Developing Real World/Virtual World Hands-on Experiments for IT Students

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Abstract

This paper outlines the design and development of an interactive virtual laboratory toolset, TelcSim, designed to enhance students' learning of basic telecommunication principles. This study establishes the increasing demand for technically competent IT professionals throughout this decade. Next, the mix, motivation, and background of students entering the university environment to obtain the skills necessary to meet this demand are explored. Based on the result of this analysis and the examination of current learning theories, their use and applications, a virtual laboratory toolset (TelcSim) was developed. A preliminary evaluation of TelcSim shows great promise and meets the goals set forth during its design. Recommendations for further development and enhancements are explored in conclusion of this article. Included are screen prints showing a sample of TelcSim features.

Keywords: IT Education, Telecommunications, Simulation, Virtual Laboratory

Introduction

This paper outlines the continuing demand for trained IT professionals and the need for increased technical competence in IT majors. The mix, motivation, and background of students that are entering the university environment are examined. Next, current learning theory is explored and used to design TelcSim, a virtual laboratory environment for teaching telecommunication principles. An evaluation of the first release of TelcSim follows with recommendations for further development and enhancement

Lack of and Need for Trained – Competent IT Professionals

According to the Bureau of Labor Statistics (BLS) of the US Department of Labor (BLS Releases 2000-2010 Employment Projections, 2001) computer and information systems managers held about 313,000 jobs in 2000. Employment of computer and information systems managers is expected to increase more than 36 percent faster than the average for all occupations through the year 2010.

The Presidents Information and Technology Advisory Committee (PTAC, 1999) states that a "continuous supply of well-trained, high-quality-professionals in information technology is critical for companies to maintain global competitiveness". This is also in line with the projection given by the Department of Education as seen in Figure 1.

This growth is attributed primarily to increasingly rapid technological advancement in science, engineering, and businesses. This fact has created enormous interest to the field of information technology management and computer related jobs. This interest is not limited to the younger generation, high school graduates, but also, to many mature individuals who are retraining to provide themselves with better job opportunities. Table 1 gives the current and projected employment fig-

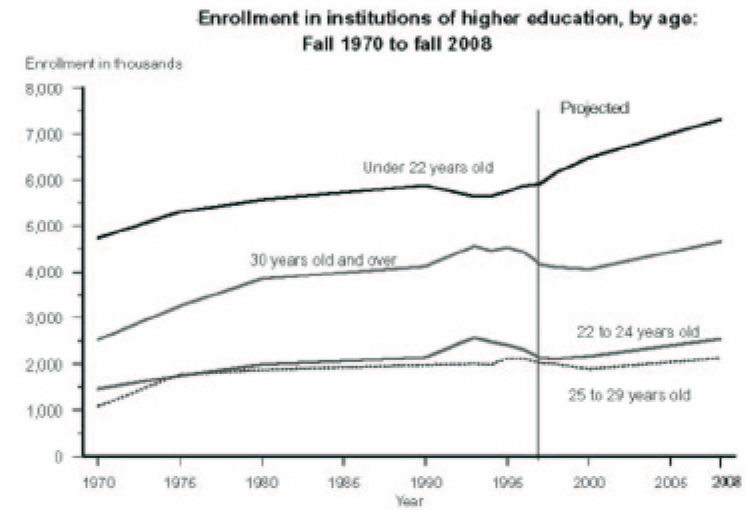

Figure 1: Enrolment in institutions of higher education, by age:
Fall 1970-Fall 2008 (US Department of Education, 1999).

	Employment		Change	
	2000	**2010**	**Number**	**Percent**
Computer software engineers, applications	380	760	380	100
Computer support specialists	506	996	490	97
Computer software engineers, systems software	317	601	284	90
Network systems and data communications analysts	119	211	92	77
Desktop publishers	38	63	25	67
Database administrators	106	176	70	66
Personal and home care aides	414	672	258	62
Computer systems analysts	431	689	258	60
Medical assistants	329	516	187	57

Table 1. Fastest growing occupations, 2000-10 (Numbers in thousands of jobs)
(BLS Releases 2000-2010 Employment Projections, 1999)

ures for the fastest growing occupations from the year of 2000 through the year of 2010. Table 2 provides a comparison between the occupations with the largest job growth for the same period. As it is indicated in Table 2, this increase is 97% for Computer support specialists and 100% for Computer software engineers, applications. This comparison is seen more clearly in Figure 2.

