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ABSTRACT

Although information technology (IT) is used extensively in the education of all disciplines, the computing-related fields are facing tremendous challenges, such as declining student enrollment and a lack of representation from minorities and women. Strengthening the connection between computing and other fields could help instructors to integrate IT in their teaching and to support the learning of students, who will become the next generation of Knowledge Society builders. Presently, this connection is weak due to the lack of interdisciplinary collaboration and mutual understanding among faculty in computing and other fields. Our ongoing effort entitled “Living in the KnowlEdge Society (LIKES) Community Building Project” aims to build a community that will define a socially-relevant way to make systemic changes in how computing and IT concepts are taught and applied in both computing and other fields. In this paper, we review previous efforts in this area and summarize our project’s achievements and lessons learned. We also provide recommendations on integrating IT into other curricula and on strengthening interdisciplinary collaborations.

Keywords

Knowledge Society, computing curriculum, information technology, interdisciplinary collaboration, LIKES, undergraduate education.

INTRODUCTION

The recent decades are characterized by intensive use of information technology (IT) to support knowledge work in all aspects of human lives. Areas such as electronic commerce, e-government, digital entertainment, cyber-learning, and electronic health care underscore the emergence of the Knowledge Society. A report published by the United Nations Economic, Scientific and Cultural Organization emphasizes the capabilities of IT in shaping a knowledge society, which engages a large number of people whose lives and work depend heavily on shared knowledge (UNESCO, 2005). Peter Drucker, widely recognized as the father of modern management, said that the new knowledge economy will rely heavily on knowledge workers, such as software designers, clinical lab analysts, and paralegals (Drucker, 2001). These workers will become the dominant social force in the coming decades. Educating today’s college students is therefore paramount for developing and sustaining the Knowledge Society.

While computing and IT are used extensively to support education in different fields, the fields of computing are facing tremendous challenges, such as declining student enrollment and a lack of representation from minorities and women. Strengthening the connection between computing and other fields could address both students’ needs of learning and instructors’ needs of integrating IT in their teaching. Thus today’s students would be better equipped to build the Knowledge Society. However, this connection is weak due to the lack of interdisciplinary collaboration and mutual understanding among faculty in computing and other fields. Unfortunately, there is a lack of large-scale effort to support integrating computing with different fields.

In this paper, we describe our ongoing effort entitled “Living in the KnowlEdge Society (LIKES) Community Building Project” (Fox, Beck, Carr, Chung, Evia, Fan, Sheetz and Zobel, 2009) that addresses the aforementioned needs. We review works related to our project, describe the current outcomes of the LIKES project, discuss insights and lessons learned, and propose recommendations to educators who are interested in integrating IT in their curricula and teaching.

LITERATURE REVIEW

Computing exists as different related fields in today’s colleges and universities. The Association for Computing Machinery (ACM) and the IEEE Computer Society (IEEE-CS) identified five main computing fields: computer science, computer engineering, information systems, information technology, and software engineering (Shackelford, Cross II, Davies, Impagliazzo, Kamali, LeBlanc, Lunt, McGettrick, Sloan and Topi, 2006). These fields collectively address various problems and issues, including computing hardware and architecture, systems infrastructure, software methods and technologies, application technologies, and organizational issues. The range of development enabled by these fields progresses from pure theoretical development to application deployment. With the breadth and depth of the computing fields, they broadly support almost all other fields in the Knowledge Society. To expose the potential of this support, we review existing computing curricula and describe examples of the use of computing concepts in other fields.

Computing Curricula

In 2001, ACM and the IEEE-CS published "Computing Curricula 2001" (The Joint Task Force on Computing Curricula, 2001), which was adopted for computer science and related programs. The Information Management (IM) part of thiscontent – essential for the Knowledge Society – was assigned only 10 (out of 280) core hours, the equivalent of 10 clock hours of lecture/lab across the undergraduate education of computer science majors. Some other small parts of CC2001 relate to the Knowledge Society, but are not integrated.

