A Modified Case Study: Using Multimedia Courseware To Teach Modular Fixturing

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Introduction

Modular fixturing is an important concept in tooling design and applications courses in the Manufacturing Engineering Technology (MET) and Industrial Technology (IT) curriculum. Traditionally, a lecture is given on the topic using computer slides, videos, CAD graphics of the tooling elements along with physical components to pass around, and/or catalogs to inspect. If the time is available, a tour of local manufacturing operations which utilize tooling applications of interest may be observed. The wide variety of tooling and fixtures are difficult to cover within a single quarter (or semester), especially if consideration of related topics on gaging, cutting tools, and geometric dimensioning and tolerancing are included. The need for interactive teaching tools for discreet technical fields such as modular fixturing in tool design applications is indicated and as a result, ToolTRAIN© was introduced as a solution to this problem.[1]

This paper illustrates the outcomes of a research project in integration of multimedia courseware in modular fixturing concepts, in which the traditional lecture on this topic was replaced by a multimedia courseware. ToolTRAIN© software was used in the area of MET and IT courses at Western Washington University, South Dakota State University and Millersville University to determine if this was a more useful learning experience for MET and IT students.

ToolTRAIN© Plus Software

The original concept to develop the courseware evolved from an interest in courseware applications for manufacturing technology curriculum[2]. There were no courseware tools found for tooling and fixture design applications available for educators and the project to fill this void was initiated. ToolTRAIN© Plus is the most recent version of this courseware. Although multimedia tutorials and courseware tools can greatly enhance learning in ways that traditional instruction can not[3], poor design of the tutorial and user interface (e.g., tutorial fails to run from the CD, or is incompatible across multiple operating system platforms) can limit its use by students[4]. ToolTRAIN© Plus addresses these issues and was developed to use with Windows 2000 and XP (tested on both versions), and the user interface was developed for ease of use.

ToolTRAIN's instruction system contains four main units: (1) Modular Fixturing; (2) Components; (3) Implementation; and (4) Quiz. A hierarchy diagram of tutorial content is shown in Figure 1. The lessons are delivered in a step-by-step format that allows students to repeatedly review the modular tooling concepts in each unit until they have achieved understanding. The sublevels of the courseware are intuitive and navigation is straightforward[5].

