using technology. Productivity gains cannot be made while ignoring the human factors. Members of upper management in industry can effectively demonstrate to their operations managers, supervisors, and hourly personnel why the status quo is unsatisfactory by utilizing methods such as the Santech simulation, and thus motivate them to accept and become proactive in implementing the necessary cultural changes in moving toward world-class competitiveness.

Mr. Deese of Santech has demonstrated the simulation exercise to participants of a small business development seminar series conducted at the ARRI (Automation and Robotics Research Institute) facility of the University of Texas/Arlington. He is also making a packaged kit including all materials and documentation available. Technology managers and technology faculty may obtain a well-developed, industry-proven tool to convey difficult "book" concepts at a reasonable cost. Information can be obtained from the author.

"Dissatisfaction with the status quo must be felt at all levels of the organization. This gives people the impetus to change. It is not sufficient for management to mandate change" (Weddle, 1994).

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Dr. Waldrop is Director of the School of Technology at Georgia Southern University, Statesboro. He is a member of the Beta Rho Chapter of Epsilon Pi Tau.

3. Computer Simulation and Virtual Reality Applications in Technology Studies

by Xueshu Song

This describes a program designed to teach welding and a research project to assess its effectiveness. The discussion that follows draws implications and conclusions concerning this instructional innovation.

Welding as an industrial technology is vital to our national economy. Experts estimate that welding is involved in about 50% of the GNP (Gross National Product). More than a million people work in 60 welding-related occupations in the United States. High tech-oriented welding procedures have been introduced by industry in recent years. The many dimensions of metallurgy, physics, mechanics, chemistry, geometry, economics, management, and psychology of welding epitomize the interdisciplinary nature of state-of-the-art modern technology studies (Song, 1995a). A welding technology curriculum, either on its own or as part of the industrial technology curriculum, is taught throughout the world.

Welding activities, however, are potentially hazardous for students due to exposure to dangerous fumes, noise, and radiation and the risk of electric shock. These hazards cause concern among students. Institutions have to take extra safety measures because most students have no experience with these processes. Most educational institutions do not possess electronic beam welding, laser welding, or explosive welding equipment because of monetary and safety constraints. There is a consensus among government, industry, and the education communities that it is imperative to find more effective, more efficient, safer, and less costly ways of educating and training the workforce in the welding industry (Song, 1995a).

The recently completed Welding Lab on Disk (WLOD) project (Song, 1996) was a further development of the WLOD system based on the original modules conceived and developed by Song (1991). The primary objectives of the project were to develop, field-test, and promote the WLOD, a sophisticated interactive computer software system simulating 10 welding processes that are most frequently used in industry.

ABOUT WLOD AND HOW IT WORKS

WLOD has high resolution graphics, an interactive, user-sensitive interface, and an adaptive-testing mechanism. Peer-competition mechanism and control parameters are simulated for different welding processes in both analytical mode, illustrating engineering fundamentals, and synthesized mode, providing the virtual realities of the welding processes (Song, 1996).

Synthesized Modules (e.g., Gas Tungsten Arc Welding)

The synthesized module simulates the movement of the electrode controlled by the mouse, and the welding parameters are adjusted through a graphic button panel. Simulated process parameters are as follows: current polarity, current intensity, arc length, welding gun travel speed, filler feeding and withdrawal, base metal thickness, type of base metal material, electrode type, electrode diameter, filler material, filler diameter, and the chemical composition of the shielding gas. Welding zones are depicted with both orthographic projection and pictorial views. The system gives a performance achievement score each time the user practices with the synthesized module. The score is based on the user's choice of welding parameters, which affects the metallurgical quality of the weld. The kinematics of the mouse movement controlled by the user determines the geometric quality of the weld. Since different users may obtain different scores, a peer pressure and competition mechanism takes place.

Analytical Modules (e.g., Shielded Metal Arc Welding)

The analytical modules reveal the physics, chemistry, mathematics, and other sciences of welding. The analytical module shows the polarity simulation under welding physics, where pixels of different colors represent ions and electrons, respectively, their direction of movement being illustrated through animation. Impacts of polarity on penetration and build-up are revealed with different melting rates represented by the speed of the proliferation of red and yellow pixels in the welding zone. Welding physics also includes simulation of the melting rate as a function of material heat capacity, heat conductivity, specific heat, and power input to the welding zone. Under welding mathematics, the definitions of weld geometry, welding geometry, and joint geometry are defined and illustrated with animated graphic images. Welding chemistry, welding safety, and welding equipment are also included.

