The Role of Computing in Education: The Next Revolution

Frederick Harris
Dept. of Computer Science
University of Nevada at Reno
Reno, Nevada 89512

Gordon Lee
Dept. of Elect & Comp Engr
San Diego State University
San Diego, CA 92182

Stuart H. Rubin
SPAWAR SSC San Diego
53560 Hull Street
San Diego, CA 92152

T.C. Ting
Dept. of Comp Sc and Engr
University of Connecticut
Storrs, Connecticut 06269

Billy Gaston
Research & Development
Anautics, Inc.
Oklahoma City, OK 73110

Gongzhu Hu
Dept. of Computer Science University of
Central Michigan University
Mount Pleasant, MI 48859

Abstract

As computing technologies continue to rapidly advance, the knowledge economy also continues to be a more important part of the world economy. Ubiquitous computing is here to stay and it has become one of the main fibers of social, cultural, and economical life. It is an enabling technology that can increase the productivity in a wide range of applications and economical activities. Besides economic growth potential, computing also provides an opportunity for educational growth; this paper represents a summary of the discussions of researchers from industry, government and academia who were assembled to address how this evolution of computing can impact education in the next revolution.

1. Introduction

The concept of *computing* has been continuously evolving. In the early 1980s, it was the marriage of computing and communication technologies that created the era of internet-based information resources that continues to affect and penetrate into our daily activities through information accessing. Currently, this polygamy of computing, communication, storage, sensory and displaying technologies impacts almost all social, cultural, and economical development as well as our daily life. That is, the impact of computing places a multitude of opportunities into the homes and control of ordinary people, thus enhancing lives on a global scale. This phenomenon can be seen with the widespread use of the telephone, computers, electronic databases and the internet. The telephone provides a platform for communication, the computer provides computing power to the individual, database systems provide a place to store and organize data efficiently, and the internet provides a wide-scale platform for the searching for solutions. The world continues to benefit from enhanced global communication, data organization and retrieval, and computing. These technologies have greatly affected the economy of countries that are able to properly leverage them without extreme restrictions. Technologies have enabled individuals, small groups, and small countries to have an equal voice by providing as much access, visibility and opportunities as large businesses and advanced countries.

One of the major impacts of computing is in the area of human learning, that is, cognitive and logical inference activities that will inevitably change the way we learn, work and live [1]. Lifelong learning will be the focus for long term and continuous economical development. In a report from the European Parliament and the Council on Key Competences for Lifelong

Learning [2], “digital competence” and ”learning to learn” are among eight key competences for citizens in order to easily adapt to a rapid changing and highly interconnected world.

The importance of computing and computers in engineering education has been known for several years and several educators have shared their experiences and activities in this regard. For example, in [3-5], engineering education researchers in the disciplines of civil engineering and computational science have developed special software tools which enhance the academic environment. These computer-based instructional guides supplement the teacher in the classroom by providing design examples, additional practice problems in the computational aspects of the field, and self-paced learning.

Further, researchers realize the power of the web as a learning tool [6-7, for example]. Through the web, students and teachers are able to draw upon the vast database of information available through a flexible and global media.

The purpose of this paper is to support the claim that computing continues to have a major impact in engineering education as well as to project how computing can provide an even greater influence in engineering education through digital tutors and web-based learning. The paper is organized as follows: Section 2 provides some information on the current state of education in the US which warrants the need for improvement which Section 3 discusses the challenges in using computing to address the shortcomings in the current educational environment. In Section 4, one option is presented, the KASER, as a platform to assist with the educational reform using computing and, in Section 5, we summarize how we as educators can support the new educational revolution using computing.

2. The Current Educational Situation

Several countries have already recognized the value of education as an integral component of economic growth; these countries place great emphases on education, particularly in fields where there is a large gap between the availability of skilled workers and market demands (e.g., the STEM disciplines – science, technology, engineering, and mathematics). There is a large disparity in the quality of mathematics and science education amongst countries. When compared to many other countries, the educational system in the U.S. is lacking more and more in preparing students for the transition from high school to college and from college to industry as is shown below.