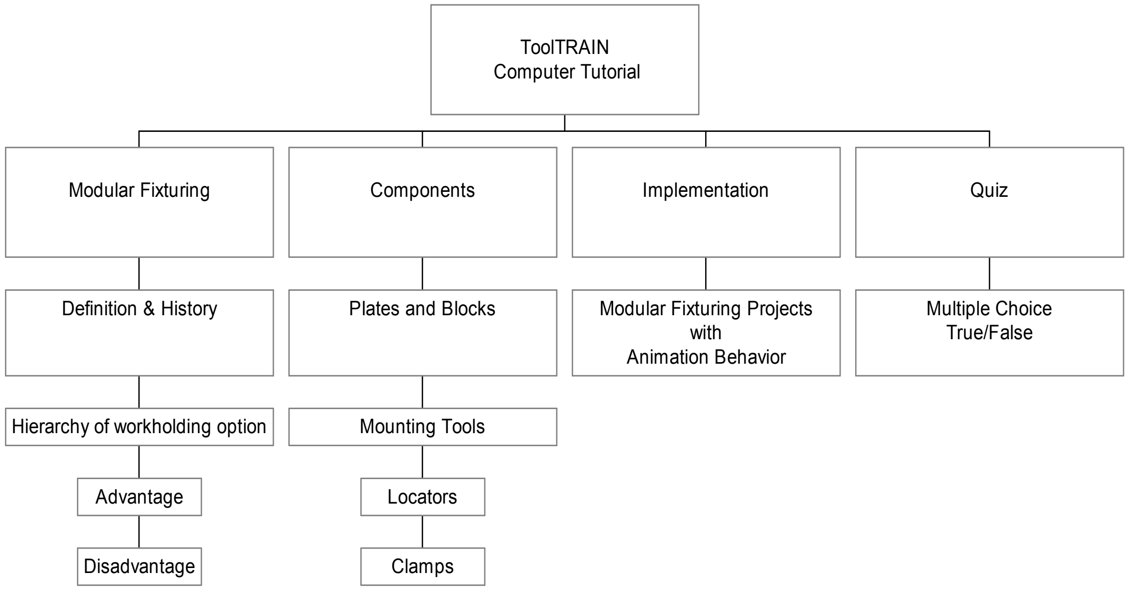


Figure 1. Hierarchy diagram of tutorial content

<u>Modular Fixturing Unit</u>

The modular fixturing unit provides a definition, history, an applications perspective, hierarchy of related workholders or other tooling, and covers the advantages and disadvantages of using modular fixturing. The modular fixturing unit also includes a video clip from a tool design professor who shares an alternative idea for a modular fixturing concept. The unit incorporates graphics, written definitions in a sample application that give the student insight into appropriate drawing layout. Figure 2 shows an example screen of the modular fixturing unit – history.

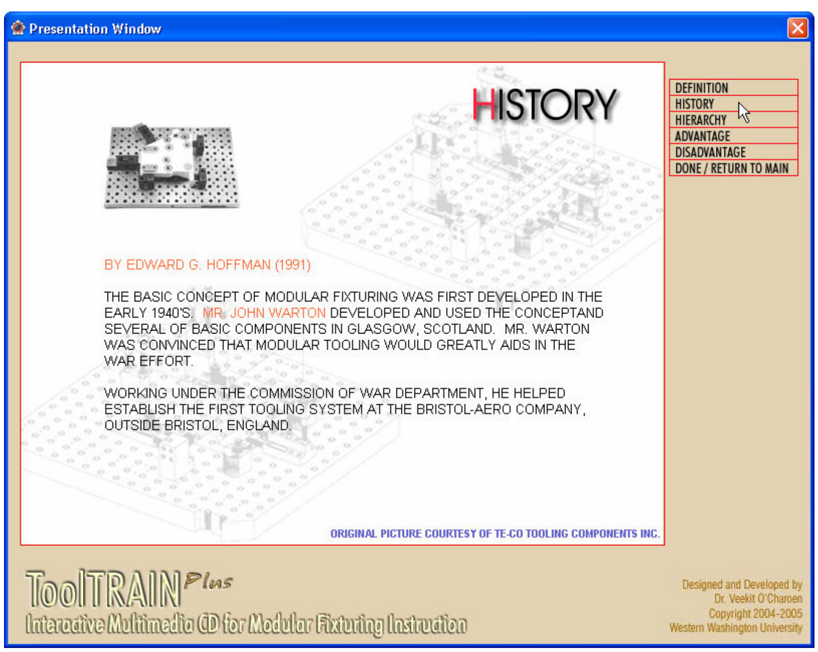


Figure 2. Modular fixturing unit with history section

Component Unit
The components unit presents the fundamentals of modular fixturing components. Four main basic components of modular fixturing are introduced: (1) tooling plates and blocks; (2) mounting tools; (3) locators; and (4) clamps. Figure 4 shows an example screen of the component unit – a rectangular tooling plate. For novices to tooling nomenclature and technology, the component units are especially valuable as the subtle differences between styles and correct application are critical to well-designed production fixturing.

