Integration of Interactive Simulations and Virtual Experiments in Fiber Optics and Wireless Communications Courses for Onsite, Online and Hybrid Delivery

Yakov E. Cherner*, Amin Karim, Ahmed S. Khan****
***ATeL, LLC, **DeVry University**

Abstract

Rapid pace of technological growth has placed new demands on the skills, competencies and knowledgebase of engineering and engineering technology graduates. In order to be successful in the 21st century workplace, graduates are required to acquire Digital-age literacy. The engineering and engineering technology graduates are not only expected to understand the theory behind state-of-the-art technologies, but also to exhibit hands-on, analytical, problem solving, expert thinking, and complex communication skills.

To address these changing needs, it is imperative that new technological tools and teaching methodologies be incorporated in the curricula so that students can acquire Digital-age literacy for becoming life-long learners. However, incorporation and implementation of state-of-art technological tools requires considerable investment of time and financial resources. Keeping curricula and lab resources current with respect to the fast pace of technological advances in the field is another challenge for faculty

Educators can address these challenges by using the simulation and virtual experiments. With the availability of broadband technologies, which offer high data rate connections, simulation-based e-learning is rapidly becoming a significant and effective component of the teaching and learning process. The use of virtual systems enables students engaged in distance learning to master practical skills at any time and at any place. This paper presents an introduction to "Active Learning Suite (*ALSuite*)" software developed for interactive simulations and virtual experiments, and discusses its application for Fiber Optics and Wireless Communications Courses, for onsite, online and hybrid delivery modes.

I. Introduction

In the first half of the 20th century, students were required to acquire three basic skills: reading, writing and calculating. These skills were considered appropriate to become literate and to build on these skills students' knowledgebase. But in this day and age, the exponential growth of technology has imposed new demands on students and educators. To achieve success in learning and in pursuing a successful career, a student in the 21st century needs to attain proficiency in science, technology, and culture, in addition to the reading, writing and calculating skills. The Digital-age literacy requires students to gain understanding of information in all its forms: basic literacy, scientific literacy, economic literacy, technological literacy, visual literacy, information literacy, multicultural literacy, and global awareness (Table 1).[1]

Table 1: Digital-Age Literacy for the 21st Century

Literacy Type	Description
Basic Literacy	Language proficiency that enables a student to develop his/her knowledge-base
Scientific Literacy	Knowledge and understanding of scientific concepts and processes, that enables students to make personal decisions, participate in civic and cultural affairs and contribute to economic productivity.
Economic Literacy	Ability to identify economic problems, alternatives, costs, and benefits; analyze economic situations; and examine public policies; and weigh costs against benefits.
Technological Literacy	Knowledge about what technology is, how it works, and its potential applications to achieve specific goals in an effective and efficient manner.
Visual Literacy	Ability to interpret, use, appreciate, and create image and video, using multimedia tools to advance thinking, decision making, communication, and learning.
Information Literacy	Ability to evaluate information across a range of media; recognize when information is needed; locate synthesize, and use information effectively; and accomplish these task using appropriate technological tools.
Multicultural Literacy	The ability to understand and appreciate the similarities and difference in the customs, values, and beliefs of one's own culture and the culture of others.
Global Awareness	The recognition and understanding of interrelationships among international organizations, nation-states, public and private economic entities, socio-cultural groups, and individuals all over the globe.
Source: Digital-Age Literacy (http://www.ncrel.org/engauge/skills/agelit.htm)	

In the book *In The New Division of Labor: How Computers are Creating the Next Job Market*, Harvard Professor Richard Murnane and MIT economist Frank Levy have examined the role of computers in reshaping the job market and types of human skills required in today's marketplace. Professors Levy and Murnane contend that the jobs growing in numbers share two general skills that the computer cannot replicate: expert thinking and complex communication. The first skill, expert thinking, addresses the ability to solve new problems that cannot be solved by rules. The second general skill, complex communications, addresses the ability not only to transmit information, but to convey a particular interpretation of information to others in jobs like teaching, selling, and negotiation. [2,3] According to Professor R. Murnane "Training all students to engage in complex communication and expert thinking is the challenge American schools have never met, there is an enormous capacity building challenge…. It is the problem solving skills that will trump that digital technology." [4]

The phenomenal growth in the wide spectrum of technologies has led to an increase in the productivity of the workplace. Therefore, industry seeks graduates with appropriate background and training. The engineering and engineering technology graduates are not only expected to understand the theory behind state-of-the-art technologies, but also to exhibit hands-on analytical, problem solving, expert thinking, and complex communication skills.

To address these changing industrial needs, it is imperative that new technological tools and teaching methodologies be incorporated in the curricula so that students can acquire Digital-age literacy for becoming life-long learners. However, incorporation and implementation of state-of-art technological tools requires considerable investment of time and financial resources. Keeping curricula and lab resources current with respect to the fast pace of technological advances in the field is another challenge for faculty.[5]

College and university professors can address these challenges by using the simulation and virtual experiments. With the availability of broadband technologies, which offer high data rate connections, simulation-based e-learning is rapidly becoming a significant and effective element of the teaching and learning process. The use of virtual systems enables students engaged in distance learning to master practical skills at any time and at any place.

II. Active Learning Suite (*ALSuite*)

To address pedagogical and laboratory needs, an advanced simulation-based e-learning software, "Active Learning Suite" (*ALSuite*) has been developed. It uses real-life processes and objects, such as those related to fiber optics, wireless and wired communications as the context for science and technology investigations. This enables students to: (a) learn the relationship between the scientific theory and its practical applications in technology, and (b) explore the processes occurring in the system and constraints between its parts and parameters, and (c) observe system limitations and bottlenecks. *ALSuite* is based on a proven pedagogical assumption that students learn effectively and master science and technical concepts efficiently if they can understand the concrete phenomena that are being studied and if they become aware of the potential applications of the theoretical knowledge they are acquiring.

