Being Efficient in Lab:
Multi-media Tutorials for Laboratory Projects

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Introduction

One of the most time consuming teaching tasks is running a mainstream laboratory with a limited number of hardware setups. These setups can be complex and require considerable effort from both faculty and students to master. With limited setups, students attempt laboratory modules long after receiving training on the equipment. As a result, they are sometimes unable to complete the lab, even with detailed instructions, and faculty members spend extra time in re-explaining the laboratory to frustrated students. A different type of problem can occur when the setup is so complex that the real learning is replaced by a rote following of step-by-step instructions.

One example of the above type of problems that we face here at CSM is with our Electronics Prototyping Facility.[1,2] Undergraduate students use this facility to construct printed circuit boards that they assemble to working systems for their electronics laboratories. Going from simulation to fabrication, students must use four (4) new software programs for schematic capture through PCB construction. Because there is only one hardware setup, students come in after lab hours to work on their designs. Often, they attempt their projects weeks or months after the initial demonstration. With the long sequence of steps and extended delay between instruction and implementation, it is no surprise that students often run into roadblocks, even with detailed instruction manuals available.

The approach we are trying here at the CSM is to use the recently available tools for authoring interactive computer-based, multi-media tutorials as an additional way to give our students the information and understanding they need, *when they need it*, to accomplish their laboratory projects. Although this development requires a substantial upfront investment, we are targeting situations where it promises to help both students and faculty make the best use of their time.

Computer Based Training – Effectiveness and Cost

While multi-media tools are not new, the recent availability of affordable and easy to use tools now makes it possible for a new set of developers to author their own multi-media presentation rather than relying on professional (expensive) production. Another feature is that many of these tools are world-wide-web (WWW) compatible and can translate their presentation to HTML for web browsing and wide dissemination.

There are a number of documented benefits in computer-based training (CBT). J. D. Fletcher[3] provides a thorough survey of the field. A summary of his findings for the benefits of computer-based training:
- Improves instructional effectiveness.
- Reduces time to reach instructional objectives by about 30%.
- Promotes equity in achievement.
- Appears to be equally effective for knowledge and performance outcomes.
- Can be used to teach "soft skills" involving social interactions (leadership techniques)
- Interactivity is important.
- Lowers instructional costs and appears to be cost-effective.

Fletcher also cautions that a summary of research results such as presented in his paper must necessarily slide over many issues of intent, design, implementation, and evaluation. He details several caveats to the above conclusions including that the evaluations of the benefits are often performed by the developers with a vested interest.

Fletcher's work[3] also presents a cost assessment for various traditional and CBT techniques. He normalizes the results to cost (1985 dollars) to raise comprehensive test scores one standard deviation. A shorted version of those results is shown in Table 1. The cost associated with computer-based training is relatively modest in comparison to most alternative traditional methods.

Teaching Method	Cost (1985 $) per Standard Deviation Gain
Traditional Teaching Methods	
Tutoring by peers	$286
Reduce Class Size from 35 to 20	$1195
Increase Instruction Time 30 min/day	$2667
Computer Based Methods	
CBT for 10 min/day for Grade 3	$192
CBT for 10 min/day for Grade 5	$206

Table 1. Cost effectiveness of various teaching methods presented by J. D. Fletcher.[3]

One main drawback is the large upfront cost of CBT. It is estimated 300-400 hours of developer hours is required for each hour of computer-based training.[4] Commercially, the cost for each CBT hour ranges from about $20k to $80k depending on the quality and

complexity level.[5] While academic developers are not under the same cost/quality constraints as a commercial developer, it is clear that CBT requires substantial upfront commitment that will be justified only in certain circumstances.

There are a large number of tools for authoring multi-media computer-based training presentations.[6,7] The choice of the best tool depends on the needs and use. In addressing laboratory tutorials, our target audience will have a computer available but may not have access to the web. Further, cost constraints and the need for an established user and third party community for support material were important to us. From these requirements we choose to use Authorware Academic® (Prentice Hall) as the initial cost was only $150 and it provided a full set of development tools.

Laboratory Training Modules -- Approach and Learning

The two target applications we have for CBT are for hands-on laboratory instruction. These applications differs significantly from typical knowledge-directed/class-based CBT in that they are focused on developing laboratory skills that the students put to immediate hands-on use.

To develop any CBT an application should meet certain key criteria to ensure that the effort is worth the cost in development (Table 2). As we gain proficiency in the tools and the ease of use for these tools improves, new areas of CBT development may be justified.

1.	The information needed is well established and relatively unchanging
2.	Other delivery methods are either inadequate (instruction manual) or expensive (faculty/TA instructional time)
3.	Working at different times or different locations is important
4.	Will impact a large number of users
5.	Adequate computers are available at the site(s)

Table 2. Some key criteria for developing computer-based training modules.