The ACM, Association for Information Systems (AIS), and Association of Information Technology Professionals (AITP) published the "Model Curriculum and Guidelines for Undergraduate Degree Programs in Information Systems" in 2002 (Gorgone, Davis, Valacich, Topi, Feinstein and Longenecker, 2002). This curriculum has been widely adopted as the undergraduate IT curriculum by universities in the U.S. and abroad. However, the primary goal of the curriculum is to train the IT workforce rather than integrate IT education with different disciplines. Further, its relatively out-of-date content calls for review of computing and IT curricula.

In 2006, the ACM and AIS published the "Model Curriculum and Guidelines for Graduate Degree Programs in Information Systems" (Gorgone, Gray, Stohr, Valacich and Wigand, 2006). Considering the growing need for IS professionals and the shortage of supply of such people, the curriculum tried to update the previous curriculum and to specify a common body of knowledge that MSIS graduates should acquire. While its focus lies solely on filling industry requirements, the broader needs for producing college graduates who possess the knowledge and skills to build the Knowledge Society must be addressed soon.

Use of Computing Concepts in Other Fields

Colleges and universities have their core curricula, or liberal education programs, to help prepare students for life after graduation. While these curricula consist of some courses on science and technology, most of them are not up-to-date to provide adequate exposure and training to prepare students to build the Knowledge Society. This is understandable because even professional associations as mentioned above fall short of doing do. The notion of "IT as a tool" is not capable of leveraging the intellectual capabilities of today's students. Providing them with the knowledge of computing and IT concepts has the potential to transform their thinking about what they are capable of doing. Examples of the need for using these concepts include:

- Using quantitative analysis (enabled by software packages) to support qualitative judgment in the study of history (Lloyd-Jones and Lewis, 2000; Ramos and Wheeler, 1989),
- Computer-aided design in the study of architecture,
- Analysis and visualization of spatial data in the field of geographic information systems (Kinzel and Wright, 2008),
- Roles of program design and programming language in digital music composition (Music Technology curriculum at the University of Northern Colorado, http://www.arts.unco.edu/musictech/),
- Understanding of data structures and information visualization in biology, and
- Analyzing demographic and poll data in political science.

The examples above illustrate the potential for integrating computing concepts in different fields. As the Knowledge Society becomes more dominant in human lives (Drucker, 2001), computing and IT are increasingly required to be integrated with other fields. As a result, there is an urgent need for a large-scale, holistic effort to bridge computing and other fields in college and universities.

THE LIKES PROJECT

Figure 1 shows that meeting the needs of the Knowledge Society of today and the future are at the center of our needs as a nation and global society. Surrounding the Knowledge Society core are the myriad of computing concepts that enable it, if they are understood and applied. The application disciplines (outer ring) shown in Figure 1 connect with the vast array of problems that can be impacted through the application of computing. These disciplines have been developed to study the human society, to understand the natural world, and to address the needs of people. Professionals and scholars working in these disciplines have developed many strategies and techniques that leverage the power of computing and IT to solve their problems. Many unique applications of computing also have emerged to tackle these problems and to produce reliable solutions. Today's computing and IT education plays an important role in ensuring that the next generation of Knowledge Society builders is capable of applying computing concepts and tools in their fields.

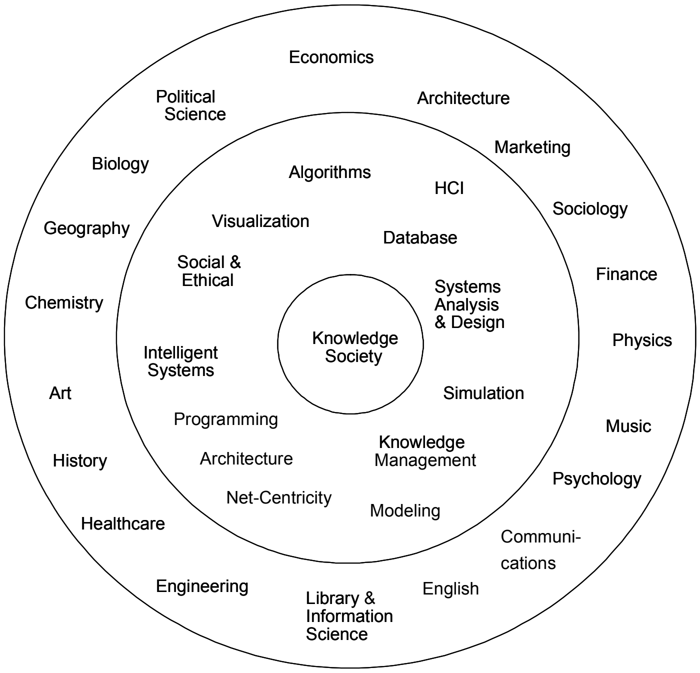

Figure 1. Knowledge Society core surrounded by enabling computing concepts and other disciplines