With reference to the Global IT Report for academic year 2007-2008 [8], the countries ranked in the top ten in mathematics and science education are listed in Table 1. The scores in the table were based on the World Economic Forum Executive Opinion Survey 2006–2007 survey data (where 1 = lags far behind most other countries and 7 = are amongst the best in the world).

One observes that the United States is not in the top ten and is, in fact, ranked 43th. There has been a coordinated effort from government, academia, and industry in the U.S. to improve and reform the education systems to put greater emphasis on STEM education at the precollege levels to attract more young people into these fields. Several U.S. government agencies, including the Department of Education and the National Science Foundation, have been actively promoting STEM education. Yet, there is still a large disparity between the performance of US students and other countries.

Table 1. Quality of Math and Science Education [8]

Rank	Country/Region	Score
1	Singapore	6.34
2	Belgium	6.29
3	Finland	6.17
4	Hong Kong SAR	5.85
5	Switzerland	5.72
6	France	5.71
7	Tunisia	5.62
8	Taiwan, China	5.59
9	Czech Republic	5.53
10	Korea	5.46

The result of the Global IT Report is not the only indicator that the U.S educational system is failing. The failure rates are staggering; over 1,000,000 students drop out of school each year [9] and many of those students who do graduate are still ill-prepared for the workforce. With the shrinking budget and limited resources, educational reform can best be served by computer-based training, which is vital to our national economic infrastructure in the medium term on out. Success in educational reform is contingent upon success in computational creativity. It is noted that many details and justifications for this premise are necessarily omitted from this paper for the sake of brevity.

The then Presidential-candidate Barack Obama said on October 15, 2008 that no nation in history has ever maintained a strong military in the absence of fiscal solvency [10]. One aspect of fiscal solvency is a relatively full employment, in keeping with the Phillips curve (i.e., allowing for 4 percent unemployment) [11]. But this is not the complete picture. We need to maintain and thus invest in an evermore educated workforce to remain economically competitive in the global economy. How do we do this? This responsibility was given to the schools which had the main role of education. However in the current form of our educational system, schools can not effectively reach students under the current or foreseeable budget. What is needed is the introduction of affordable computer technologies to capture good instructional practice to deliver quality education to each and every individual where it is needed and when it is needed. This form of education can support and supplement our educational system thereby reducing the resources strain that is currently afflicting our schools.

3. Challenges in Computing

Computing will continue to impact the economy in the years to come. To sustain such an impact, we will need to address several issues concerning the development of computing technologies [1]:

(1) It should be a technology that fosters more collaboration with others versus one that removes human interaction and social development, unless human life is at stake.
(2) Researchers must be careful to determine if efforts should be focused on leveraging technology to think for us, to interpret and understand for us, to instruct us, or to predict/forecast the future for us. Some may deem that as creating a sort of god for mankind.
(3) One must ensure that technology not prevent users from knowing and experiencing fundamental concepts and learning experiences.
(4) The technology should enable the enhancement of communication, computing, production, and thus economic opportunities. It is important to leverage this enhancement byproduct without eliminating the fundamental skills that should be learned by an individual. It can be stated with caution that, knowing that computing is changing the human society, what was once noted as fundamental in one age may be obsolete in another; it is suggested that the domain of fundamental skills is in a gradual process of re-definition.

4. The Next Revolution

What areas will provide the basis for the next revolution in technology? Computing power, communication, storage capability and collaboration techniques provide some insight in addressing this question. These areas are driven by the immense need to access, analyze, process, and distribute information more intelligently. *Information* is the common denominator which is also the main denominator in education. It is sometimes said that information/knowledge is power; however, it should be correctly stated that applied information/knowledge is power, assuming that the information being applied is of the necessary quality.

Over the past few years, steps have been taken by a number of government and commercial entities to capture data to address the issue of providing a more informative, preventative and predictive analysis. Unfortunately, whether it is historical data stored in legacy systems, current data captured by mechanics, or future data acquired by the use of sensor technology, some of the underlined issues still remain. These issues include, but are not limited to, making sense of the captured data, acquiring the appropriate combinations of data, making the proper relationships between data, as well as determining the relevance of said data.