Occupation	Employment		Change	
	2000	2010	Number	Percent
A. Combined food preparation and serving workers, including fast food	2,206	2,879	673	30
B. Customer service representatives	19,64	2,577	631	32
C. Registered nurses	21,94	2,757	561	26
D. Retail salespersons	4,109	4,619	510	12
E. Computer support specialists	**506**	**996**	**490**	**97**
F. Cashiers, except gaming	33,25	3,799	474	14
G. Office clerks, general	2,705	3,135	430	16
H. Security guards	1,106	1,497	391	35
I. Computer software engineers, applications	**380**	**760**	**380**	**100**
J. Waiters and waitresses	1,983	2,347	364	18

Table 2. Occupations with the largest job growth, 2000-10 **(Numbers in thousands of jobs)**
(BLS Releases 2000-2010 Employment Projections, 2002)

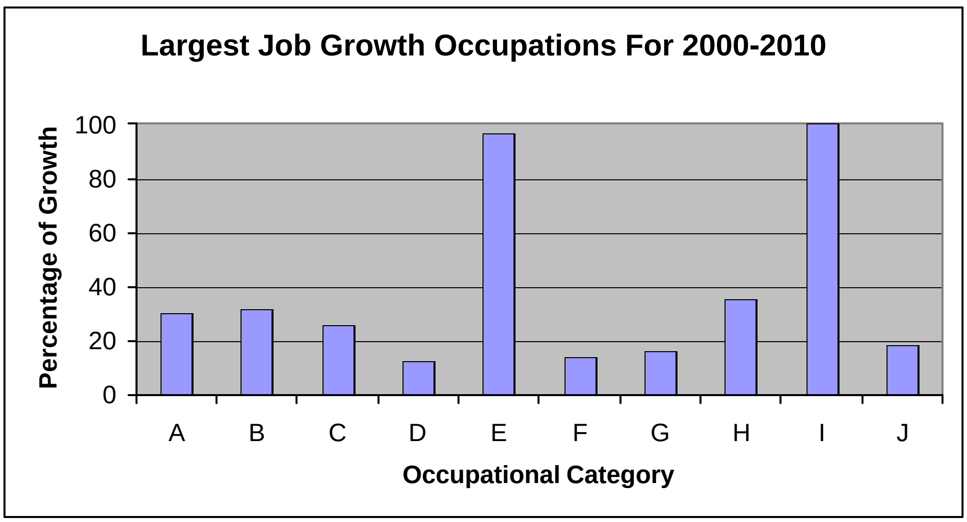

Figure2: Percentage of largest job growth occupations for 200-2010.
The categories correspond to Table 2.

Skills Required For an IT Professional

Increasingly, companies are using information technology (IT) as their primary customer interface for sales, customer support, logistical support, and electronic commerce between companies. The use of technology plays a vital role in the stability and growth of any organization. Computers and information system managers are involved in a broad spectrum of responsibilities from creation of a business plans to implementation of networks, and communication systems to achieve the business goals. They also must be aware of new technologies as they emerge and be able to apply this technology as a tool to cut costs, increase revenue, productivity, and competitiveness. The responsibilities and involvement of IT managers within an organization require competencies in both business and information technology.

The Market Demands More Technical Competence

There is an academic debate when developing information technology management (ITM) curricula as to the level and depth of technical information that should be covered. Some schools choose to concentrate on the softer, less technical aspects of ITM and more on the general business aspects of the field. Others choose to focus more on providing a technical foundation with a strong business core requirement. When reviewing current literature, there seems to be more support for the latter approach than the former one.

One of the earliest definitions for ITM is given by Shannon (1948) states that "IS/IT has its foundation in the science of information and its link to decision making". Another, more specific definition is given by Field (2001) states that ITM is a combination of Computer Engineering, Telecommunications and Computer Science and is becoming part of school of business core disciplines along with Accounting, Economics, Finance Marketing, Organizational Behavior.

The need for more technical skills taught in the ITM field can be seen in the changing job requirements for IT personnel. Computer and information systems manager positions increasingly require technical knowledge and expertise, business expertise, higher education, and experience. There is a move toward more "hands-on" management where the IT manager can act as a technical resource to provide guidance to their subordinates and function as an interpreter and technical consultant communicating ideas and recommendations in non-technical terms to senior management or peer managers. Therefore, students studying in this area must master technical skills in the course of their studies as well as strong business skills if they are to become successful in this area

The Educational Challenge

Many people are attracted to the field of ITM for obvious reasons. These include the relatively high salaries and high demand for IT professionals even in the current state of the economy and foreseeable future. To qualify for these jobs, many individuals seek their IT education through formal degree programs at higher education institutions. This group is the focus of this study. Students in this group can be further divided into two generations, The Nintendo Generation, and The Graying Scholars.