The Living In the KnowlEdge Society (LIKES) Community Building Project (Fox et al., 2009), led by four sites (Virginia Polytechnic Institute and State University (Virginia Tech, VT), Villanova University, North Carolina A&T (NC A&T), and Santa Clara University (SCU)) and funded by the US National Science Foundation (NSF), aims to transform undergraduate computing education for the 21st century. The vision of LIKES is to build a community that will define the way to make systemic changes in how computing and IT concepts are taught and applied in both computing and other fields, thus better preparing the next-generation Knowledge Society builders. Then, these graduates will be well-equipped with the IT competencies and skills required for the nation's health, security, and prosperity in the 21st century.

The goals of the LIKES project are:

1. To collaborate with a broad range of disciplines (the outer ring in Figure 1) in order to identify the key problems important to each of these disciplines,
2. To identify additional key computing concepts (the middle ring in Figure 1), and then to identify how the computing concepts can be applied to solving the problems of the application disciplines (the outer ring in Figure 1),
3. To define the problem-centered pedagogy most appropriate for teaching the computing concepts, and
4. To demonstrate the feasibility of LIKES for transforming computing education by developing and testing course modules and tools in both computing and other disciplines using the pedagogy (from Goal 3) and a matrix of relating discipline-based problems and computing concepts (from Goal 2).

PROJECT OUTCOMES

As of this writing, three LIKES workshops have been held in three participating sites (SCU, NC A&T, and VT). In the first LIKES workshop (with 34 participants) held in Santa Clara University on November 30 and December 1, 2007, we solicited input from participants on the learning and importance of computing concepts in undergraduate studies (Chung, Fox, Carr, Beck, Evia, Fan, Sheetz and Zobel, 2008). In the second and third LIKES workshops held respectively at NC A&T in April 2008 (with 45 participants) (Carr, Fox, Chung, Beck, Evia, Fan, Sheetz and Zobel, 2008) and at VT in October 2008 (with 32 participants) we invited scholars in different fields to identify ways to integrate computing and IT with their fields. We also discussed challenges and concerns from these scholars. In addition, we have launched and are planning new curricular initiatives at the participating sites. The fourth LIKES workshop will be held at Villanova University in March 2009. Faculty

Development Institute sessions will be held in the summer of 2009 at VT to introduce LIKES to more faculty, and to further expand the LIKES community. The following describes current outcomes of our project.

Perceptions of Computing Concepts in Undergraduate Studies

In the first LIKES workshop, we investigated participants' perceptions of the computing concepts that are listed in Table 1 (Chung et al., 2008). The 25 participants participated in group sessions to rate the importance of the computing concepts and to suggest which concepts would be easiest for students to learn.

Computing Concepts	Definition	Importance Rank	Ease of Learning Rank
Social Context	Students need to develop the ability to ask serious questions about the social impact of computing and to evaluate proposed answers to those questions.	1	2
IP, Privacy, Civil Liberties	Students need to be aware of the basic legal rights of software and hardware vendors and users, and appreciate the ethical values that are the basis for those rights.	2	1
Algorithms/Problem Solving	An algorithm is a method or process used to solve a problem.	3	8
Logic	Logic is the study of the principles and criteria of valid inference and demonstration.	4	5
Knowledge Representation, Retrieval, Storage	This area includes the capture, digitization, representation, organization, transformation, and presentation of information – along with algorithms for efficient and effective access and updating of stored information.	5	9
Computer Literacy	User familiarity with basic knowledge of MS Office (or open source equivalents), email, the Internet, etc.	6	3
Communications and Networking	Net-centric computing covers a range of sub-specialties including: communication network concepts and protocols, multimedia systems, Web standards and technologies, network security, and wireless and mobile computing.	7	6
Database and Data Modeling	Database systems include DBMS functions, database architecture, data independence, data modeling, conceptual models, and object-oriented models.	8	7
Programming	Programming is the principal interface with the computer. Programmers need to understand different languages.	9	11
HCI	Human-computer interaction is the design, evaluation and implementation of interactive computing systems.	10	4
Modeling and Simulation	A computer program, or network of computers, that attempts to simulate an abstract model system. Computer simulations are mathematical models applied to many natural systems.	11	12
Graphs and Trees	A data structure is any data representation and its operations. Data structures can implement mathematical constructs with well-defined properties, such as graphs and trees.	12	10