The realistic *ALSuite* simulations enable students to experience workplace-like virtual environments. State-of-the-art graphical interfaces and realistic models provide an "insight" view of the process and allow students to imitate authentic tasks that are similar to or identical with real tasks they will encounter in their potential workplace. Students can quickly and safely experiment with a variety of scenarios and see the effects of their experimentation, become familiar with internal structure and operation of complex telecommunication systems and devices, and learn effective sequential processes, along with the development of other professional and vocationally appropriate skills.

III. Features of Active Learning Suite

The *ALSuite* software implements technologies that can provide instructional opportunities in many ways, whether at a campus/school (traditional teaching), at home (warm-ups, post-class tasks, or self-learning), in a corporate setting, or through distance learning. ATeL's realistic simulations (complex JAVA and Macromedia Flash applets with associated HTML/XML parts and scripts) enable learners to:

(1) observe the physical processes insightfully at different levels of detail
(2) analyze constraints between relevant parameters
(3) push these parameters beyond normal allowed values to simulate infrequent operating conditions or casualty situations,

(4) run "what if" scenarios

(5) acquire data from virtual experiments* for detailed analysis and comparison to actual operating conditions in a theory to practice approach.

Incorporated into each simulation are both help files and an online resource, which provide information and pertinent explanations and theory. Most simulations have the option to toggle instantly between the American (British) system of units and the International system (SI).

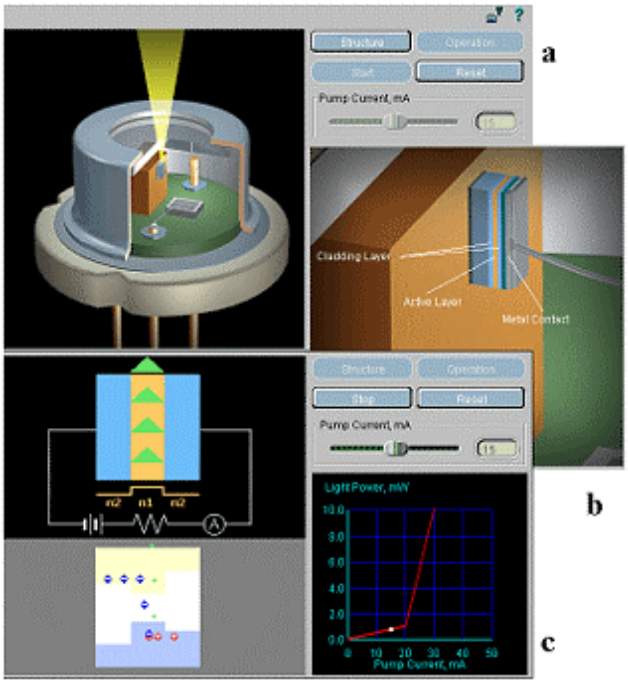

Figure. 1. Screenshot fragments for the simulation that is designed to present **Laser Diode** (LD) construction, operational principles and the physics behind it. From a general view, the simulation brings the student inside a LD (**a**). Then semiconductor laser chip can be zoomed (**b**) in order to visualize and study its double heterostructure and the functions of each part. Clicking on the "Operation" button opens a panel with a schematic picture of the key layers (**c**) that enables the student to learn and understand the operation of a LD and its link with fundamental optical laws, interatomic processes and quantum concepts. The graph on the right displays how altering pump current affects the light output.

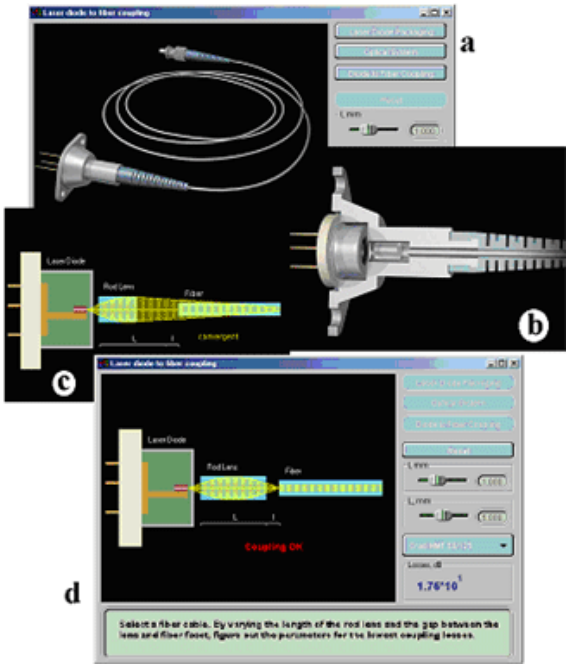

Figure. 2. This virtual experiment "**Diode To Fiber Coupling**" enables a student to explore the coupling unit conditions required for transmitting a laser beam emitted by laser diode into a fiber cable. The external design (**a**) and internal structure (**b**) of a laser diode package can be displayed. During the experiment (**c** and **d**) the student can select various fibers from an online catalog and examine how modification of the rod lens properties and the parts arrangement affect the process and losses. He or she can then be asked to determine the unit configuration for a specified optical cable that will provides minimum loss.

