A VIRTUAL LABORATORY FOR MACHINE-TOOL OPERATIONS AND MAINTENANCE ENGINEERING TECHNOLOGY

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Abstract

This paper describes the results of the development and field tests of a *Virtual Laboratory for Machine Tool Operations and Maintenance Technicians* funded by the National Science Foundation under NSF Award Number 0071014. Internet-based and database-supported interactive multimedia simulations were developed in a multidimensional approach to multimedia applications, which combines the development of procedural, technical, scientific, social-economic, skills with critical and creative thinking. Descriptive and inferential statistics from large scale field tests using pre- and post tests with control and test groups indicated significant cost and pedagogical advantages of the developed virtual laboratory.

Development of the Virtual Laboratory

Machine Tools Operation

The project developed interactive, multimedia, and Internet-based curriculum modules, covering basic concepts and procedures for machine tools operations, machine tools hydraulics, and machine tools electrical, contributing to a Virtual Laboratory for Machine Tools Operation and Maintenance Technicians, currently accessible at

http://www.ceet.niu.edu/faculty/song/vlmt/hydraulics/HYmanu.html
http://www.ceet.niu.edu/faculty/song/vlmt/operation/HYmanu.html
http://demos.multitrex.edu/

Interactive, multimedia, and programming intensive Internet movies and software sub-modules were developed for the machine tools operations module. The movies were incorporated under a comprehensive menu system, which is an interactive, multimedia Internet movie itself. The movie sequence was developed to include safety procedures for machine tools operation, hand tools operation procedures, accumulator operation and malignance principals, orthogonal cutting force simulation, and geometric and dimensional tolerance, featuring dramatized dialogues among anthropomorphic machine parts and tools explain the operation and maintenance procedures in the interactive Internet movies.

The Geometric Dimensioning and Tolerance (GDT) sub-module was based on ASME Y14.5M -1994 with a bilingual audio format with English and Spanish translations, and the basic milling machine module included installing mill cutters, mounting a mill vise, mounting the work piece, cutting a flat surface, squaring a block, using an edge finder, setting mill speeds, drilling and reaming, and boring operations.

Additional interactive Internet movies assisted the calculation of mill, drill, and reamer speeds to guide students in the use of standard tables and explain the calculations performed to determine proper tool speeds. Practice exercises and feedback were incorporated as skill checks. Each digital video or Internet movie illustrates a specifically targeted standard practice in machine tools operation.

Machine Tools Hydraulics

The machine hydraulics module was developed as an interactive simulation of the machine tool hydraulic components and systems that included fundamental mathematics and sciences applications in machine tools hydraulic systems, trouble shooting procedures by examples, dramatized interviews and teamwork of machine tools operator and maintenance technicians, simulated interactive trouble shooting, interactive repair actions, and the evaluations of time and cost effectiveness.

Throughout the hydraulic module, realistic machine tools hydraulic system images were juxtaposed with schematic illustrations of the system being studied, illuminating the scientific nature of the processes, epitomizing the ideal of using virtual reality to supplement and enhance the traditional educational laboratory reality. Interwoven with the revealing technical and procedural knowledge was the socioeconomic and psychological impetus to interactive learning, practice, and discovery.

The development activities instigated creative thinking among the project teams in seeking more efficient ways of interactively simulating technical procedures via the Internet. One of the more important concepts emanating from this project, was a multidimensional approach to multimedia application, which combined the development of procedural, technical, scientific, social-economic, with creative and critical thinking.

First, functional and procedural machine tools hydraulic systems were simulated under normal and malfunction conditions. These simulations aimed to foster students' comprehension and appreciation of those systems, as well as a strong sense of responsibility for human and process safety, by demonstrating the disastrous consequences of poor maintenance or operations performed. Figure 1 shows a simulation interface of the machine tool hydraulics module.

Second, humorous cartoon movies showed the concepts of fundamental engineering science and their relevance to machine tools hydraulic system problem solving, bridging theory with practice. Figure 2 shows an interface of such a process.

Third, the maintenance troubleshooting emphasized simulated teamwork and communications between the maintenance technicians and the machine tool operators, and the simulated measuring of system parameters. Figure 3 shows a troubleshooting interface of the machine tool hydraulics module.

Fourth, labor costs of the simulated trouble shooting and costs of component replacement or repair were monitored in real-time by the system during the interactive repair actions, with real-time feedback scores tracking the students' performance in terms of time effectiveness.

