the design at three levels. (1) The *IT Field level* describes the context: the structure and diversity of the field, its body of knowledge, its essential professional practices, its levels of competence, its ethical standards, and its models of innovation and lifelong learning. (2) The *Customer level* selects seven groups of professionals deemed most important by the UAEU and defines curricula that will advance them to entry-level professional status in their professional disciplines. (3) The *Resources level* is catalog of all courses and infrastructure used by the College to advance their customers to their educational goals.

We mapped this to a curriculum by defining a common IT core to be used in the second (sophomore) year by all majors, followed by a third (junior) and fourth (senior) year in the respective majors. Students progress through the curriculum by a *progressive-competence model*, not simply by accumulating course hours. At the end of each year, they must pass an *exhibition* in which they demonstrate through action that they have achieved the professional knowledge and practices associated with that stage of the curriculum. The three exhibitions represent three major milestones, certifying that the students have progressed to beginner, then to advanced beginner, and finally to entry-level professional in their chosen degree field. An exhibition will not be a gateway delaying entrance to the next year of the program; it is a special common experience and opportunity for assessment.

Within this structure, we have offered a rigorous curriculum that emphasizes math, science, humanities, and technology in each of the degree programs.

Innovations

The curriculum model proposed here introduces several significant innovations. They are:

- The E-Commerce degree program: the first-ever rigorously technical undergraduate program in this area.
- The Network Engineering degree program: the first-ever undergraduate program in this area.
- The Information Security degree program: the first-ever undergraduate program in this area.
- The Software Engineering degree program; few universities have such degree for undergraduates.
- The definition of a certificate program in Educational Technologies.
- The definition of a single IT core curriculum that can be used by all majors of all the IT degrees.
- The progressive-competence model for structuring the curriculum so that graduates are guaranteed to meet recognized standards for entry-level professionals.
- The exhibition, a curriculum milestone used to assess whether a student has achieved beginner, advanced beginner, or entry-level professional status.
- Practice in effective public presentation and written communication as part of exhibitions.
- Development of effective team and collaborative practices as part of project teams and exhibition teams.
- Development of business sense and entrepreneurial sense in all students; will help graduates function in the "New Economy" and help those interested to start their own Internet businesses.
- Requirement that all students complete a semester in industry (through an internship program) as part of their degree programs.
- Strong emphasis on systems thinking through the curriculum -- specification, integration, measurement, testing, modeling, and evaluation.
- Definition of IT body of knowledge as a matrix specifying theory, abstraction, design, and technology for each major area of IT.
- Addition of a technology dimension (in addition to theory, abstraction, and design) to the structure of the field.

Ideals of a Liberal Education

Bill Murray, a senior Information Security consultant and analyst, recently issued a plea for curricula that emphasize enduring principles over transient technologies, and for curricula that teach students how to have a rewarding life and not simply find a job in the current market. His words are worth pondering as we think what kind of a graduate we want to produce:

> [As an employer I want] people with what used to be called a "liberal education." I want people who understand that they are part of a culture, one with a past and a future. I want people who understand that, for better or worse, such mark as they are going to leave, they are going to leave on that culture.
>
> I want people who have read enough history that they can choose the direction of the future that they want and enough power to influence that future.
>
> I want people who have studied enough geography that they know where they are and that they are not here alone.
>
> I want people who have studied enough science that they can recognize the elegance of truth and the truth in elegance, people who cannot be easily misled by the inevitable quacks, charlatans, and demagogues.
>
> I want people who have studied enough art and music that they can appreciate, foster, and enjoy beauty and recognize ugly and evil when they see them.
>
> I want people that appreciate the miracle of life and the wonder of civilization. I want people who have the knowledge, vision, freedom, and wisdom to build the future they want rather than to be the victims of one chosen by authority, people who are fit to participate in their own government.
>
> I want people who understand the value of work and the joy of a job well done but who, when the work day is done, can tell stories, paint pictures, sing, dance, play games, and visit distant places in search of adventure, beauty, and truth.
>
> People who, when they lay down their tools for the last time, can look at the corpus of their work and say, "It is good."

Full text: <http://www.cs.jmu.edu/users/reynolcw/InfoSec/Murray.htm>