Control devices and testing equipment used in the telecommunications industry enable technicians to measure and define correlations between virtually all internal and external

* The difference between a simulation and related virtual experiment lies in the presence of a step-by-step instruction for students in the virtual experiment. Hence in a virtual experiment the student is expected to follow the instruction to accomplish an assignment, whereas there are no restrictions on the student's action when he/she works with a simulation. In addition, as real hands-on experiments, virtual experiments include objectives, assignment, and assessment.

parameters that describe a process or object's properties. The majority of technical college students and corporate maintenance/service staff are more empirical than abstract learners.[6-8] Often they struggle to understand processes at a qualitative level and prefer to learn through "hands-on" activities. Vast majority of experiments in real photonics laboratories look like sets of boxes linked with wires, this provides only an "external" view of the process, phenomena or operation of a device without visual exposure to what is going on inside and how it is related to fundamental laws and principles. This does not excite students' imagination or visual perception. *ALSuite's* simulations and virtual experiments provide both "inside/insight" and "outside" views of the process. The simulations shown in the Figures 1 and 2 reveal the processes taking place inside the fiber optic devices and components and links parameter changes with quantum mechanical concepts and with the internal device design and structures.

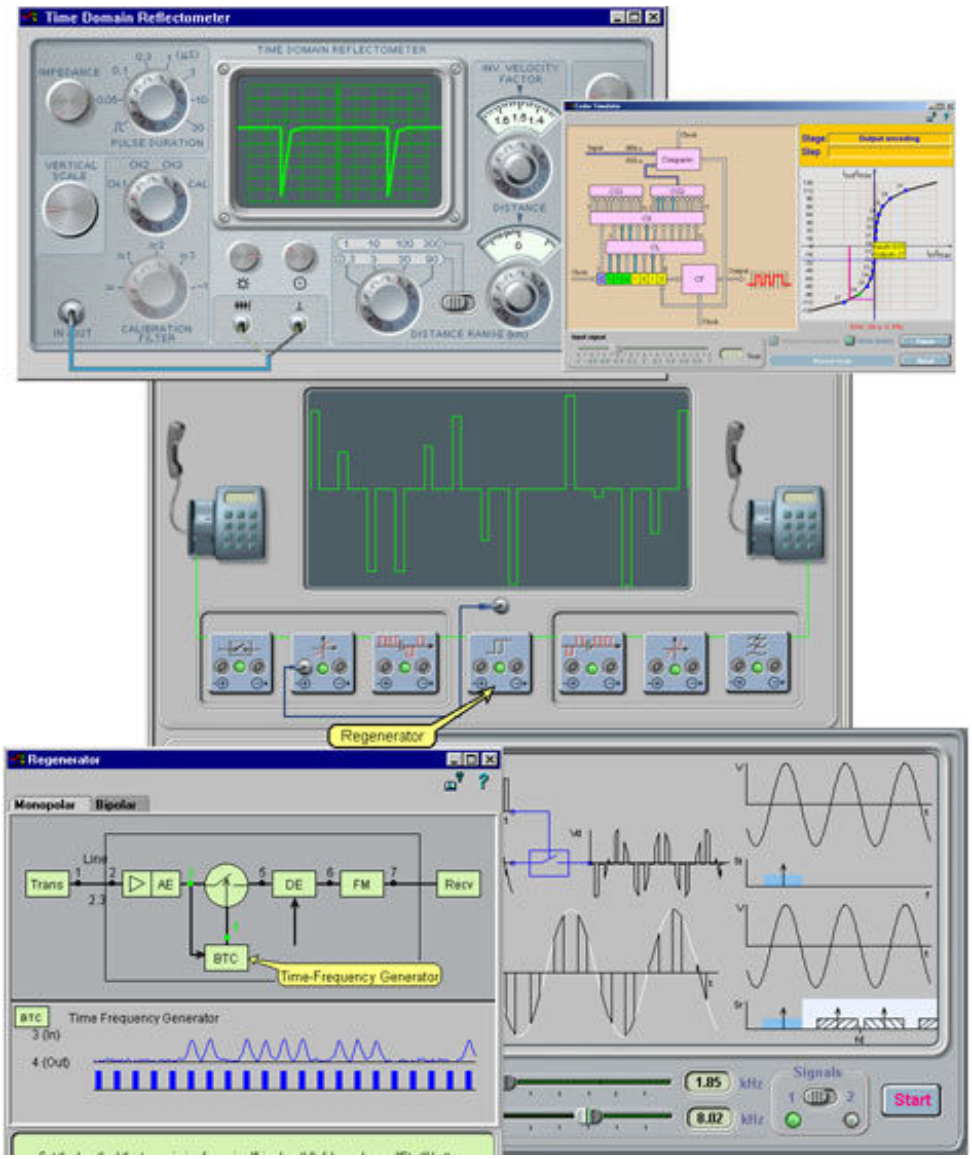

Figure 3. The simulations on the right are designed to assist learners in exploring the architecture and operational principles of a wired telephone system and its parts. The simulation in the middle presents all major devices that form a communication track as well as input and output signals for each device. A click on a device icon launches the second level program that simulates the design and operation of the chosen device (Regenerator- bottom left and Non-linear decoder – top right). It enables the learner to fully explore the device functionality and structure. The embedded tool enables the student to digitize graphs and convert them into tabular data. The bottom right simulation visualizes all sequences of the processes occurring during the voice transmission from trigger the simulation screen into a display of a virtual oscilloscope and examine signals in detail. The virtual Time Domain Reflectometer (top left) allows a student to analyze signals and master the use of the apparatus for tasks in the field.