A general flow chart for our tutorials is shown on Figure 1. Tutorial modules are broken down into short (10 min or less) sessions, each with clear set of objectives, module information and several interactive exercises. At the end of each module, the student may then take the quiz. If the student's score does not reflect a good understanding of the material then he or she will have to revisit that module again. User identification, scores and other session information (such as time spent in each module, feedback, etc.) are stored in a file for use by the instructor. These files contains information that will be very useful for assessment and continuous improvement of the learning process. In addition to the tutorial modules, a key word reference link page as well as various background information are included.

CBT Project #1: A Tutorial for the CSM Electronics Prototyping Facility

As stated in the introduction, students use the CSM Electronics Prototyping Facility to construct working electronic systems by fabricating their own printed circuit boards. This entails using four new computer programs for schematic capture, PCB layout, PCB board preparation, and for controlling the mill/drill machine. In addition, students must then assemble (solder) and test their systems. Six hours of laboratory instruction gives the students a good grasp of the schematic capture and PCB layout as well as an demonstration of the next two programs and system assembly.
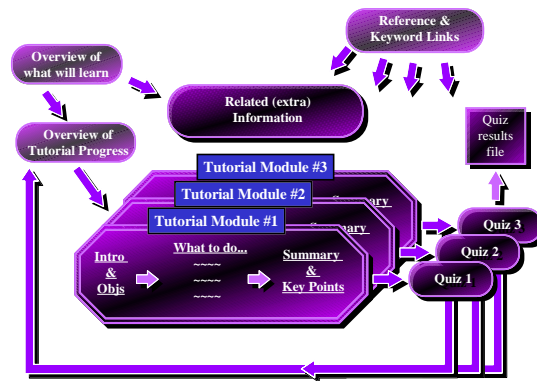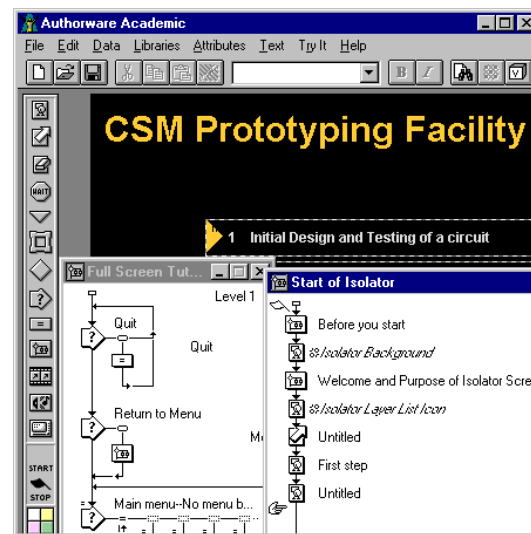

Figure 1. Shown is the general flow of the computer-based training modules for laboratory projects.

By the time students attempt to use this facility (weeks later) they have forgotten many of the details. While a detailed reference manual is available, it appears that students get out of synch with the manual steps and attempt actions that are wrong. This CBT module will typically be used in the prototyping facility, but will be on the WWW for downloads and outside access. Several dedicated computers are available in this facility to run the CAD/CAM programs for PCB design and production. Initial use of the tutorial modules show that students bring up both the CAD/CAM programs and the tutorial to "see" and understand what they should do at each step.

The objectives for our development of this laboratory CBT module are:

♦ Provide a tutorial module for each computer program, the mill/drill machine, and other assembly techniques
  - Step-by-step instructions
  - Visualization of what should see
  - Emphasize why and an overview picture
  - Require completion of quizzes to re-enforce knowledge
  - Use interactively to engage students and allow experimentation
  - Use prior to starting laboratory

Figure 2. Screen shot of the CBT designing process using Authorware®

♦ Develop a search engine and/or key word reference table
  - To use to find just the one piece of information needed (on-line help)
♦ Add extra information on industrial electronics fabrication methods for background knowledge.

CBT Project #2: Take Home Laboratory Module - Using a Student Data Acquisition System to Measure & Improve the Efficiency of your Refrigerator

Though curriculum reform we are developing a new, common laboratory sequence[8] for all our Division of Engineering students (about 250 per class). This new lab focuses on laboratory projects that are interdisciplinary and teach students basic hands-on skills. One experiment we are trying is to take the laboratory project out of the lab and to the student's location. They will use a "Student Data Acquisition System"[9,10] developed here at CSM to develop a system that takes data, makes real-time decisions, and controls output actuators. They then take data over an extended interval and use appropriate analysis to implement specific actions and make conclusions.

The specific laboratory project we are starting with is to instrument their refrigerator at the student's residence with temperature, power and open/shut indicators and determine the efficiency of operation over three days of use. With this data and analysis, they then work towards improving the efficiency of operation and document their progress. They then make an economic analysis to determine how well their unit is operating and the relative merits of purchasing a new unit.