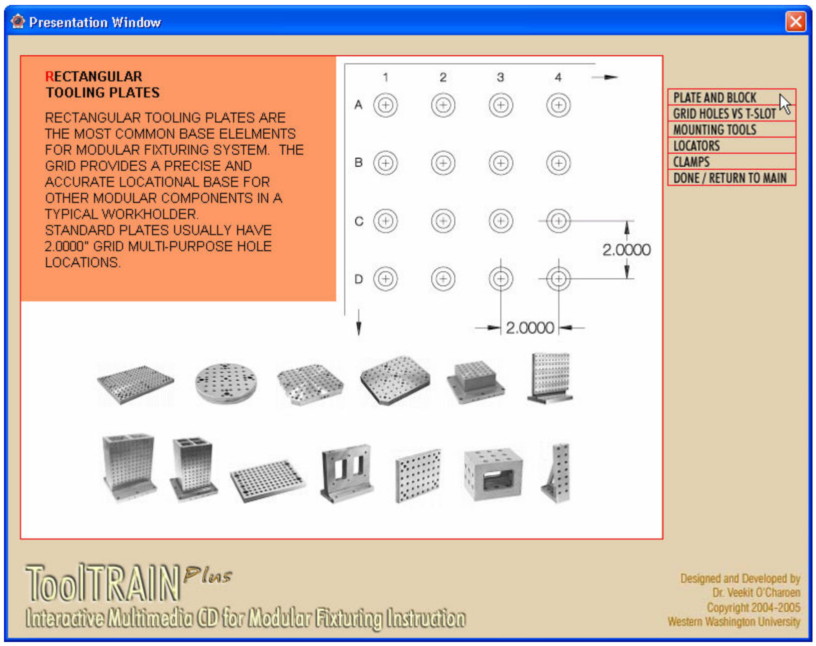


Figure 3. Component unit – tooling plates

Implementation Unit
There are three main steps in the Computer-Aided Fixture Design (CAFD) process: setup planning, fixture planning, and fixture configuration design[6]. The objective of fixture configuration is to select fixture elements and place them into a final configuration in order to locate and clamp the workpiece. The intent of implementation unit in ToolTRAIN© is to introduce a basic concept of modular fixturing components and samples of fixture configuration designs, therefore setup planning and fixture planning are not currently addressed in ToolTRAIN© courseware. The implementation unit in ToolTRAIN© contains five projects based on different part geometry (see Table 1). The use of animation series in the implementation unit is very helpful for student learning especially when several modular fixture components are moved into a final configuration. Figure 4 shows an example screen of the implementation unit.

Quiz Unit
Assessment of student knowledge and its congruence with stated objectives is an integral part of courseware development[7]. Therefore, the last teaching unit in ToolTRAIN© is a quiz where students test their knowledge through multiple choice and true/false questions based upon material covered in previous units (i.e., fixturing definitions, components, and implementation).