Symbolic Menu System (e.g., Electron Beam Welding)

An F-16 fighter in the background constitutes a symbolic menu. Clicking on the cockpit will produce the lab that provides the eye-hand coordination training. The engine represents the fundamental level, where the math, physics, chemistry, metallurgy, and other scientific principles of welding are simulated. The right-hand missile carries the quiz, while the left-hand missile launches the safety module. The rudder provides help and the afterburner nozzle indicates the quit button. This graphic menu system is carefully designed to attract young people to learn welding engineering technology.

RESULTS OF A FIELD TEST

Field test participants included 61 college and high school students and 30 welding teachers as well as representatives from industry and government agencies. Participants were divided into two groups: a WLOD group that used the WLOD system and the non-WLOD group that did not use the WLOD system (Song, 1996).

Improved Attitude

Pre and posttests were designed to measure the students' change of attitude before and after using the WLOD. Variables included students' attitude toward welding, computer simulation, computer programming, mathematics, physics, chemistry, science, engineering, and advanced technology. A score of 5 was assigned to "Strongly Agree," 4 for "Agree," 3 for "No Opinion," 2 for "Disagree," and 1 for "Strongly Disagree."

For the 61 participants of the field test, the mean score difference between pre and posttests for the WLOD group was 0.5525, or a change of 14.73%, based on the pretest mean score. The mean score difference between the pre and the posttests of the non-WLOD group was -0.0125, or a change of -0.334%, based on the pretest mean score. The difference between changes of attitude scores of the two groups was 0.5650. The t test showed that a 95% confidence interval of this difference was (0.0305, 0.8250) at a significance level of $p < 0.0001$.

Similar pre and posttests were designed to measure the teachers' attitudes toward effectiveness of computer simulation in teaching, welding, science, and advanced technology. The mean score from the pretest was 3.420 and the mean score from the posttest was 3.807. An increase of 11.3% was shown based on the pretest mean score. The t test showed that the difference between the means of the pretest and the posttest was within a 95% confidence interval of (.235, .538) at a significance level of $p < 0.00001$.

Increased Test Scores

Questions were designed to measure the students' knowledge of all the 10 welding processes that the WLOD simulates and related math and scientific fundamentals. A score of 1 was assigned to each correct answer.

For all 61 participants of the field test, the mean score difference between pre and posttests for the WLOD group was 20.40, or a change of 102.0%, based on the pretest mean score. The mean score difference between the pre and the posttests of the non-WLOD group was 5.20, or a change of 26.0%, based on the pretest mean score. The difference between the changes in the knowledge scores of the two groups was 15.20. The t test showed that the 95% confidence interval of this difference was (10.10, 20.20) at a significance level of $p < 0.0002$.

Reduced Lab Time Needed to Complete a Satisfactory Weld

For both the WLOD group and non-WLOD group, the time, in minutes, needed to complete a satisfactory weld was recorded. Since each participant in each group completed two welds, scores were combined and the average time needed to complete one weld was used in analysis.

For the 61 participants in the field test, the mean time for the WLOD group was 37.3 minutes per weld, while the mean time for the non-WLOD group was 52.9 minutes. By using the WLOD, weld time was reduced by 29.48%, based on the mean time needed for the non-WLOD group. The difference between the mean time needed by the two groups was 15.6 minutes per weld. The t test showed that this difference was contained in a 95% confidence interval of (9.30, 21.90) at a significance level of $p < 0.00001$.

Lab Updating Cost and Salvage Value

As compared with actual equipment upgrading and lab personnel retraining, the updating of the WLOD is much less costly because the software system can be easily updated electronically. When physical depreciation of the computers is ignored, the WLOD has a full salvage value, since the cost for a new CD-ROM is nominal when compared with the cost of updating actual equipment needed for 10 different welding processes. Moreover, the actual welding equipment usually has much less salvage value at upgrading, as compared with the initial expenditure. This low cost advantage of the WLOD is especially significant because today's accelerated technological changes in welding processes and equipment require more frequent, responsive, and efficient updating of teachers' and students' welding knowledge.

WLOD IN EDUCATION

Virtual Technology Laboratory

The cost of using sophisticated scientific modeling in engineering research is usually significantly less than experiential procedures (Song, 1995b). The same can be said of technology studies. In general, many technology lab procedures can be costly and hazardous, and some technology principles can simply not be demonstrated in the lab at all. When an environmental issue is involved such as when some lab materials and processes are contaminative to the environment, simulation and VR can reduce or eliminate the use of such materials or processes with a direct positive impact on environmental problems. Simulation and VR can also be used in regulating students during ergonomic procedures to enhance safety. One logical extension of the WLOD research is to enlarge the knowledge domain leading to more virtual technology laboratories.