There are many new aspects to this laboratory project, but the key issues is that it is done at the student's location without supervision. This leads us to believe that we must create a computer-based training module to give them the knowledge and skills they need to complete this lab *on their own*. This CBT module will need to cover two main areas: (1) the data acquisition system, sensors, etc., and (2) the laboratory steps and procedures.
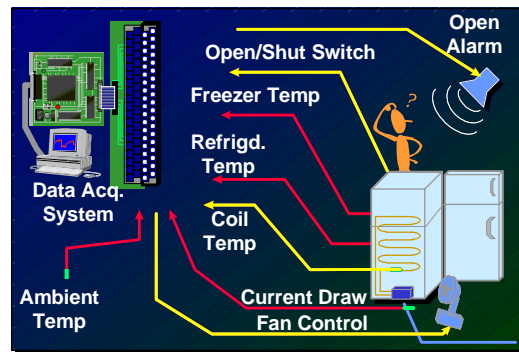
Figure 3. A conceptual drawing of the take-home laboratory project

The objectives for our development of this laboratory CBT module are:
- ◆ Provide a tutorial module for the "Student Data Acquisition System"
  - • How the system works, what is data acquisition/control
  - • Showing setup and use of sensors and actuators
  - • How to use the software, how to log and analyze data
  - • A complete example project
- ◆ A tutorial module for implementing the specific laboratory project
  - • Cover why and overview of project
  - • Specific steps needed, how tos
  - • Use of software tools, typical results and analysis
  - • How to write up lab
- ◆ Develop a search engine and/or key word reference table
  - • To use to find just the one piece of information needed (on-line help)

Progress and Conclusions

The framework of each tutorial module has been developed. We are in the progress of adding information and interactivity. The two tutorials will be used in the Spring 97 in two different classes. Results from this pilot evaluation will direct us towards future improvements.

A significant issue is the assessment of this approach. While we would like to implement a control group and a test group, this level of effort is beyond the resources we have. We will, however, use survey information, spot interviews, and the result information file from the each student's tutorial session(s). The result information files will give a quantitative measure on how much difficulty (number of right/wrong, number of retests) as well as how long students spent in each of the tutorial modules. This will be augmented by an assessment of the effectiveness of the tutorials in providing the skills and information needed.

Being efficient in faculty, staff and student time is important as resources are finite. For the existing need (the Electronic Prototyping Facility), there is substantial on-going effort by the faculty/TA to re-explain procedures and resolve problems. For our new take-home laboratory project (refrigerator efficiency), we need to develop a very high level of documentation to help the students overcome obstacles without help from faculty and staff. A computer-based tutorial offers the promise of meeting these needs.

At CSM, we are starting the process of changing the way we teach laboratory projects. By making use of available computer-based training tools to author multi-media presentations, we are working towards making the learning experience for the students more self-directed, independent of time or location and, perhaps, more efficient in terms of the student and faculty time. We are developing CBT modules for two example projects: one for our Electronics Prototyping Facility, and one for a take-home laboratory.[11] Our progress to date has been encouraging and we look forward to presenting test results from use in Spring 97.

References

[1] C. Braun, "Electronics System Fabrication for Undergraduate Electronics Laboratories," Proceedings of the 1996 ASEE Conference, 1996, (CD ROM).

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[3] J. D. Fletcher "Does This Stuff Work? Some Findings from Applications of Technology to Education and Training" Proceedings of Conference on Teacher Education and the Use of Technology Based Learning Systems. Warrenton, VA: Society for Applied Learning Technology, 1996. URL: http://ott.sc.ist.ucf.edu//1_2/salt.htm

[4] From discussions with commercial developers and the AWARE newslist/web site URL: http://www.hvu.nl/aware/

[5] Joel Benson, "First Time CBT Designers Requesting Advise from Wizards," AWARE Archives, URL: http://www.hvu.nl/aware/gems/cbt.html

[6] NewMedia Magazine on-line guide for under $1000 authoring software URL: http://www.hyperstand.com/NewMedia/96/13/bg/table1.html

[7] NewMedia Magazine on-line guide for high end authoring software URL: http://www.hyperstand.com/NewMedia/95/11/bg/storage/highauthtable.html

[8] N. Middleton, B. King, "An Integrated, Unified Laboratory for Engineering Students," Proceedings of the 1996 FIE Conference, 1996, (CD ROM).

[9] C. Braun, "Hardware Homework using a Student Data Acquisition System," Proceedings of the 1996 ASEE Conference, 1996, (CD ROM).

[10] C. Braun, "Transforming the Way we Teach Laboratories: A Student Data Acquisition System", Proceedings of the 1996 Frontiers in Education Conference, 1996, (CD ROM).

[11] CBT tutorials and results can be found on the CSM Division of Engineering Web page, URL: http://www.mines.colorado.edu/Academic/eng/

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Biographical Information

Dr. Christopher G. Braun received his S.B. from MIT in 1982 and M.S. and Ph.D. from USC in 1984 and 1987, respectively. Since 1992 he has been a professor at the Division of Engineering at the Colorado School of Mines. Dr. Braun is very active in developing new approaches in teaching electronics. He can be reached at cbraun@mines.edu.