All computer simulations are based on scientific-mathematical models, which contain certain assumptions and neglect some phenomena. Depending on the topic under study, the purpose of simulations, and available recourses, the model can be more or less sophisticated and thereby describe the original phenomena for better or worse. For prospective engineers, it is crucially important to understand the accuracy of simulated results and limits of their applicability. *ALSuite* simulations enable students to export virtual data to MS Excel or other data acquisition software. The ability to compare data acquired from student hands-on experiments with data generated by a simulation based on various models (from simple to more sophisticated ones) provides a unique opportunity for the professor to discuss with students the discrepancies between real-world processes and theoretical schemes, as well as the accepted assumptions, limitations and applicability of science models.

In addition, realistically looking *ALSuite* simulations can help students conceptualize the physical principles underlying the operation of a real device.

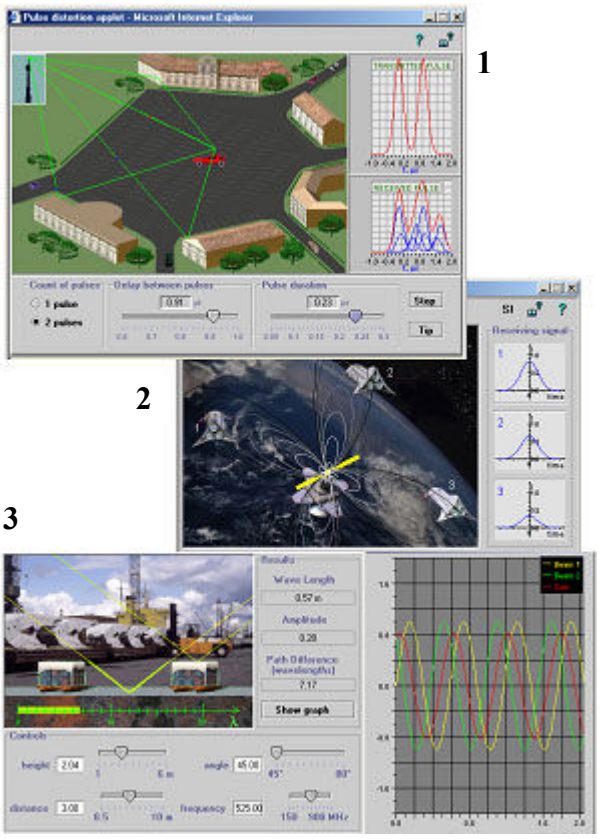

Figure 4. Three simulations shown above enable a student to explore (1) how a multipath pulse distortion reduces the data-transfer rate by dragging and dropping a car around a parking lot; (2) properties and operation of a linear antenna by rotating and expanding a space station antenna to connect to each of three satellites, and (3) to understand the impact of surface roughness on the reflecting signal by moving and resizing containers.

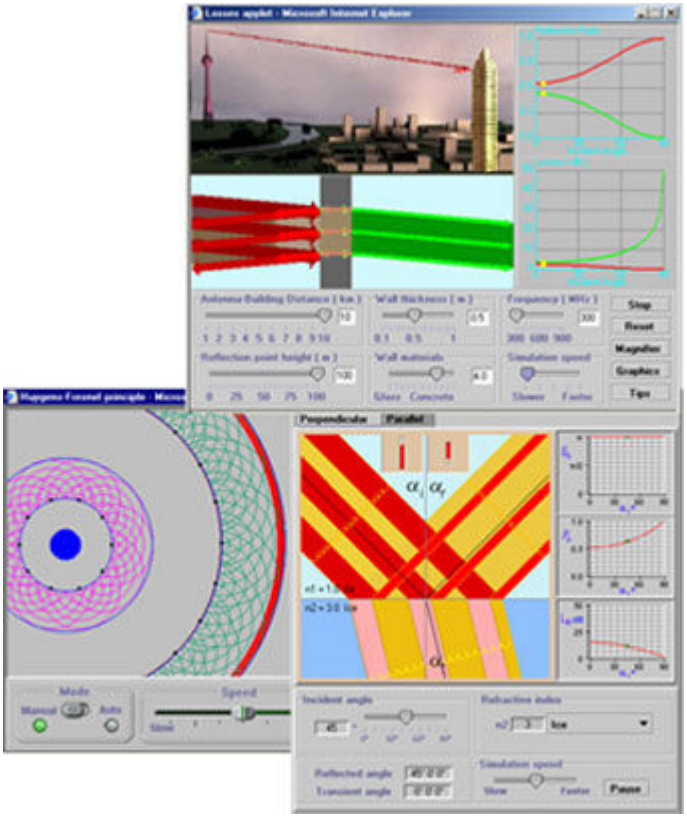

Figure. 5 The interlinked simulations presented in the figure are designed to explore processes, which occur when an electromagnetic wave penetrates a building. In the top experiment the learners can vary the distance between the antenna and the building, receiver altitude, wall thickness, as well as wall materials. Two lower interactive simulations assist the student in understanding Huygens principle and Fresnel theory, which describes wave refraction and reflection.

A virtual experiment can provide an opportunity to separate the particular impacts of each of several parameters that affect the outcomes of measurements. Using simulations the student is able to isolate and analyze the contribution of a specific process and by this means to recognize and evaluate errors in actual measurements made in laboratory experiments.

There are a number of hands-on labs that require unique and expensive equipment, complicated multi-step actions, or require specific training. In contrast, simulations and virtual experiments allow students to perform real hands-on labs efficiently with greater safety. For example, *ALSuite*'s "*Fiber Cable Fusion"* and "*Connectors*" virtual experiments (see Figures 6 and 7) can be used to guide students virtually through all the steps of the splicing/welding process before a student has mastered real splicing/welding techniques. Such warm-up preparation will increase the effectiveness of hands-on labs, making student's learning more proactive, and thus reducing the time to understand the functionality of unique equipment. Distance learners can use virtual experiments on a regular basis from a college web site while occasionally performing a hands-on laboratory session at the college.

