Virtual Laboratory for Machine Tool Technicians – Concept, Development and Examples

Xueshu Song[1], Radha Balamuralikrishna[1] & Philip Pilcher[2]
Northern Illinois University/Rockford Abilities Center

Overview

This paper is an outcome of an NSF sponsored project designed to pave the way for an Internet based learning tool for training machine tool operators and technicians (Song *et. al*., 2000). The objective in using this novel approach is to accelerate and improve the process of learning and development of skills in machine tool technology. We present concepts using an integrated multi-media approach that reflects present day technological and socio-cultural aspects. The three learning modules developed thus far address diverse topics such as machine tool circuits, geometric dimensioning and tolerancing (GDT), and hydraulics, all geared towards the development of established competencies of the trade. The overall intent of this project was to create an application that would serve as a complete self-learning tool that not only delivers subject matter content but also helps the learner engage in trouble-shooting exercises, examine and manipulate the application to analyze several what-if scenarios, and perform self-testing in order to gage individual success in learning.

This paper will focus on the three major tasks undertaken to complete the project:

1. Processes employed to identify the topics and subject matter content
2. The pedagogical insight and technical agents used to develop the package
3. Field testing and results

Significance of the Project

The customary approach used to train technicians is expensive and has some inherent disadvantages in terms of safety and other health hazards. Although, the use of integrated multi-media tools is not a complete substitute for hands-on learning, preliminary results demonstrate that discreet use and promotion of evolving pedagogical concepts such as just-in-time, contextual, and transactional learning can make training technicians much more efficient, effective and complete (Raschke, 1999). Also, the idea of using the Internet as a media specifically in the field of training machine tool technicians is novel and untested. By placing high quality, multiple intelligences approach based learning materials on the Internet, we are providing enhanced opportunities for individuals to improve their skills regardless of time and geographical boundaries (Gardner, 1993).

Description of the Modules
Multidimensional approaches were employed in developing the learning system. These simulations aim to foster students' comprehension and appreciation of those systems, as well as a strong sense of responsibility for human and process safety which was achieved by demonstrating the disastrous consequences of poor maintenance or operations performed. Second, humorous cartoon movies show the concepts of fundamental engineering science and their relevance to machine tools hydraulic system problem solving, bridging theory with practice. Third, we emphasize and utilize potential opportunities to promote simulated teamwork and communications between the maintenance technicians and the machine tool operators, and the simulated measuring of system parameters. Spanish translations in audio format are available for selected parts of the modules.

Throughout the development of individual instruction segments, images are juxtaposed with schematic illustrations of the system being studied. This illuminates 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 is the socioeconomic and psychological impetus to interactive learning, practice, and discovery. Throughout the system, we have embedded new and more efficient ways of interactively simulating technical procedures via the Internet. One key aspect of the philosophy embedded in the concept and development of this project is our desire to incorporate a multidimensional approach to multimedia application (Gardner, 1993). This approach fosters training the individual for the development of procedural, technical, scientific, social-economic, and intellectual skills - all within the completed software system.

The technology employed to create the media and the pedagogical approach remains consistent across the three modules. Careful attention to usability and functionality has resulted in electronic lessons with lively content and straightforward navigation, which does not place extreme demands on computing resources. For example, learners may open several Flash windows at once in order to view a circuit's functional explanation while working a troubleshooting problem. In addition, each window may be sized to conserve screen space, yet allow magnification of important details. Navigation is designed to allow users to find specific topics quickly, or go step-by-step through the material. In addition, a 'resource map' lists all activities, explanations, and demonstrations by topic. This will make it easy for an instructor to locate animations or other visual aids for classroom use. A high level of interactivity promotes learner engagement, while use of the Flash format ensures short download times. Individual highlights of the modules developed accompanied by an example of an actual screen captured image are provided in the next few sections.

Machine Tool Circuits
This section helps learners visualize the connection between schematic diagrams and real circuits and components and provides a basic understanding of analog machine controls. It is self-guided but will function best as a supplement to an instructor-guided course. The site incorporates 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 the connection between schematic diagrams and real circuits and components.
- Explain how typical circuits function.
- Determine faults in circuits by testing continuity and measuring voltage.

The topics include but are not limited to basic electrical theory such as series and parallel circuits, direct and alternating current, electromagnetics, ladder diagrams, relays and circuit analysis. Power-Off & Power-On troubleshooting is emphasized. At this time, a demo site may be seen at http://demos.multitrex.edu. Interested readers may contact the lead author for a full version on CD-ROM. The basic presentation format uses HTML pages to navigate between Flash pop-up windows that contain explanations and exercises. Users view animations depicting relay operation, AC & 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.