One of the biggest problems of data collection is determining what exactly one can keep and/or disregard. This creates a problem in an unnecessary cost of storage, which can be high when processing a large amount of data. Discovering and defining relationships between similar documents or sets of information have become rather common and needs to be addressed within all areas of government, business and industry. Entities needing this capability range from potentially small scale systems, such as a small elementary school library book management systems, to large scale systems, such as military government information systems servicing several international logistic depots. The *right information* is often needed to obtain real time situational awareness, mission capability, damage assessment, and risk analysis. These issues affect all types of business and government organizations and may prove beneficial in business decisions, medical discoveries, advances in information retrieval and organization, environmental management, aircraft maintenance management and the like. The same principles apply in education.

Throughout the business world, whether commercial or noncommercial, there exists the need for a solution that can capture input from disparate data sources, analyze the information, discover new information of relevance, link related information, and from said information allow the necessary personnel to make intelligible decisions. The term “necessary” is used because such a solution should possess the capability to adapt the distributed information to each end-user based on ability, role, clearance, learning capacity, and level of need. This involves some knowledge and interaction with the user. This technology should enable intelligent information access and interaction and not information overload. Specifically it should provide the necessary understanding to make optimal decisions and not hinder decision making.

How can this revolution impact education? Again, *information* access is the key. We believe that the next revolution in education will be the instant access to global information. The vast majority of intelligent tutors and trainers these days have good graphics and multimedia support. They are lacking in intelligence, however. It is our opinion that the best architecture for delivering intelligence in tutoring and training applications is to arrange all multimedia materials as small objects that are maintained in an object-oriented relational database and brought up by a simple rule-based production system. The input to this expert system can be quiz questions (even connected to simulation programs), meant to elicit student feedback. The pattern of responses serves as the context to the intelligent system. While such a system can be prototyped and will certainly work, there is a problem.

At this point, we need to introduce the concept of the KASER family of intelligent systems [12]. The KASER is a knowledge amplifier (the acronym stands for *K*nowledge *A*mplification by *S*tructural *E*xpert *R*andomization) based on the principle of randomization. This principle refers to the use of fundamental knowledge in the capture and reduction of a larger, dependent space of knowledge (not excluding self-reference). KASERs allow for the definition of computational architectures that allow for the delivery of educational content in a reusable, augmentable, cost effective manner that offers to make text-based instruction all but obsolete. Key actions to enhance e-skills readiness are shown in Table 2 [13].

With the use of KASERs, information searching, for example, will be an accelerated learning experience between pupil *and* the knowledge-base. Such systems can learn from user feedback; by minimizing the system training required of the knowledge engineer, we can more effectively process vast free-text databases of knowledge for minimal development cost. Furthermore, these bases may be concurrently created and maintained and search algorithms can run on parallel processors connected in heterogeneous distributed networks. Imagine a student coming home from a physics class in need of more explanation on how to compute the angle of an arrow to maximize the distance to a target. She could simply access her digital tutor, ask the question and gain access to web sites, videos and pdf files on the subject. Some sites may be irrelevant while other provide detailed graphics to enhance the learning. Figure 1 illustrates an example of what a web search may be using the KASER to say search for information on radiation blasts and the fallout for a student term paper.

Further, learning is a lifelong experience; it is through computing that we can enhance this learning experience!