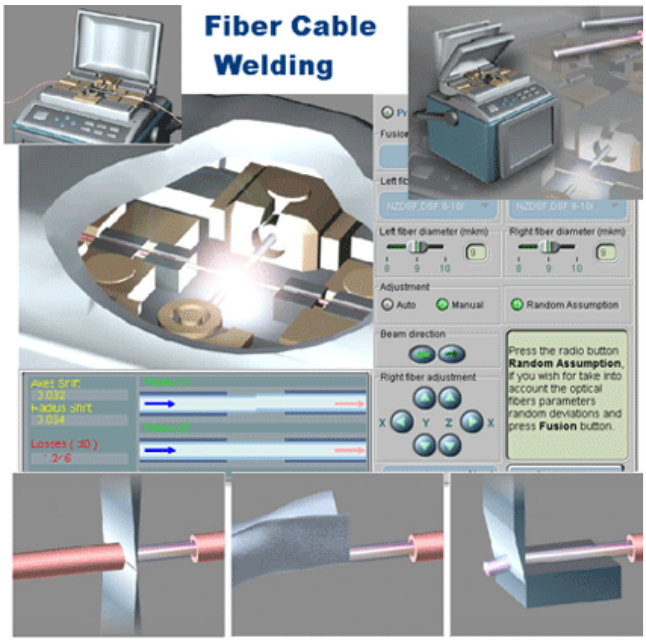

Figure. 6. The virtual experiment **Fiber Cable Welding** is designed to introduce to students, in detail, all steps of a welding process, welding equipment, and factors which affect the quality of welded cable and signal losses. The learner is able to explore all stages of the preparation phase, select the cables for welding either from a list of standard industrial products or set up customer cable parameters. In the Fusion phase, he/she can launch an automatic Fusion Splicing or adjust the cables manually and measure the losses if the adjustment was not perfect.

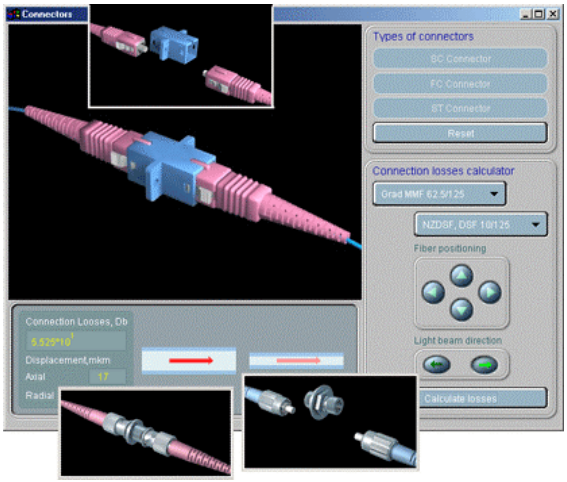

Figure 7. The virtual experiment **Connectors** enables the student to learn pros and cons of different types of connectors. He/she is able to connect various cables, adjust them and measure losses in both directions.

The *ALSuite* software implements technologies that can provide instructional opportunities in many ways, whether at a campus/school (traditional classroom settings), at home (warm-ups, post-class tasks, or self-learning), in a corporate setting, or through distance learning.

When used in a lecture-lab environment, learning can be very efficient because students can immediately apply their theoretical knowledge by conducting a virtual experiment. When incorporated in online courses, virtual experiments dramatically enhance the quality of distance learning.