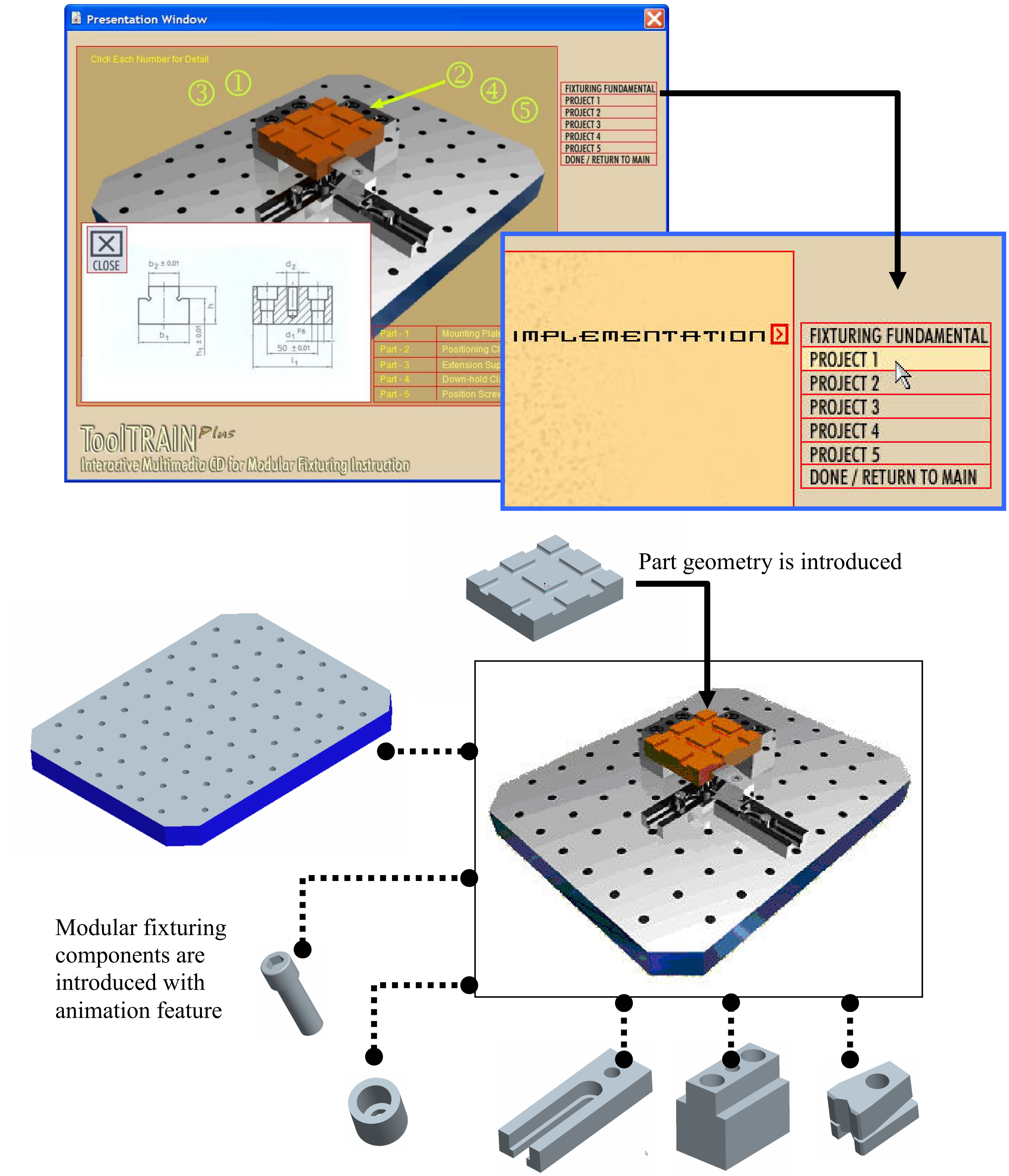


Figure 4. Example of implementation project (modular fixturing configuration) in ToolTRAIN©

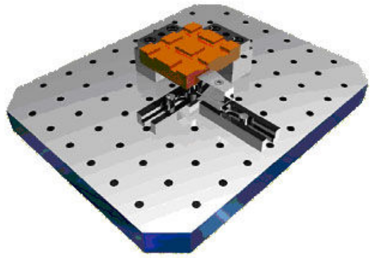
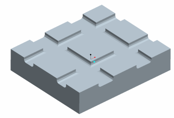
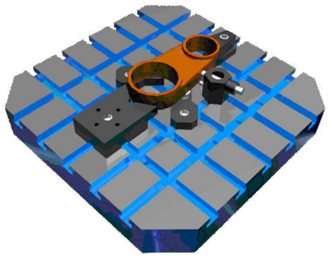
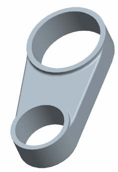
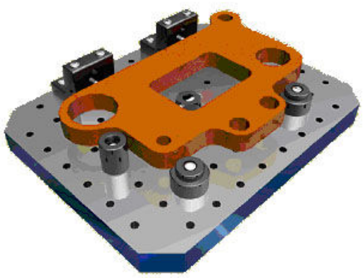
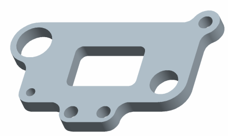
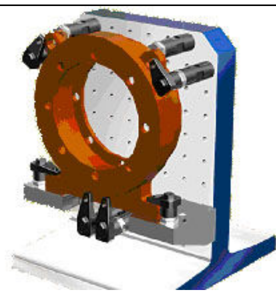
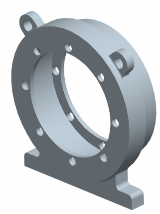
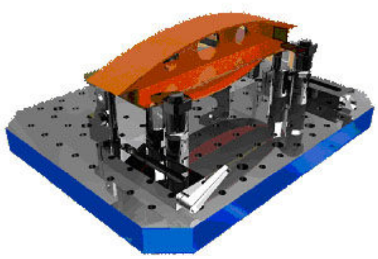
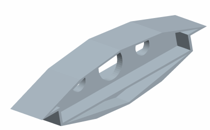
Fixture Configuration	Workpiece
 Project 1	
 Project 2	
 Project 3	
 Project 4	
 Project 5	

Table 1. Modular Fixturing Configuration in ToolTRAIN© Plus.