Machine Tools Electrical

This comprehensive web-based module helped learners visualize the connection between schematic diagrams and real circuits and components, designed to give a basic understanding of analog machine controls. It incorporated explanations, demonstrations, review and practice experiences, a glossary, and simulations of normal & faulty circuits. Sections on theory, magnetic devices, and ladder diagrams prepare users to explore common circuit configurations. Learners who use this site will be able to visualize and understand how typical circuits function, and find faults in circuits by testing continuity and measuring voltage. Navigation was designed to allow users to find specific topics quickly, or go step-by-step through the material. In addition, a 'resource map' listed all activities, explanations, and demonstrations by topic.

The topics included electrical theory, current, voltage, resistance, power, conductor, insulator, circuit path, definitions of DC and AC, series and parallel circuits, magnetic devices, electromagnetism, relays, solenoids, transformers, ladder diagrams, JIC symbols, diagram construction, building logic with relays, circuit examples, functional explanation, detailed explanation of components, and power-off & power-on troubleshooting. In addition to

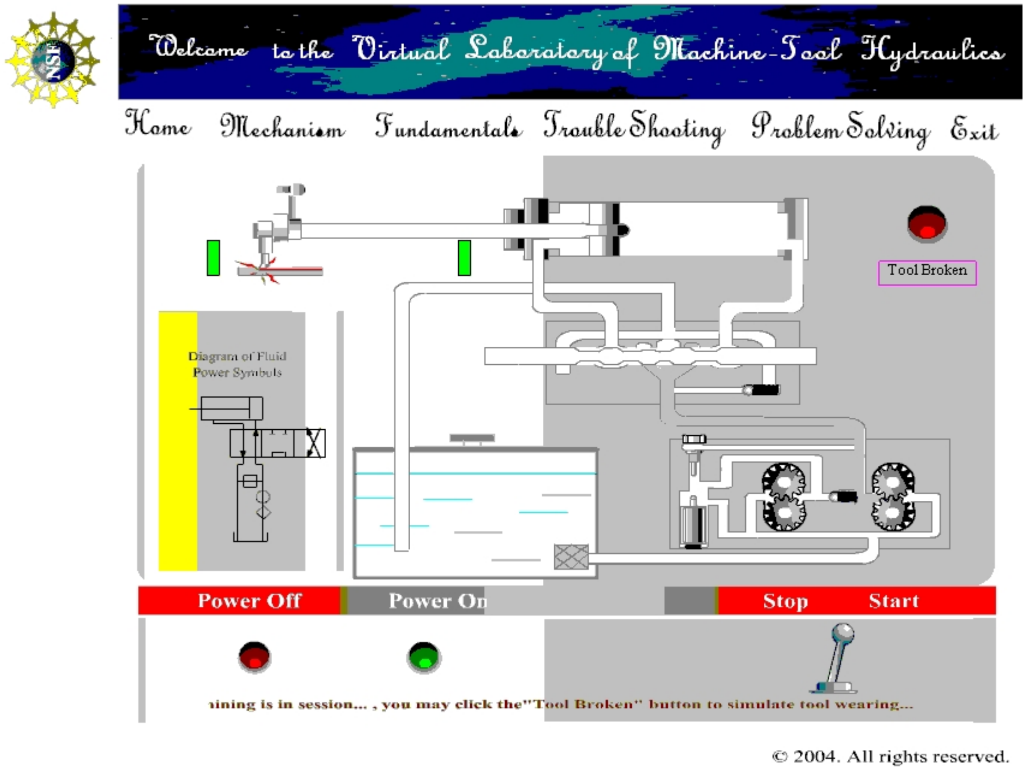

Figure1.