Table 1. Computing Concepts Identified by Participants with Importance and Ease of Learning Rankings

First, each participant rated the importance of the concept for students in non-computing disciplines. Table 1 column three shows the resulting ranking. The concepts of Social Context, Intellectual Property/Privacy, and Algorithms/Problem Solving were deemed most important, while the Foundations of HCI, Modeling/Simulation, and Using Graphs/Trees were deemed the least important. The level of agreement on the overall ranking of the importance of the concepts was low (Kendall's W= .22, p=.001). We believe this was due to the wide range of disciplines represented by the participants, including biological sciences and atmospheric sciences, along with computer science and information systems. In particular, people in disciplines distant from computing generally are unfamiliar with the sub-areas of computing and IT, and so may not be aware of their applicability, even in the context of their discipline.

Next, participants assessed the ease of learning the computing concepts for non-computing students, Table 1 Column 4, shows how each concept ranked for ease of learning. The concepts of Social Context, Intellectual Property/Privacy and Computer Literacy were viewed as the easiest for students to learn, while participants disagree that Using Graphs/Trees, Programming, and Modeling/Simulation concepts will be easy for students to learn. Moderate agreement (Kendall's W= .44, p=.001) existed among the participants on the relative ease of learning of the concepts.

Comparing the importance and ease of learning rankings of concepts indicates that the two most important things to know are also the easiest to learn. Similarly, least important concepts, i.e., Modeling and Simulation and Programming, are also among the most difficult to learn. Perhaps this implies that these topics should not be pursued until later in the learning sequence. More critically, the Algorithms/Problem Solving and Knowledge Representation concepts are perceived as substantially more important than they are easy to learn, suggesting that innovative approaches will be needed for teaching these concepts.

Finally, we investigated participants' perceptions of learning relationships among the using a Group Cognitive Mapping System (GCMS) (Tegarden and Sheetz, 2003). All participants identified 283 relationships, about 11 per participant, among the computing concepts. Due to space limitations in the computer lab, participants were split into two groups, consisting of 11 participants in Group 1 and 14 in Group 2.

The GCMS then computed the shared relationships from the individual responses for each group. Figure 2 presents the shared relationships for a majority of participants in group one. Their views include virtuous cycles (positive relationships in both directions) between Programming and Algorithms, and between Programming and Computer Literacy, suggesting that the Programming concept is the most important for this group. Perhaps this is related to the common perception of those outside computing that the field is all about programming, since they are unaware of many of the other sub-areas.

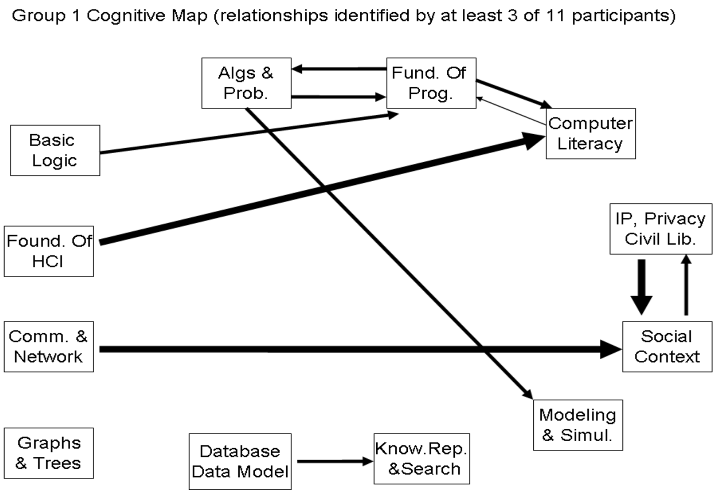
Group 1 Cognitive Map (relationships identified by at least 3 of 11 participants)

Figure 2. Group cognitive map for Group 1

Figure 3 presents the shared relationships for group two. It emphasizes that basic logic is needed before learning other computing concepts. With five strong outflow relationships it is the most cognitively central concept for the group and has strong influence over the next most cognitively central concepts of algorithms/problem solving, fundamentals of programming, database, and modeling/simulation. It seems this group believes that knowledge of basic logic should precede almost all learning of computing concepts.