All components are modeled by Veekit O'Charoen (except project 5 by Brian Perry); Original fixture design concept from Halder Norn &Technik, Flexible Fixturing System. Inc., East Granby, CT 06026-0787

Courseware Testing and Validation

Validation of the instrument (ToolTRAIN©) was established through a jury of experts. To accomplish this, three manufacturing and industrial technology faculty, one mechanical designer and one information system analyst were contacted prior to the experimental group was utilized the courseware. The jurors were given a briefing on the research study and were asked to (a) examine the instructional objectives, and to (b) use the courseware and test. A form was given to the jurors asking them to rate the extent to which the comprehension evaluation measured the acquisition of knowledge as stated in the instructional objectives on a scale from 1 (poor) to 9 (excellent). The jurors' mean rating on the comprehension evaluation test was 7.5 out of a possible 9 (see Table 2). These ratings suggest that the courseware has content validity. It also suggests that the computer tutorial program is accurate and therefore it is suitable for use in a college setting.

Expert	Test Rating
1	7
2	7
3	7
4	8
5	7
6	9
M	**7.5**

Table 2. Validity ratings of the pretest-posttest on a scale of 1 to 9

ToolTRAIN© courseware has been subjected to extensive testing on undergraduate students in manufacturing technology tooling courses. Corrections and additional training units have been performed as a result[1]. A quasi-experimental design of the non-equivalent control group was utilized for the previous study with ToolTRAIN© Release 4. The population of the study was comprised of the students who enrolled in the Manufacturing Technology, Electro Mechanical System, General Industry & Technology and Technology Education programs at the University of Northern Iowa during the spring of 2000 semester. The samples from the population for the study were 15 students enrolled in the experimental group and another 15 students enrolled in the control group.

Three hours were used to teach the control group by lecture. The experimental group was expected to utilize ToolTRAIN© for three hours. The posttest was administered to measure knowledge gain of modular fixturing design concepts after the instruction. To test each hypothesis, a separate independent group's t-test was computed comparing the change scores obtained by the computer tutorial group with those obtained by the lecture group. For each test, the null hypothesis was that there is no difference in the means of the two groups; the statistical alternative is that the means of the two groups are different in which case the direction of the difference was examined to determine which group showed more improvement. Table 3 shows the mean and standard deviation on the change in scores based on four areas of knowledge.

Areas	Control			Experimental		
	M	SD	n	M	SD	n
Basic Concept – Introduction	0.60	1.18	15	2.27	1.10	15
Components	1.53	2.29	15	3.67	2.61	15
Implementation	0.33	1.72	15	2.27	1.58	15
Full Scale	2.47	2.47	15	8.20	3.59	15

Table 3. Mean and standard deviations on the difference in score (change in score) based on four areas of knowledge.

For the basic concepts and principles of modular fixturing scale, as predicted, there were significant differences between group means, $t(28) = -3.996$, $p < 0.001$ with the experimental group improving more. For the modular fixturing components scale, as predicted, there were significant differences between group means, $t(28) = -2.378$, $p < 0.05$, with the greater change in the experimental group. For the modular fixturing implementation scale, the change scores also showed that there were significant differences between group means, $t(28) = -3.208$, $p < 0.05$, again favoring the computer (experimental) group. Finally, for general performance on the test score (full scale), as predicted, the experimental group achieved significantly higher change in scores than the control group, $t(28) = -5.093$, $p < 0.001$.