The Nintendo Generation

The majority of today's incoming traditional students (recent High School graduates) are familiar with the technologies used by educators to enhance students' comprehension of materials taught in classes. They are familiar with the use of computers and most have spent significant time on the Internet. They perceive themselves to have knowledge of computer technology. However, this knowledge is often superficial. Typically, they know how to use technology, but do not have any in-depth understanding of the technology being utilized or how it is created. Many of them rely heavily on the use of computers or calculators to solve problems, but they may have no concept of how to solve the same problems when given a pencil and paper.

The GrayingSscholars

Over the last decade, adult education has increasingly become an integral part of most institutions of higher education. The US Department of Education predicts that this trend is likely to continue at a relatively high rate. A graph of this trend is shown in Figure 1.

In today's job market, rapid changes in technology have affected every industry enormously. This has forced a lot of companies to reinvent, change or modify their use of technology constantly to be able to compete and even survive in today's market. These issues fuel high demand for IT personnel, even with the current state of economy, according to Bureau of Labor Statistics (BLS, 2001), the demand in the field of computer science and information technology still surpasses other areas of the job market. A recent survey conducted by Information Week 500 study 2002 finds "98% of the companies participating in the survey provide company-paid educational or training opportunities to their IT staff (Foley, 2002)."

Several factors must be considered when teaching mature students. First, these students are used to traditional methods of teaching and may not be very comfortable with the new technologies used in classrooms. Second, these students have often forgotten much of the quantitative skills they learned earlier in their scholastic careers. Third, these students usually have family responsibilities and may be working during the day.

The educational challenges confronted by educators are not only limited by classes made up of either the Nintendo Generation or the Graying Scholars but also, these challenges are exacerbated in the classroom environments that are made up of a mixture of both of these groups of students. Adults in a classroom are usually coming from different backgrounds with different responsibilities, and are from different age groups. This requires the use of different teaching techniques to accommodate the learning issues of the majority of students in a class.

Traditional Ways of Approaching Education

In a recent study, Biggs (1999) finds that students are attending a university "not out of a driving curiosity about a particular subject or a burning ambition to excel in a particular profession but to obtain qualification for a job. … have less developed background of relevant knowledge … come to lecture with few questions … want only to put in sufficient effort to pass." Our own experience strongly reflects this finding. This is particularly true in the high tech areas such as IT or MIS where there is a hypothetical pot of gold to be obtained upon completion of the degree requirements.

Success in a given field requires a mastery of the basic principles and in-depth knowledge of all component areas. Students learn best what they practice and perform on their own and receive real time feedback on errors (Lovett & Greenhouse, 2000). To facilitate this goal, the instructor should encourage students to discover principles by themselves. The task of the instructor is to translate information to be learned into a format appropriate to the learner's current level of understanding (Bruner, 1990).

The constructivist theory of education (Semple, 2000) states that knowledge is constructed from the experience of the learner and that knowledge resides in the mind rather than externally. Learning is a personal interpretation of the world in which a learner's beliefs and values are used in interpreting objects and events. Learning is an active process of creating meaning from experience.

The behavioralist theory of education is concerned with evaluating what can be observed. It states that the learning process should be short and should arise from previously learned behavior. This theory states that learning should be rewarded and reinforced and that the feedback should be immediate.

In cognitive theory, learning is viewed as making symbolic, mental constructions involving active mental processing on the part of the learner. Computer technologies are cognitive learning or mind tools amplifying human abilities such as memory and processing rather than instructional media (Greening, 1998). Jonassen (1994) argues that children cannot use computers without thinking deeply about the content that they are learning; these cognitive tools activate thinking and learning takes place through the process of using the tool.

It appears that current educational theory finds that the most effective method of learning requires independent hands-on practice and the discovery of new concepts based on extending current knowledge. Different students master techniques at different rates. One requirement to incorporate these theories is to provide a virtual laboratory environment to allow students to perform experiments that will enable students to master basic concepts of the subject.

Need for a Lab Environment

This paper focuses on developing an optimum environment for teaching students the fundamentals of telecommunications. Based on curriculum guidelines and industry requirements, this is one of the key areas where all IT personnel must be knowledgeable and competent. Many applications are distributed across the Internet. The demands for new applications in this environment are growing daily as the need for efficiencies achieved through business-to-business (B to B) and business-to-consumer (B to C) applications are required to meet profitability goals. Telecommunications is the glue that integrates heterogeneous systems into homogeneous solutions to business problems.