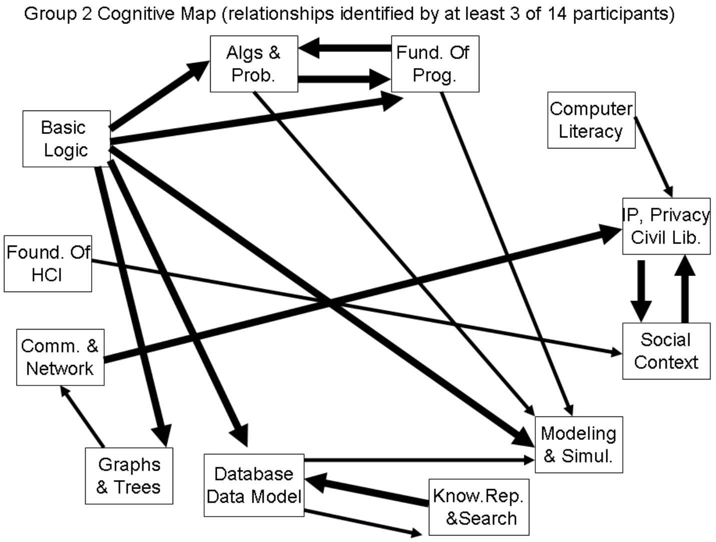

Figure 3. Group cognitive map for Group 2

Participants see networking issues as a prerequisite for understanding the social context and IP concepts. Both groups also identify the interaction of learning algorithms and problem solving with programming in a virtuous cycle. And they see programming as highly cognitively central to their views of learning computing concepts, yet they did not rank it among the most important concepts. This difference in explicit and implicit importance implies that participants are conflicted somewhat in their views of programming.

The learning sequences implied by the shared relationships are shown in Table 2. Three themes emerge. The first theme is the Social Context Theme which provides students with the most important and easiest to learn concepts. The Problem Solving Theme also appeared in the shared relationships for both groups. The final theme is the Data/Knowledge Theme, which includes the influence of Database on Knowledge Representation concepts in both group maps. HCI is included in this theme; since both groups see it as not requiring learning a previous concept.

Curriculum Step 1	**Curriculum Step 2**	**Curriculum Step 3**	**Curriculum Step 4**
Social Theme (required)			
Networking	IP,Privacy,Civil Lib	Social Context	
Problem Solving Theme			
Basic logic	Programming	Algorithms/Prob.	Computer Literacy
Data/Knowledge Theme			
HCI	Database	Knowledge Rep	Modeling/Sim.

Table 2. Curriculum themes and sequences derived from group cognitive maps

Recommendations on Integrating Computing and IT into Other Curricula

Based on the findings we obtained from the first LIKES workshop, we identified a number of fields that may benefit from the integration of computing concepts into their curricula. We then invited faculty and scholars of these disciplines to participate in the second and third LIKES workshops held at NC A&T and VT respectively. We divided these participants into groups, each having four to six participants belonging to a field. We asked the participants to identify computing concepts that are taught or could be integrated into their curricula, and to discuss ideal implementations of the integration and teaching pedagogy. We summarize below the findings of the fields studied (Carr et al., 2008).

Geography (Geographic Information Systems)

The following concepts were identified by the GIS group: Effects of map scale, Data capture, Database management and data schema/structures, Data quality, Programming, Visualization, Data transformation, Pattern analysis, Display / delivery / communication, Network analysis, and Geospatial analysis. While the computing fields and GIS share many concepts and tools in their curricula, the group found similarities and differences in terminologies used by these disciplines. For example, the term “data structure” in GIS refers to database schema but the same term in computing refers to data representation in a computer. The term “scale” in GIS means spatial scale but means performance adaptability in computing. The term “topology” in GIS refers to geographical point location while the same term means network configuration in computing. Furthermore, the two disciplines sometimes use different terms to refer to the same thing. For example, “pattern analysis” in GIS means extracting interesting patterns from large amounts of geographic data, which coincides with the definition of “data mining” in computing.