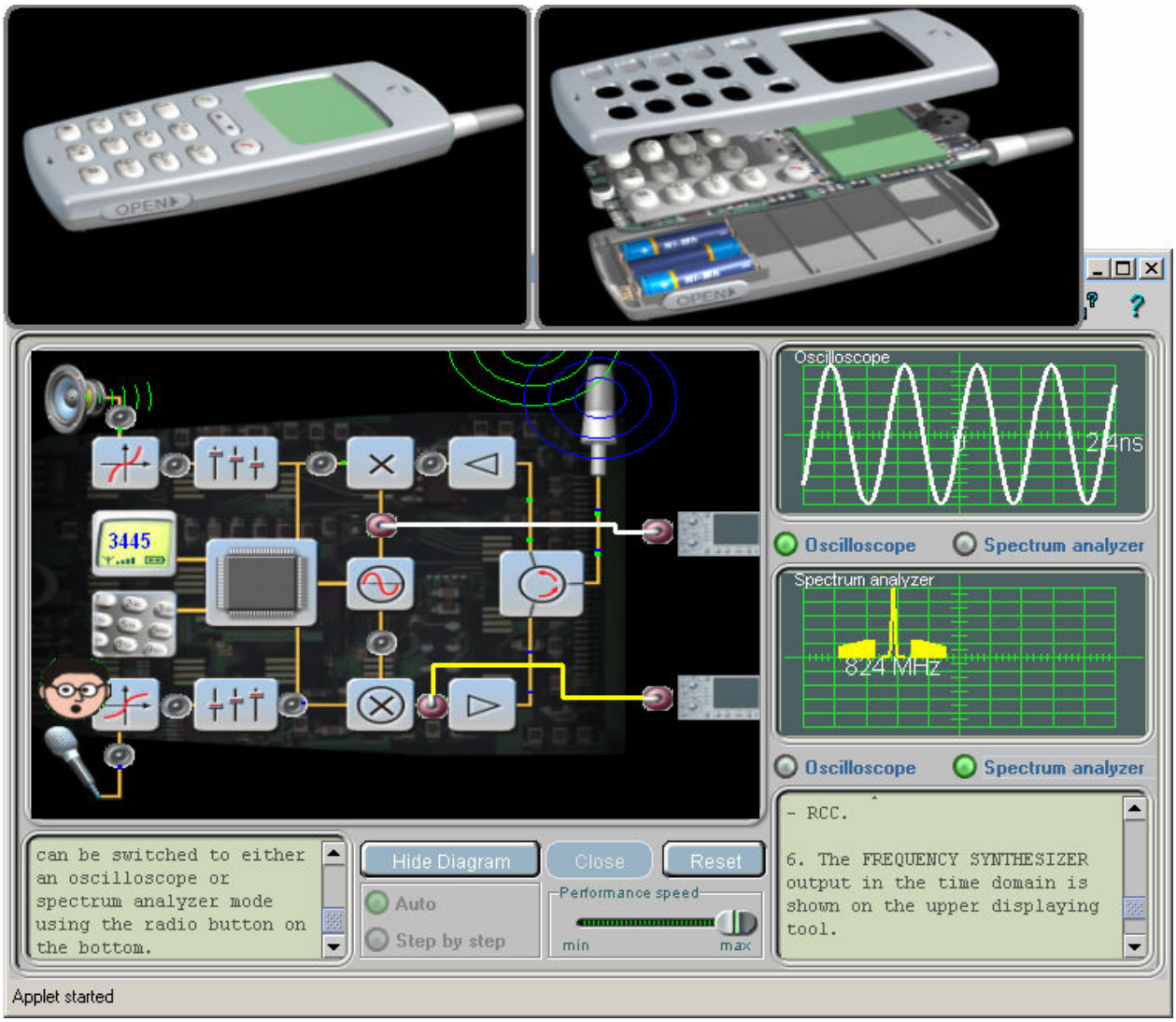

Figure 8. The simulation above introduces learners to the concept of cell phone design and functionality of its major components. A learner can open the unit and see its structure (top right). The diagram enables him/her explore major phone components and their interaction. Input and out of each component can be connected with either oscilloscope or spectrum analyzer to investigate signal on each stage of its transformation. The right bottom panel displays the current process status and its brief description. The left bottom panel provides students with instructions haw to manipulate the simulation.

ALSuite is intended for problem-based learning and "learning-by-doing." [9-12] However, it can facilitate more traditional learning and teaching strategies as well. The interactive exercises and virtual experiments in *ALSuite* are designed to challenge learners to develop effective problem-solving, critical and expert thinking skills. This enables the learner to discover the connections between theoretical concepts of the technology and their practical applications in the real world.

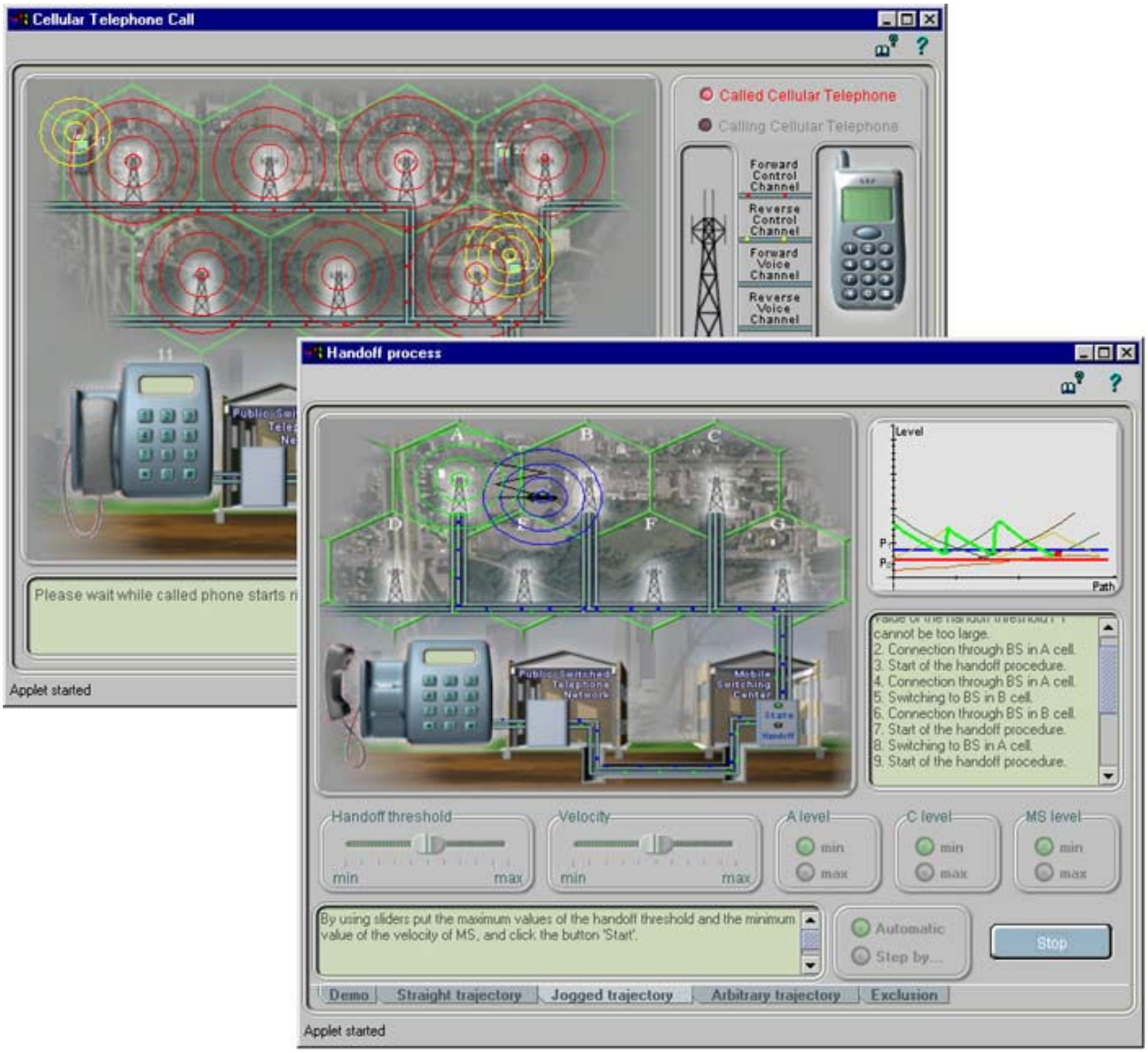

Figure 9 The simulations above foster students' understanding of basic concepts of cellular telephony and the sequence of processes occurring during establishing a connection between two callers.