The heart of telecommunications is the transmission of data. Understanding data transmission requires an in-depth understanding of signal creation, propagation, transmission, and constraints such as attenuation, noise or interference. Traditionally, this subject has been taught using an engineering orientation. For example, signal analysis is described using mathematical tools such as Fourier analysis. This approach is successful if the student can visualize how the signal will respond as key parameters are changed or additional elements such as noise or harmonics are added to the original signal. This visualization usually requires a more comprehensive mathematical background than the typical ITM student has acquired.

One of the more difficult concepts for beginning telecommunications students to master is the decomposition of complex signals by identifying the harmonic sine waves, amplitudes and frequencies the signal is composed of. The creation of an analog square wave by using Fourier transforms is often used to introduce some of these basic principles. Building on these concepts, delay distortion and signal distortion that occur during propagation are introduced.

A typical mathematical expression for expressing the summation of the harmonics of the signal is as follows:

$$S(t) = \sin(2pft) + \frac{1}{3}\sin(2p(3f)t) + \frac{1}{5}\sin(2p(5f)t) + \frac{1}{7}\sin(2p(7f)t) + \ldots$$

Faced with this equation, students often enter a glossy eyed trance never to recover.

Lab facilities

Imagery has been shown to facilitate recall in many studies. It also plays a major role in problem-solving and creativity (Miller, 1984). Visualization of complex signals and effects is often reinforced during laboratory experiments where circuits are created and signals are seen on an oscilloscope. Most IT students lack the skills and inclination to perform electrical engineering laboratory experiments.

One viable alternative to bridge the gap outlined above is to create a virtual laboratory simulator where a student can interactively create and modify signal parameters and view the results on the computer screen in a real time basis. A virtual laboratory uses computer based graphical simulation to teach concepts such as signal analysis and encoding.

Simulation - An Alternative to Physical Laboratory

Flight simulator is used to teach students the fundamentals of flying without the risk and expense of using an airplane. In teaching telecommunications, visual simulations may help students master the basic concepts of signal theory as well as network and protocol simulations.

A simulation program might prove even more effective than a live laboratory. Potosky (1997) finds that students learn the material in a third to a quarter of the time using an interactive computer simulation rather than a live laboratory. Peter Li (1993) finds that the use of interactive simulation material promotes increased student motivation as well as a faster and deeper understanding of the principles being presented. These studies indicate that there is a real value in the use of computer simulation to increase student learning and motivation. An ancillary benefit of a virtual laboratory is that it requires no additional dedicated space, additional equipment or resources for training or maintenance.

TelcSim Tool Description

Based on the needs and issues outlined above, a decision was made to create TelcSim, a virtual laboratory tool to assist in educating students in the fundamental principles of telecommunications.

Design criteria

Based on a preliminary analysis of our needs for a simulation environment to assist in the learning of basic telecommunication principles, we settled on the following requirements and constraints.

The tool must:

1) provide a comparable learning experience to a physical laboratory.
2) require no additional training to use.
3) integrate easily into class environment.
4) have a visual orientation.
5) provide instant feedback to changes.

Figure 3. Main Menu

The constraints were:

1) must run on an IBMPC Pentium 90 or better with at least 32MB of memory.
2) execute under the Windows Operating System 9x, 2000, XP +.
3) low cost to implement and maintain.

Operating environment selection

The TelcSim tool must run in an environment that is readily available to most schools. Today that environment is PC based workstations running the Microsoft Windows operating system. The tool selected to develop the initial release of TelcSim is Microsoft Visual Basic 6. Visual Basic has a strong graphics presentation capability and is easily learned and assimilated by staff and students. Other environments such as C++ and Java were considered, but we found Visual Basic skills more readily available.