The group considered computing/IT both as a tool and as a concept. When viewed as a tool, computing/IT are applied in GIS programming, data management, simulation, and Web support. For example, .NET, Visual Basic, and Javascript are some programming languages taught and used in GIS visualization software. Microsoft Access and SQL queries are taught in GIS courses to facilitate data management and pattern analysis. Visualization tools are used in traffic simulation. Although the Web becomes an important platform for GIS applications (e.g., Google Map), the group found that major Web technologies such as XML, Web services, and protocols are not widely taught in existing GIS curriculum. When viewed as a concept, computing/IT are learned through managing GIS data, building GIS software programs, and modeling processes. For example, students learn the concepts of database management through data modeling, knowledge representation, database design and development, and geographic pattern analysis. Students learn software engineering concepts and skills through developing GIS software and designing GIS tools’ user interfaces. Students learn simulation concepts through modeling real-world phenomena, such as land-use changes, tracking malaria hotspots, and forest fire modeling.

Four ideal implementations of teaching computing/IT concepts in GIS topics were identified by the group.

(1) Teaching system development methodology in advanced GIS projects – At the advanced level of the GIS curriculum, capstone courses could allow students to demonstrate and apply their knowledge in real-world domains. Projects conducted by groups consisting of computing/IT and GIS students can be an excellent tool to facilitate their learning of the relevant concepts. For example, software engineering methodology can be learned in such a capstone course group project.

(2) Process modeling in GIS – Some computing concepts and techniques are suitable for process modeling. For example, Petri-nets can be used in traffic modeling. Multi-agent simulation can be used in forest fire modeling. Spatial modeling can be used in studying soil erosion and habitability.

(3) Teaching Social Computing in Introductory GIS Courses – As social computing is an emerging trend in recent years, it can be incorporated into the teaching of introductory GIS courses. Possible topics include location-aware computing, GPS applications, mash-up and its effects, and Web GIS applications such as Google Map.

(4) Privacy, Intellectual Properties, and Ethics – Some emerging issues related to GIS and computing include accessibility of location information and open-source GIS software. The group suggests including these topics in the GIS curriculum to enrich the current course topics.

Physics, Statistics, and Biology

The three groups identified key concepts in computing that relate to their fields as well as identifying where areas of their fields and computation overlapped. The key concepts identified were: logic, algorithms and problem solving, programming, communications and networking, human-computer interaction, graphics and visualization, knowledge representation, information retrieval and storage, database and modeling, intellectual property, privacy and civil liberties, and computer literacy.

Four ideal implementations of teaching computing/IT concepts were identified by the groups: (1) Emphasis on algorithm development skills throughout their curricula; (2) Computational emphasis: Development of computational models to expand the scope of problems and understanding; (3) Using animation and visualization to support conceptual understanding in introductory courses; and (4) Teaching computational methods and numerical algorithms in error analysis and correction.

Music

The music group identified a number of computing concepts in their field: graphic/sensorial representation of music and performances, video-recording and broadcasting, automated sheet music, social networking, and music distribution. The participants identified five ideal implementations of teaching computing/IT concepts in their field: (1) Learning to create websites to distribute music online; (2) Using a tool (such as a programming language or a software) to produce and record music; (3) Learning about signal processing in acoustics; (4) Teaching students to create their own electronic devices; and (5) Using machine learning in advanced signal processing.

History

The history group identified the computing concepts and tools applicable to their field: computer and information literacy, programming and system development (for bridging gaps between existing software tools' capabilities and the needs for conducting humanity analysis), and textual representation of historical events and knowledge. The group suggested a number of measures to enhance the integration of computing concepts and tools into their field: (1) Teaching students to use multiple different accounts and historical writings to assess information obtained from the Internet; (2) Incorporating computational thinking into historical analysis; (3) Increasing collaboration between historians and people from other fields (e.g, (NiCHE, 2009)); and (4) Teaching history students to program so they can develop their own customized tools for data analysis (e.g., The Programming Historian project is an open source / open access introduction to Python programming for historians and other humanists (Turkel and MacEachern, 2008)).