A recent study based on a statistical analysis of 10,212 observations of student evaluations of technology teaching accumulated from 1986 to 1992 has shown that class size is inversely proportional to the student rating of teaching quality (Song & Li, 1993). Virtual technology laboratories can be highly flexible to any individual student since they reduce class size to a minimum with a one-to-one relationship between student and teacher (i.e., the computer). The added adaptive testing system can automatically diagnose the student's progress and set the adapted level of intellectual challenge and speed of learning. This idea can be further extended to the concept of a flexible education system.

Flexible Education System

Modern flexible manufacturing systems began in the early 1970s to meet the competitive challenge of the world economy for frequent updating of products and high production rates. Such systems maintain both mass production productivity and blacksmith workshop flexibility, two fundamental necessities for adapting to the rapidly changing marketplace. Today's technology educators are confronted with similar challenges of those faced by manufacturing industries in the early 1970s. Because careers are changing faster and with a higher degree of unpredictability than ever before, technology curriculums must be designed with maximum flexibility to adapt to the changing world, its post-industrial economy, and its labor markets.

While the necessity for a modern flexible education system is evident, the feasibility of designing and implementing such a system lies in the conceptual structure of a flexible education system, which is analogous to the modern flexible manufacturing system in the combination of educational group technology (Song & Li, 1994) and computer simulation and VR. The initial cost for developing and implementing the computer-integrated education systems can be reduced through the concept of recursive education.

Recursive Education System

Certain natural laws have been seen to apply recursively at different scales and in different disciplines. In computer programming, a function defined partially by calling itself a function is called recursive programming. Similarly, in recursive education, students are involved not only as users but also as definers or developers of subsets of software packages similar to the WLOD. The feasibility of combining students' roles as both users and developers has been studied (Song & Stoia, 1993). This combination of the user and developer roles has potential not only to foster positive attitudes of students as users from a sociopsychological point of view, but also enhances the information reproduction rate in modern technology education from the educational economy perspectives.

History tells us that scientific fantasy leads to engineering and technological reality. Aristotle, quoting Plato, asserted that philosophy begins with awe. "We may generalize further and say that all true learning begins with wonder" (Schindler, 1991). Schindler pointed out that the first task of a "teacher is to romance the students: to excite their curiosity and awe." But how? "...in any way that is legal," Schindler continued. Computer simulation and VR are definitely two of the ways that are both legal and exciting.

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Dr. Song is an Associate Professor in the Department of Technology at Northern Illinois University, DeKalb. He is a member-at-large of Epsilon Pi Tau.

4. Universal Performance Behaviors: What Ought to Be in the Technologist's Toolkit

by John W. Sinn

This is the second in a series of three IDEAS articles on development and application of a conceptual model. The first article, identified in the author's note, described the model and the underlying rationale that guided its development. The current article, the second in the series, articulates and identifies behaviors that ought to be part of the array of competencies, or behaviors, of all technologists, regardless of their specific professional assignment.

If the profession accepts the notion that there is, indeed, a common set of behaviors, then it follows that the core skills and knowledge that are appropriate to preparing technologists and the instructional and learning arrangements that will ensure that these happen ought to be considered by the profession. The third article, which will be published in this journal's Winter/Spring 1998 issue, will provide content recommendations and learning instruction strategies for education and training programs based on the considerations of the common behaviors. **JS**

Although this article can stand alone, it should be read in conjunction with a companion piece, "Building a Model for Technology Studies," which appeared in the Journal's Volume 22, Number 2, Summer/Fall 1996 issue. The model discussed in that article has undergone revision based upon reader, client, and user feedback. Changes based on these inputs are reflected here. The model was originally conceived to guide the work of the Center for Quality, Measurement, and Automation (CQMA) in the College of Technology at Bowling Green State University (BGSU). CQMA experiences with a number of technology transfer projects for business and industrial clients have contributed much to the refinement of the model. Also, participation in the development of an Applied Quality Science bachelor's degree program further tested, refined, and demonstrated the efficacy of the model as did more recent experiences with a research project conducted for the American Society for Quality Control (ASQC) to define core knowledge for technologists. Details and reports of these experiences may be obtained from the author.

This article is about first considerations that lead to suggestions for instruction and learning in traditional and nontraditional circumstances. It enumerates and describes behaviors that are universal or common to all technologist functions. Based upon these behaviors, the technologist's toolkit of core content and skills is derived.

Universal Technologist Behaviors

Several behaviors can be identified as common or universal to technologist performance regardless of an individual's specific industrial responsibilities or technology focus.

Technologists are team builders, problem solvers, and technical manag-