Practice exercises allow students to polish troubleshooting skills without having access to expensive machinery and test instruments. This module reinforces the connection between a symbol-based representation of a circuit (ladder diagram) and the physical world by using photographs of actual components arranged as they might be in a control cabinet. As users test points in the 'cabinet', those points light up on the ladder diagram, helping students to make the connection between a drawing and the actual objects. Photographs and video enhance the fidelity of the experience, while animated explanations provide insight into processes that happen over time. Labor costs of the simulated trouble shooting and costs of component replacement or repair are 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- and cost-effectiveness.

Geometric dimensioning and Tolerancing (GDT) Module

This part of the project has culminated in an online reference that contains useful features for anyone who must apply or interpret geometric tolerances based on ASME Y14.5M -1994. GDT has continued to positively impact product development practices in industry and there is an established need for a deeper understanding of this subject matter in modern manufacturing (Krulikowski, 1991, Balamuralikrishna, Pilcher & Song, 2002).

Clear interpretation of geometric tolerances is a critical step of the product design and development process: design, production, and inspection and in training to attain proficiency as a machine tool technician. This module improves upon currently available print references by providing clear, concise explanations and drawings that use color and user interaction to help reinforce concepts. Large-format (8.5x11) pages may be printed from the site in a portable document format (pdf), allowing users to bring high-resolution media to their work area. Color photographs show the relationship between prints and physical objects.

Features include:

- Click any GDT ANSI symbol for a short description of the tolerance.

- One-page PDF files include drawings and give more complete descriptions of the tolerance. These are suitable for printing and require Adobe
- Acrobat Reader.
- A pop-up glossary for common terms.
- Skill tests to check your understanding.

It is our understanding that this is a unique pedagogical tool addressing GDT that is available in the market today.

Hydraulics Module
First, functional and procedural machine tools hydraulic systems are simulated under normal and malfunction conditions. Discrete movies will be incorporated under a comprehensive menu system, which is currently being developed. The movie sequence will include 1) interactive simulation of the machine tool hydraulic systems, 2) fundamentals of applied science involved in the hydraulic systems, 3) trouble shooting procedural examples, 4) interviews between machine tool operator and machine tool maintenance technicians, 5) interactive trouble shooting, and 6) repair actions.

This module incorporates five underlying themes developed and recurred throughout the three modules to reveal the math, sciences, and engineering technology concepts in task performance through the virtual laboratory and to foster the ability for safe, efficient, and creative problem solving and professional task performance throughout the curriculums. Theme 1 is the recursive safety principle. Theme 2 is technical communication skills through blue print reading and records keeping. Theme 3 is critical and analytical thinking ability development via trouble shooting the machine tool systems. Theme 4 is the efficiency of problem solving, designed to inspire students to seek their own optimal learning efficiency. Theme 5 is the humanistic nature of machine tool building and maintenance technology symbolized by "teamwork" of the anthropomorphic parts of the machine tool systems and variables in fundamental formula in dramatized task performance guides online (Song, 1999). All modules will emphasize relationships among fundamental math, sciences, and engineering concepts and laws, and the general methods and attitudes (Robinson, 1998) that have engendered the inventions and growth of the machine tool industry.

Each of the sub-modules contains a complete set of multimedia simulations, task scenarios, multimedia task-performance drama clips, complete and detailed performance guidelines to the tasks in multi formats, similar tasks for student self-exercising, and three different formats of one set of questions to be used in the pre- and post-tests in both ongoing and confirmative field tests. Each task-performance capsule consists of a warm-up session that introduces the math, sciences and technology concepts and general task analysis and completion procedures, a work order session that presents the task scenario with detailed explanation by an instructor on video, a performance session that provides a simulation platform for students to perform the task, and an evaluation session that reveals the feedback of the system regarding the number and type of mistakes a student makes, a performance score, and a supplemental report on the student's learning style detected by the system during the performance session.

Multidimensional approaches have been employed in the system development. First, functional and procedural mechanisms of aircraft systems are simulated under normal and malfunction conditions, where the simulation of both normal and disastrous consequences aims to foster students' comprehension and appreciation of aircraft systems and a strong sense of responsibility for human safety. Second, humorous cartoon movies show the concepts of fundamental engineering science and their relevance to aircraft maintenance problem solving, bridging theory with practice. Third, the maintenance trouble shooting features simulated teamwork and communications between pilots and maintenance technicians and the simulated measuring of system parameters. Fourth, time of labor and costs of the simulated trouble shooting and components replacement or repairs are monitored in real-time by the system during the interactive repair actions, with real-time feedback scores evaluating the students' performance. Figure 1 shows an example of the graphic interface of the hydraulic module.