New Courses and Programs

Described below are new courses and programs introduced or being developed in the LIKES sites.

Virginia Polytechnic Institute and State University (Virginia Tech, VT)

A new course entitled "Introduction to Living in the Knowledge Society" is being offered as part of a pathway through the undergraduate core curriculum at VT since Fall 2008. It is cross listed in three disciplines: Computer Science, Business and Information Technology, and Accounting and Information Systems. The course introduces computing concepts needed by students to live in the emerging Knowledge Society and prepares students to take the LIKES themed core courses in VT's Curriculum for Liberal Education (CLE). The course surveys key paradigms of computing, including problem solving, programming, modeling and simulation, and software engineering. It relates these to the Knowledge Society, covering data, information, and knowledge, considering hypermedia, Human-Computer Interaction, presentation, visualization, networking, and communication. Upon completion of this introductory course and 12 credits of LIKES-designated courses, students will take a capstone course, "LIKES Capstone" (planned), to complete the requirements for receiving a LIKES certificate.

North Carolina A&T

A new undergraduate program named "Web Engineering" is being developed at NC A&T and should be offered in the 2009-2010 academic year (pending approval). This program is a response to three trends: the dominance of the Web as the major platform for economic and social activities in the Knowledge Society, the popularity of Internet-related courses at NC A&T, and the declining student enrollment in computing, especially among women. Learning in the program will be largely problem-driven and project-based. Students majoring in Web engineering are required to take a total of 124 semester hours, of which 37 hours are required Web engineering courses. These courses include introduction to Web engineering, syntactic structures for the Web, schemas and transformations, object-oriented programming and design, social and economic aspects of the Web, trust and security, Web services, semantic Web, Web site engineering, systems for social computing, and senior project. It is expected that program graduates will have the background needed for mastering the scientific, technical, and social challenges of the Web.

Santa Clara University

A new course titled "Science, Information Technology, Business and Society" has been proposed as part of the new undergraduate core curriculum to be launched at SCU in the 2009-2010 academic year (http://www.scu.edu/core2009). The course will be required for all business school undergraduate students and will replace the existing required course "Management Information Systems." In the proposed new course, students will examine the complex relationships between science, information technology, business, and society; investigate major breakthroughs in information technology (how they were influenced by business needs and how they affect business and society); and examine social and cultural values in science and technology, as well as economic challenges posed by IT. The course also will introduce major components of IT used in business today. Upon completion, students are expected to understand the capabilities of IT to support the Knowledge Society.

Villanova University

Instead of the one-way incorporation of computing software (e.g., using a software tool for specialized activity in a discipline), a course titled "The Laptop Instrument" interweaves basic lessons of music and programming languages for students from various disciplines from the beginning of the course. This is well expressed in its course syllabus – odd days are for music learning days and even days for programming learning days. The course aims to provide both theories and practices of music and programming so that the students could read music notation, understand music theory, do programming using a language called ChucK, and import music into computers. It is expected that enrollment in computing will be increased due to the addition of this course.

CONCLUSION

As computing and IT become integral to human life, there is an urgent need for colleges and universities to prepare students who are well-equipped to build and to sustain the Knowledge Society. Addressing this need would require a large-scale effort to integrate computing concepts and tools into all fields of study. In this paper, we describe our ongoing project entitled "Living In the KnowlEdge Society (LIKES) Community Building Project" that aims to build a community to define the way to make systemic changes in how computing and IT concepts are taught and applied in both computing and other fields. This paper is the first comprehensive account of our project's outcomes so far. As of now, three of the scheduled four workshops have been successfully held. We studied how computing and IT concepts can be integrated into different fields and recommend improved implementation of such integration in their curricula. New courses and programs are introduced or being developed at participating sites. In the near future, we plan to hold the fourth LIKES workshop at Villanova University to further expand our reach to other fields and to examine ways to develop course modules that support the integration of computing concepts into these fields. These efforts are paving the way toward a revitalized undergraduate computing education.

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