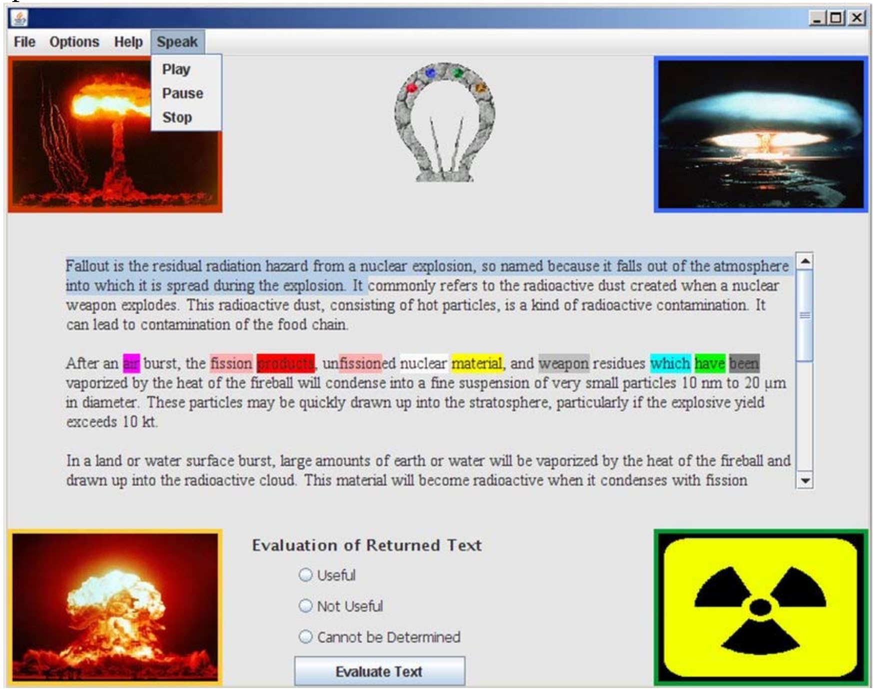

Figure 1: Example of the use of a KASER to Perform a Web Search

5. New Directions in Computing

In the competitive world, a strong cooperation between government, academia, and industry play a vital role critical to the health and prosperity of our economies and to improve the quality of life of our citizens. Bruno Lanvin suggested five key actions to take in work force enhancement [13], as shown in Table 2.

Although the five key actions above were targeted to the European Union, we believe they are also universally applicable to other countries including the U.S. As researchers and practitioners in the field of computing, we are an integral part of the national and international coordinated effort for the advancement of computing to sustain economic growth.

In particular, the following points highlight what the research community in computing should do in the next decade [1]:

(1) Develop more focused efforts.
(2) Specifically market government and commercial businesses to come to conferences (e.g. provide discount registration, create incentives for teaming with universities, and encourage program committees to include industry partners).
(3) Team with small businesses. Small businesses are positioned to create cost effective solutions, more innovation, and more enhanced/focused solutions. There is funding specifically set aside for small business and university research teaming.

(4) Lobby to prevent government intervention without understanding.
(5) Much more research in security and confidentiality areas need to be emphasized.
(6) Standards and compatibility for the massively connected computational and information processing systems need more research and more attention to policies for the information oriented and dependent society.
(7) Research in intelligent information processing need to focus on holistically and symbiotically for both static and dynamic data and knowledge.
(8) Software efficiency and reliability including systems as well as application software systems need to be emphasized.
(9) Intelligent and logical user/system interaction, including multimedia and sensory interfaces needs to be greatly improved and developed.
(10) Representatives from computing research and development communities need to be engaged, more actively participating in policy, legal, and regulatory processes.
(11) Most importantly, we need to actively engage in the development learning strategies and activities in schools as well as in society for preparing individuals for effective use of computing and information systems for learning and working in our current and future information oriented society.

Table 2: Actions and Drivers in the Next Revolution [13]

Key Action	Expected Leader
Share a compelling vision	government
Strengthen skills	government (visibility) industry (inclusion, action)
Formulate curricula	industry (needs) academia (formulation) government (regulatory)
Promote math and science	academia (curricula) government (vision) industry (sponsoring)
Enhance lifelong learning	industry (content, rewards) government (fiscal) academia (e-learning)

6. Conclusions

On the education front, we as researchers and educators need to be creative. Old instructional presentation formats do not work any better than do fixed micro-managed lesson plans. Due to shrinking budgets and over-burdened teachers, it is critical that we develop new paradigms to address the challenges in our educational system.

Computing provides a solution which can supplement our educational environment through creative and intelligent architectures. We must effectively use computers to augment our intellectual capabilities throughout the life. A revolution is required and only through this activity can we continue to grow economically and more importantly intellectually.

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