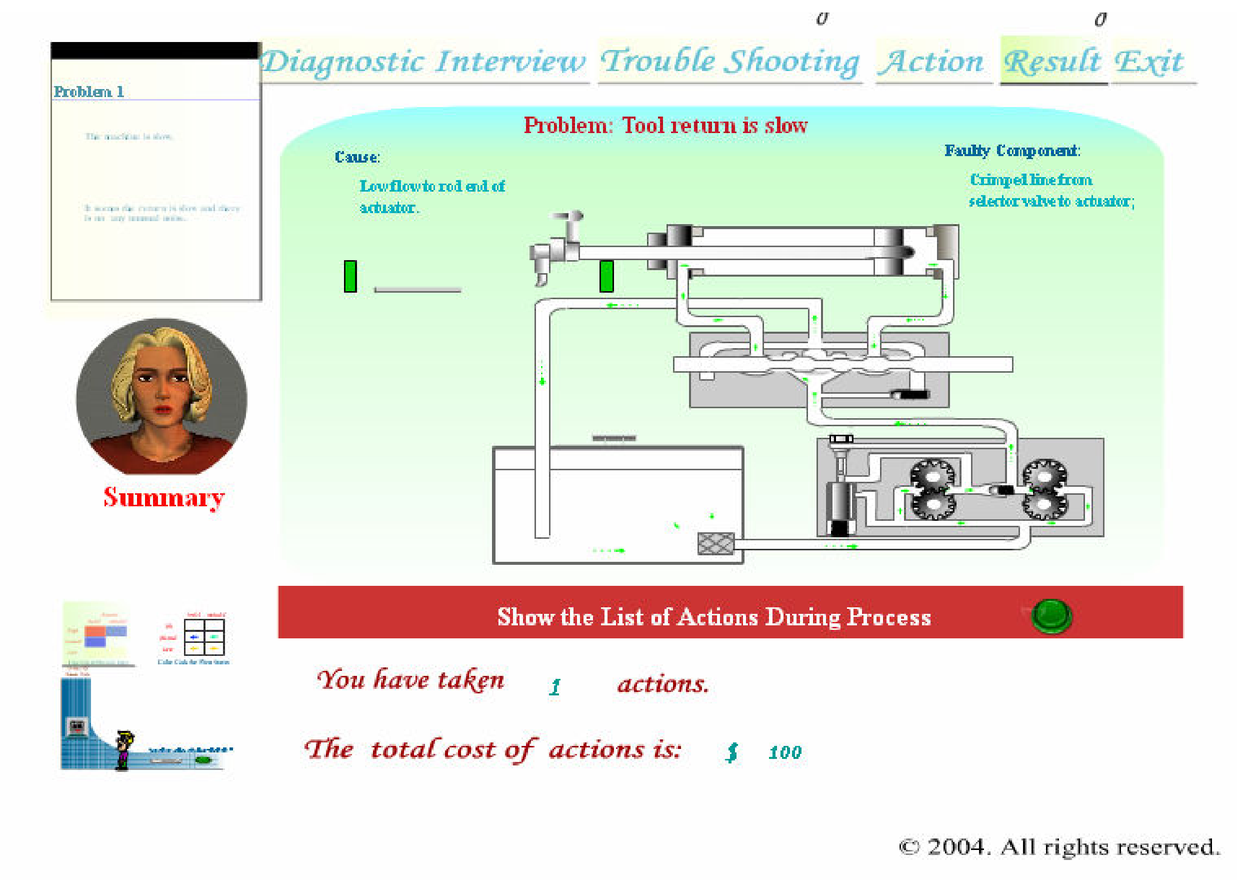

Figure 1 – Problem Solving Summary and Evaluation

The Promise of the New Learning Tool

Other advantages of this online approach include ease of distribution. Installation on a company Intranet means that everyone involved in a project is working from the same reference and timely updates and notes. Companies or institutions may modify the site with project-specific links and notes. With minor adaptations, a subset of the lessons may be used to promote engineering and engineering technology education in the K-12 arena, a premise that is cheerfully being promoted by the ASEE in recent times (Jakubowski, 2002).

One benefit of this method of organization is that it allows instructors using this module to select which Flash movies they wish to use, and even to link the Flash .swf files to a slide in a PowerPoint presentation authored by the instructor. The site will eventually contain links that allow instructors to download any of the media assets in the module. Alternatively, the site could easily be distributed on CD-ROM to those with prohibitively slow Internet access.