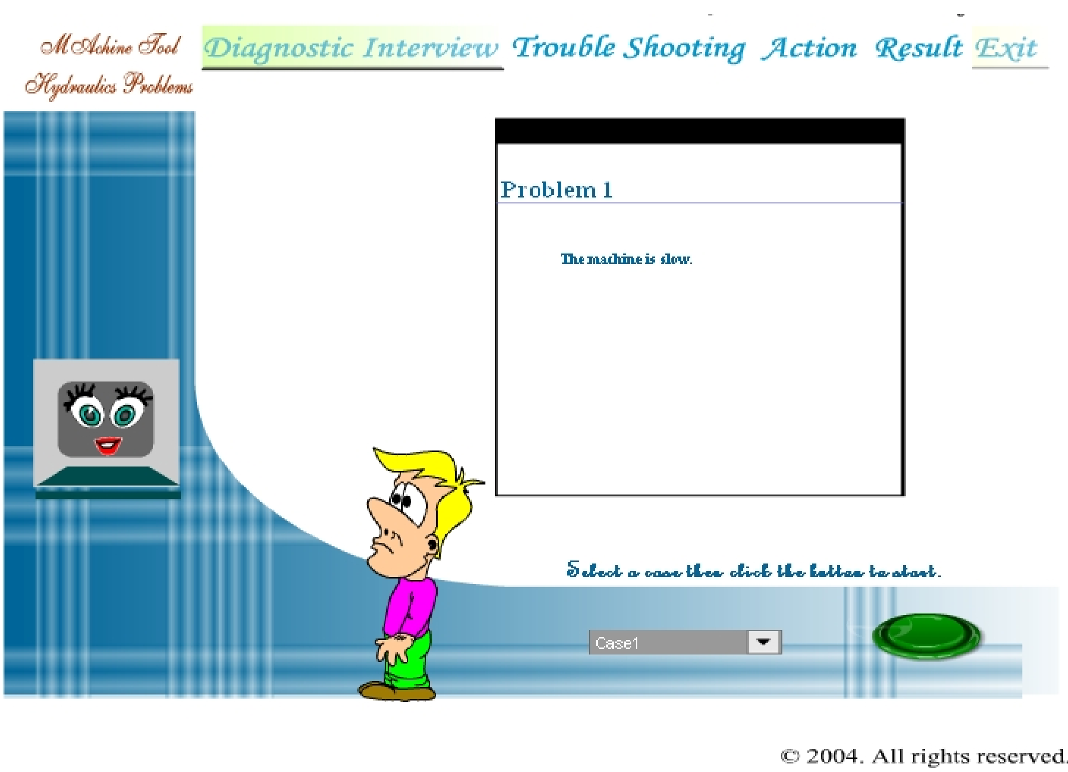

Figure 2.

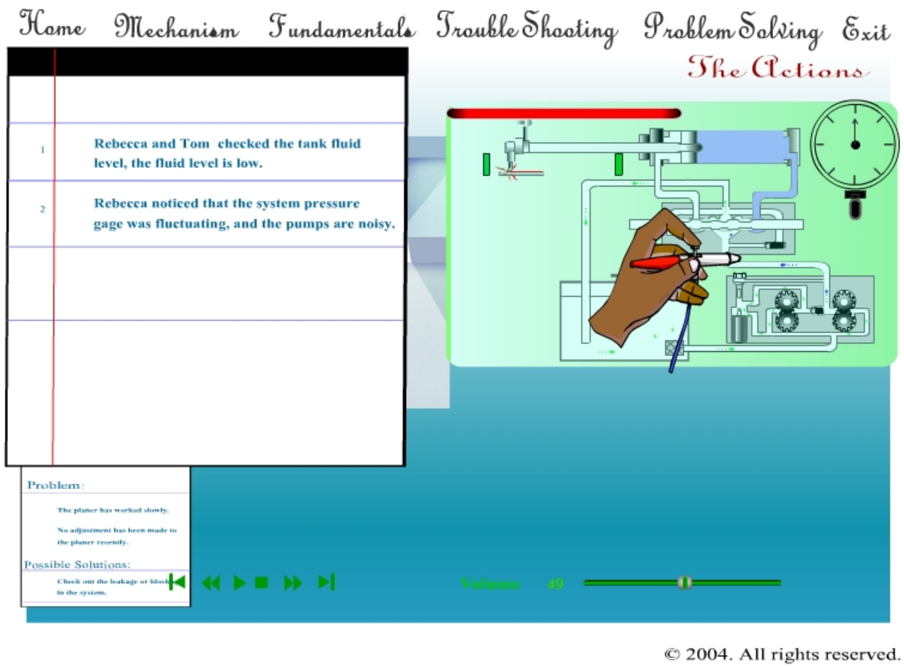

Figure 3.

the demos online, a complete version of the machine tools electrical module is also available on CD-ROM.

This module allows the learner to explore a common control circuit, its operation and components, and to troubleshoot malfunctions using an ohmmeter or voltmeter. Photographs and video enhance the fidelity of the experience, while animated explanations provide insight into processes that happen over time. Users view animations depicting relay operation, AC and DC current flow, conduction vs. insulation, circuit components, ladder diagram construction, current generation and rectification, and other principles. They may replay animations as needed and freely branch to areas of interest. Photographs of actual components are used to tie theory to actual devices and circuits.

Careful attention to usability and functionality has produced a site with lively content and straightforward navigation, which does not place extreme demands on computing resources. Learners may open several Flash windows at once in order to view a circuit's functional explanation while working a troubleshooting problem, for example. In addition, each window may be sized to conserve screen space, yet allow magnification of important details.

Field Tests

Field Tests concurrently with the development, alpha releases of the modules were conducted by selected students and reviewed by experts from both industry and faculty. Feedback from these ongoing field tests and reviews were built into the modules. Modules of Virtual Laboratory have been incorporated into manufacturing classes at Northern Illinois University.