Using the first virtual experiment (top) the student can call: (1) from a conventional telephone to a mobile phone, (2) from a mobile phone to another mobile phone, and (3) from a mobile phone to a conventional telephone. He/she will learn what processes occur during establishing of each type of communication.

The second simulation (bottom) assists the student in understanding a handoff procedure and examines the impact of various parameters on the quality of mobile communications. The student is able to vary the velocity and trajectory of a mobile receiver, the threshold P0 and signal levels, as well as explores different scenarios.

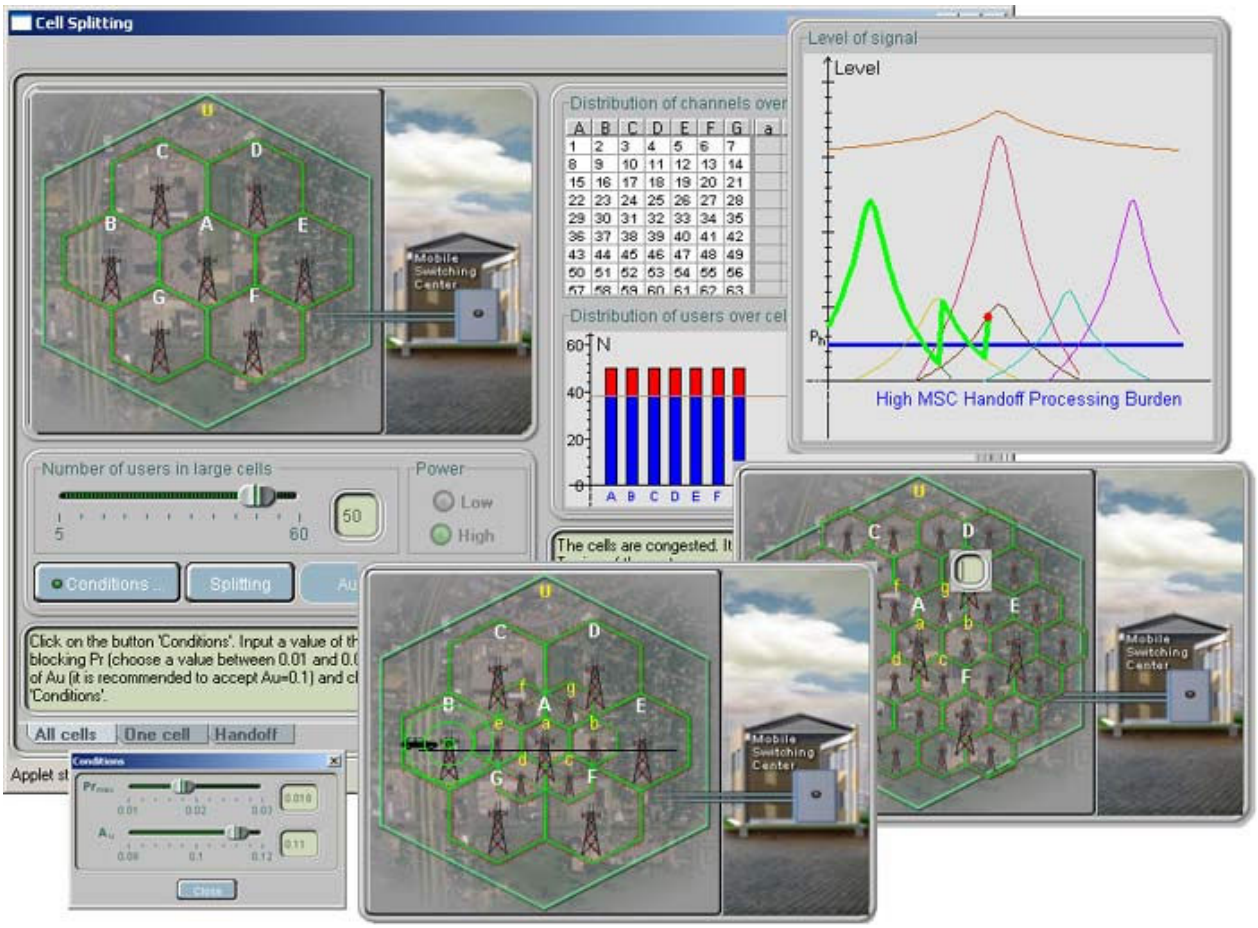

Figure 10 The simulation enables a student to explore the situations when cell splitting is appropriate and various strategies of cell splitting. The student can study how the total maximum number of users in a system increases as cells are split. The procedure of switching handing off a mobile phone from one cell to another, as it moves across cell boundaries in a system of different sized cells, can be explored as well. The student is able to change values of the probability of blocking, traffic intensity A and the number of users in initial cells.

ALSuite software can be run from:

- Web site over the Internet,
- a server via a local school or corporate network,
- CD, or hard drive of a stand-alone computer.