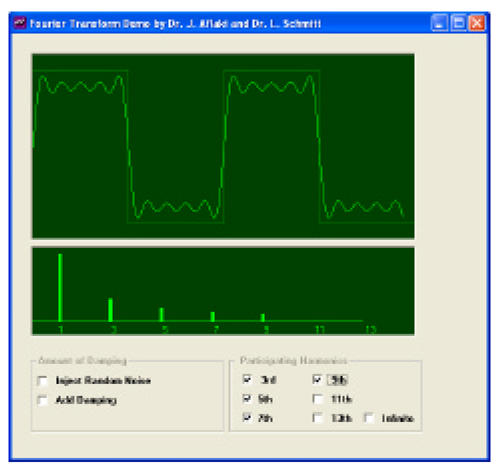
Figure 4. Fourier Transform Tool

Phase 1 TelcSim development

It was decided to implement TelcSim in several phases. The first two phases delivered the Fourier Transform Analyzer Tool and the Virtual Oscilloscope. A screen showing the main menu of TelcSim is displayed in Figure 3. A screen showing the Fourier Transform Tool is shown in Figure 4. Using this tool, students are able to visually display the use of a Fourier Transform series to construct a square wave from a series of sine waves. They can also see the effects of introducing random noise and damping of the signal due to attenuation. Results are displayed in both time and frequency domain plots. This helps students develop an understanding of basic signal creation and the effects of noise and attenuation on a signal as it is transmitted.

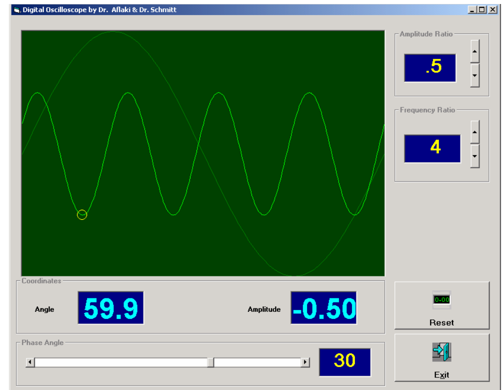

Figure 5. Virtual Oscilloscope

A screen showing the Virtual Oscilloscope function of the TelcSim tool is shown in Figure 5. The Virtual Oscilloscope provides the student with the capability to visualize the effects of changing frequency, amplitude and the phase of a signal and to compare the modified signal with a reference signal. Students can read the amplitude and the instantaneous value of a sine function by moving the cursor over the signal displayed. This is equivalent to the lab experiments typically conducted in an electrical engineering laboratory using a signal generator and digital oscilloscope.

TelcSim can be installed on any available PC. Students can work with on a given lab assignment until they reach a thorough understanding of the principle to be mastered. This is particularly advantageous to adult students who have less flexible time schedules and are usually not able to utilize a traditional laboratory.

Initial Evaluation

Based on our initial usage of TelcSim in our telecommunications classes, we have seen that it seems to lead to an increased level of understanding of the concepts being taught. In the past, we received numerous complaints from students that they did not understand the concepts being introduced in introductory telecommunications classes. This tool seems to have created more interest and motivation in learning these concepts and has alleviated some of their concerns.

TelcSim was utilized in two classes of our Introduction to Telecommunications course. The students were given a lab exercise to complete using TelcSim and asked to comment about the experience. Some of the comments were: “helped relate amplitude, phase, angle and frequency better now that I have seen it in front of me”, “liked how you can instantly see the effect of changing any variable on the signal”, “visual feedback helped me understand the concept”. Based on this initial feedback, it appears that TelcSim is a valuable and effective addition to the classroom environment. It appears that this tool and similar tools will provide a means of developing the technical depth required by industry in as viable, effective and efficient manner possible.

Recommendations for Future Research and Development

To evaluate the effectiveness of TelcSim in learning fundamental signal concepts, an evaluation instrument will be developed to assess differences in learning and retention using TelcSim versus the traditional method of instruction. The study will utilize current telecommunication students to test the efficacy of this approach. A potential evaluation flow is outlined below:

1) Two classes will be taught the Fourier module.

2) One class will be taught using mathematical models. Students will be asked to perform analysis using their knowledge of the principals taught.
3) The second class will be taught using TelcSim. Students will be asked to perform analysis using their knowledge of the principals taught.
4) Upon completion the results will be compared using the evaluation instrument.

Using the feedback from students who participated in our initial evaluation of TelcSim, we plan to develop additional tools to enhance the TelcSim package. The ultimate goal of this development effort is to provide a virtual laboratory to support learning telecommunication principles. In phase 2 of our development of TelcSim, we are developing a module that will allow students to experiment with various digital encoding schemes.

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Biographies

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Dr. James Aflaki is currently an Associate Professor of Information Technology Management at Christian Brothers University in Memphis, TN, USA. He has over eighteen years experience in MIS, design, automation, and integration of current technologies into the existing computer systems to enhance the performance and reliabilities for various programs. In addition, he has extensive training in various applications software and network operating systems such as Novell, Microsoft NT, and Microsoft Windows 2000. His expertise and broad knowledge of various computer applications has given him the ability to maintain a consulting practice offering various services in the field of data communications, networking, and system design.