Large scale confirmative field tests were conducted for the beta release of sample modules of the Virtual Laboratory. Student participants were divided randomly into two equally sized groups. Group 1 used the modules during the field tests, but Group 2 did not while both groups were given the same amount of instruction in the same classroom by the same instructors during the same time periods. Both groups were pre- and post-tested. A total of 63 students participated in the formal, confirmative field tests. A stratified randomization process was used to assign students into two groups with equal gender and ethnic representation.

Pedagogical Effectiveness

Statistically significant differences in content knowledge or skills were found for Geometrical Dimensioning and Tolerances where students who used Virtual Laboratory scored significantly higher on the content test than did the students who received traditional instruction with $F = 4.517$ and $p < .049$. For Mill Cutter Exercise, students who used the Virtual Laboratory scored significantly higher than those receiving traditional instruction with $F = 7.211$ and $p < .016$. For Trouble Shooting for Mechanical and Fluid Technicians, students who used the Virtual Laboratory scored significantly higher on the content test than did the students who received traditional instruction with $F = 12.806$ and $p < .003$. For Machine Tooling for Electrical Assembly, those who used the Virtual Laboratory scored significantly higher on the content test than those who received traditional instruction with $F = 16.149$ and $p < .001$.

Time Effectiveness

Learning modules were also sampled from the Virtual Laboratory for the testing of learning efficiency or the time effectiveness of the Virtual Laboratory, where the time effectiveness was measured in the number of minutes used for completing pre-designed exercises.

Students who completed the Virtual Laboratory module on Trouble Shooting for Mechanical and Fluid Technicians showed significantly greater time effectiveness than students completing the traditional instruction with $F = 3.576$ and $p < .077$. Those who completed the Virtual Laboratory module on Machine Tooling for Electrical Assembly showed significantly greater time effectiveness than students completing the traditional instruction with $F = 4.047$ and $p < .061$.

Statistically significant differences in the amounts of time needed to complete an exercise for the Edge finder exercise were also found where those completing the Virtual Laboratory needed significantly less time than those receiving traditional instruction with $F = 3.633$ and $p < .075$.

Ongoing Dissemination Efforts

Faculty Workshops for curriculum integration and customization were the focus of two faculty workshops conducted in 2004. Thirty one two-year community college and high school teachers were recruited from Illinois, Wisconsin, and Ohio participated in the workshops. In the first one-day workshop, the participants learned, tested, and evaluated the virtual laboratory modules and their suggestions were incorporated into the final versions.

The second one-day workshop went beyond mere use of the virtual laboratory, participants learned from previous faculty workshop participants demonstrating the applications developed by the faculty members themselves in their own areas of teaching, one in chemistry, and another in electrical circuit analysis. The current participants then brain stormed ideas on using the virtual laboratory approach in other areas of advanced technological education other than, but similar to the virtual laboratory. Participants were then introduced to basic multimedia programming and production techniques needed to create modules similar to the project's modules. These learning activities were conducted in an approach in which faculty members were treated not only as users or consumers but also as developers or producers, aimed to foster positive attitudes toward curricular innovations and computer applications, and to enhance the information reproduction and dissemination rate in advanced technological education.

Each faculty workshop participant completed a mini project by the end of the workshop. All participants made positive comments concerning the pedagogical approach, interdisciplinary nature of the modules, and the approach used to develop creative and critical thinking skills. After extensive review by national experts in the field, the complete virtual laboratory software system has been accepted by the National Center for Manufacturing Education Clearing House for national dissemination as of September 14th, 2004.

Acknowledgment

This paper is based on the project titled the Development and Field Test of a Virtual Laboratory for Machine Tool Building and Maintenance Technicians in the U. S. funded by the National Science Foundation under NSF Award Number 0071014. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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Biographical Information

Xueshu Song, Ph.D., is a licensed professional engineer in the State of Illinois, and a Professor of Engineering Technology at Northern Illinois University (NIU). He has been the lead writer and principal investigator or co-principal investigator for seven projects funded by the National Science Foundation (NSF) in the past 10 years, each of which developed, tested, and disseminated new educational software applications. He also served as the Interim Director of Technology Commercialization Office at NIU, and is the principal investigator of the virtual laboratory for machine tool engineering technology project.

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Penny Billman, Ph.D., is a senior research associate at NIU, and a former faculty member at Purdue University and Ancilla College. She received her Doctor of Philosophy in Educational Psychology from Purdue University. She served as a research specialist for measurement and statistical analyses for the virtual laboratory for machine tool engineering technology project.

Ping Wang is a former research engineer in geomechanics, a freelance computer programmer, and a senior multimedia specialist and software system developer at NIU's eLearning Services. She earned her Master of Science in Operations Management and Information Systems, Master of Accounting Science, and the title of Public Certified Accountant in 2000. She is the software architect and system developer of the virtual laboratory for machine tool engineering technology project.