The functioning portions of this module allow the learner to explore a common control circuit, its operation and components, and to troubleshoot malfunctions using an ohmmeter or voltmeter. Video segments produced for the Basic Milling Machines module give students on-demand access to precisely defined learning objects covering specific milling machine operations. These short segments may be reviewed quickly immediately before beginning an operation or during a multi-step production process. This liberates the instructor from reciting basic information to multiple students in a lab, and allows longer higher-level interactions between student and instructor. Because the video segments give clear illustrations and explanations of basic operations, the instructor has more time to guide students in problem-solving other higher-level skills.

Concluding Remarks

We are pleased with the initial results and the interest attracted by the new product described in this paper. We also plan to develop more lesson modules that incorporate other aspects of machine tool technology. This also means that we have to explore new ways to finance such plans. Finally, we hope to garner support to implement an ongoing process of continuous improvement in order to address the continuing needs of learners and promote further nationwide dissemination of our product. Field-testing of the modules is currently underway and we are currently accepting inquiries from instructors interested in using our modules in their classroom. Faculty workshops were conducted in Fall 2003 and student field tests will be completed before March 31, 2004. Interested administrators, faculty members and course instructors are encouraged to contact the lead author.

In an era of global competition, a better-educated and trained workforce will separate the winners from the losers. The economic future of America depends to a great extent on its ability to widely practice a philosophy of "no adult left behind" in addition to the "no child left behind" policy that has become a matter of national policy. The manufacturing industry sector has always been a pride for this nation and nurturing, maintaining, and promoting this sector of the economy is of vital national interest. We must continue to be innovative in creating new approaches for the training and continuing education of the manufacturing workforce; particularly those who would like to embrace the profession of machine tool technician or technologist. It is important that new initiatives undergo rigorous assessment procedures so that results can be measured.

Acknowledgment:

This material is based upon work supported by the National Science Foundation under Grant No. DUE 0071014 with lead principal investigator Xueshu Song. The software system described has been developed and copyrighted by Northern Illinois University with all rights reserved.

References

Balamuralikrishna. R., Philcher, P. & Song, X. (2002). "*The development of an on-line geometric dimensioning and tolerancing sourcebook and its implications for training the machinists for the 21st century*", Presentation at the Annual Convention of the National Association of Industrial Technology, Panama City, FL.

Gardner, H. (1993). *Frames of mind: The theory of multiple intelligences*. Basic Books: New York, NY.

Jakubowski, G. (2002). Is there a role for ASEE in K-12 education? *ASEE Prism*, 11(5): 41.

Krulikowski. A. (1991). *Fundamentals of geometric dimensioning and tolerancing*. Delmar Publishers: Albany, NY.

Raschke, C. (1999). The age of transaction and the scene of digital learning. *Syllabus*, 13(4), 15-17.

Robinson, J. T. (1998). Reflections on "science teaching and the nature of science". *Science Education,* 7(6), 635-42.

Song, X (1999). Abstractions and personifications in multimedia tutorial for the FE exam: Examples and implications. *Computers in Education Journal*, 9(3), 49-58.

Song, X., Pilcher, P., Billman, C, & Balamuralikrishna, R. (2000). *The development and testing of a virtual laboratory for machine tools building and maintenance technicians*. Proposal No. 0071014 to the National Science Foundation, Alexandria, VA.

Biographical Information

DR. XUESHU SONG is a licensed professional engineer in the State of Illinois, a principal investigator and project director of several National Science Foundation funded projects, and a full professor of technology at Northern Illinois University. He earned his Ph.D. from Penn State University. Dr. Song has published widely in technology and engineering education as well as conducted research in mechanical and manufacturing engineering and has taught over a dozen courses in computer programming, welding, and fundamental engineering. Dr. Song has widely published the results of his research in both national and international conferences.

DR. RADHA BALAMURALIKRISHNA joined the Department of Technology at Northern Illinois University in August 1997. His undergraduate degree is in Naval Architecture and Shipbuilding from Cochin University, India. Dr. "Bala" has worked in a shipyard for three years and has taught engineering design graphics and CAD at the University level for nearly 10 years. He received his M.S. Eng. from Florida Atlantic University and Ph.D. from Iowa State University. He is a licensed professional engineer in the State of Illinois.

MR. PHILIP PILCHER is the Director for Research and Development at the Abilities Center in Rockford, Illinois. His area of expertise is aviation and machine tool technology. Phil has worked on several NSF funded projects as a Co-Principal Investigator /Consultant.