ALSuite modules and components are compliant with SCORM and compatible with major learning and content management systems.

IV. Interactive Simulations and Brain-based and Constructivist Learning

The use of interactive simulations and virtual experiments in Fiber Optics and Wireless Communications Curricula support the brain-compatible teaching principles outlined by Caine and Caine:[13] (1) the brain is a parallel processor, (2) learning engages the entire physiology, (3) the search for meaning is innate, (4) the search for meaning occurs through "patterning," (5) emotions are critical to patterning, (6) the brain processes parts and wholes, (7) learning

involves both focused attention and peripheral perception, (8) learning always involves conscious and unconscious processes, (9) the brain has at least two different types of memory: a spatial memory system, and a set of systems for rote learning, (10) humans understand and remember best when facts and skills are embedded in natural, spatial memory, (11) learning is enhanced by challenge and inhibited by threat, and (12) each brain is unique.

Active Learning Suite experiments also support the constructivist approach of teaching. According to the *Thesaurus of ERIC Descriptors,* [14] constructivism is a "viewpoint in learning theory which holds that individuals acquire knowledge by building it from innate capabilities interacting with the environment" (p. 64). Constructivist teaching is based on recent research about the human brain and what is known about how learning occurs. It is an approach to teaching and learning based on the premise that cognition (learning) is the result of "mental construction." In other words, students learn by fitting new information together with what they already know.

V. Conclusion

The use of interactive simulations and virtual experiments in Fiber Optics and Wireless Communications courses delivered via online, onsite and hybrid delivery modes enables students to acquire digital-age literacy by developing critical and expert thinking skills.

ALSuite was developed with a partial support from the National Science Foundation.

References:

1. Digital-Age Literacy (2004). 21st Century Skills. Available online: http://www.ncrel.org/engauge/skills/agelit.htm
2. Levy, F. and Murnane, R. (2004). The New Division of Labor: How Computers Are Creating the Next Job Market. Princeton University Press.
3. The New Division of Labor – How to Prepare for America's Changing Job Market. Harvard Graduate School of Education (HGSE) News. Available online http://www.gse.harvard.edu/news/features/murnane05132004.html
4. Beth, P. (2004). Computer ate my Job, Economists educate the future work force at GSE lecture, available online: http://www.news.harvard.edu/gazette/2004/05.06/11-murnane.html r
5. Khan, A., Sauer, S., Moore, M., & Karim, A. (2003). A Wireless Course Sequence Design Using Global Wireless Education Consortium (GWEC) Curriculum Modules and Industry Tools. Presented at 2003 ASEE Annual Conference, Nashville, TN, June 22-25, 2003, also published in conference proceedings.
6. Shymansky, J.A.,Kyle, W.C., and Alport, J.M. *The Effect of New Science Curricula on Student Performance*, J. Res. Sci. Teaching (1983), 20, p.387;
7. *Cognitive Skills and Acquisition* (J.R.Anderson, ed.) L. Erlbaum Ass., Hilsdate, NJ, (1981).
8. Sison, R., Shimura, M. *Student Modeling and Machine Learning*, International Journal of Artificial Intelligence in Education (1998), 9, 128-158,

9. Gibbs, G.*Learning by Doing. A Guide to Teaching and Learning Methods* (1988) http://www.chelt.ac.uk/gdn/gibbs/

10. Mary E. Lee, *Distance Learning as "Learning by Doing"*. Educational Technology & Society (1999) 2 (3), http://ifets.ieee.org/periodical/vol_3_99/mary_e_lee.html

11. L.C. McDermott. *Bridging the gap between teaching and learning: The role of research*. (1997) http://www.psrc-online.org/classrooms/papers/pdf/plenary.pdf

12. Caine, R.N., & Caine, G. (1991). *Making connections: Teaching and the human brain.* Alexandria, VA:

13. Houston, J.E. (Ed.). (1995). *Thesaurus of ERIC descriptors* (13th ed.). Phoenix, AZ: Orynx Press.

Authors Biographical Information

Yakov E. Cherner, Ph.D. is a Founder and President of ATEL, LLC, combines 20+ years of research and teaching practice with extensive experience in writing curricula and developing educational software. He introduced an innovative concept of multi-layered simulation-based conceptual teaching of science and technology. This instructional approach uses real-world objects, processes and learning situations that are familiar to students as the context for virtual science, engineering and technology investigations. To facilitate this methodology for academic education, corporate and military training, his company developed new ground-breaking e-learning solutions, as well as relevant assessment and authoring tools. Dr. Cherner holds an MS in Experimental Physics, and Ph.D. in Physics and Materials Science. He published over 60 papers in national and international journals and made dozens presentations at various national and international conferences and workshops. Dr. Cherner has served as a Principal Investigator for several government-funded educational projects.

Amin Karim is the Director of Technology Programs at DeVry University. In this capacity, he is responsible for leading DeVry's undergraduate and graduate programs in engineering technology, information systems, telecommunications, and biomedical programs. Before joining DeVry in 1991, he has worked in industry, and as a faculty and as a dean of engineering technology.

Ahmed S. Khan, Ph.D. is a senior Professor in the EET dept. at DeVry University, Addison, Illinois. He received his M.Sc (applied physics) from University of Karachi, an MSEE from Michigan Technological University, and an MBA from Keller Graduate School of Management. He received his Ph.D. from Colorado State University. His research interests are in the areas of Fiber Optics Communications, faculty development, and outcomes assessment, and, Internet and distance education. He is author of "The Telecommunications Fact Book" and co-author of "Technology and Society: Crossroads to the 21st Century" and "Technology and Society: A Bridge to the 21st Century." He is a member of IEEE, ASEE, ASQ, and LIA.