The Case Study

This study sought to determine student comfort levels and limited learning outcomes using a software based teaching tool. The software, ToolTRAIN© Plus, was installed in laboratory computers at three institutions: Western Washington University, South Dakota State University and Millersville University in Pennsylvania. After working through the exercises and following quizzes in the teaching units, the students were surveyed about their reaction to the software. The survey instrument was developed and validated by manufacturing engineering and industrial technology faculty who had taught manufacturing tooling related courses. Table 4 shows the basic information about each sample and the related course.

Institution	Number of Student Respondents	Course Taken	Degree Requirement
Western Washington University	20	Tool Design	BS Manufacturing Engineering Technology BS Industrial Technolgy
South Dakota State University	9	Production Tooling Methods and Measurement	BS Manufacturing Engineering Technology
Millersville University	11	Advanced Metal Manufacturing	BS Industrial Technology

Table 4. Institutions, number of participants, course, and degree.

Tool Design course at Western Washington University (WWU)
The primary author chose the tool design course to evaluate the ToolTRAIN© software. The purpose of tool design course at WWU is to cover a design of special tooling used in manufacturing processes to include, but not limited to, inspection gauges, fixtures, jigs, assembly fixtures, punch and dies. ToolTRAIN© was introduced in the 7th week of the fall 2004 quarter. In this class students had an opportunity to work with a set of modular tool right after completing the ToolTRAIN© software.

Manufacturing Tooling course at South Dakota State University (SDSU)
At SDSU, the instructor chose the manufacturing tooling course for student participants in the study. The manufacturing tooling course provides an overview of machine tool design, application manufacture and general measurement techniques. Subject includes jigs, fixtures, molds, tools and dies in various production settings. Also included are material selection, precision machining, related manufacturing processes, dimensional metrology and geometric conformance. ToolTRAIN© was introduced in the end of the fall 2004 semester.

Advanced Metal Manufacturing course at Millersville University (MU)
The third author selected the Advanced Metal Manufacturing class for the survey at MU. Basically the class is a Computer Integrated Manufacturing (CIM) course and they discuss fixture design because the lab component deals with the design and manufacturing of a product that students work together in designing and developing the product for manufacture. They do a lot of fixture design and work with the CNC equipment. ToolTRAIN© also was introduced at the end of the fall 2004 semester.

Questionnaire Items
Demographic information and a self assessment of basic tooling knowledge were asked. These included each subject's: *Question 1*, academic standing and *Question 2*, rate your level of knowledge about manufacturing tooling applications (Figure 5 and 6).

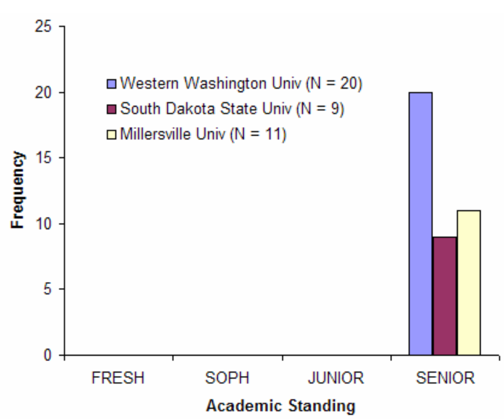


Figure 5. Academic standing

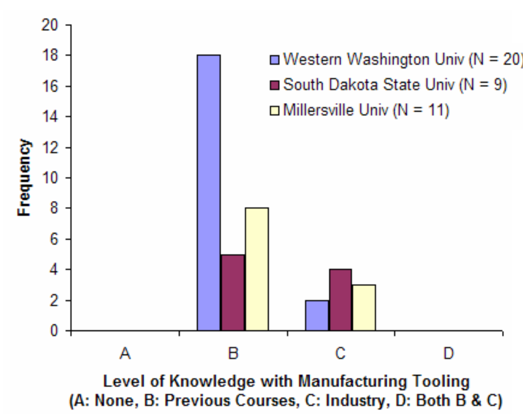


Figure 6. Tooling knowledge self assessment

Evaluation Questionnaire

Given the objective of the learning outcomes for the software, it was hoped that the evaluation would give an indication of the effectiveness of ToolTRAIN© as a teaching tool. Another goal was to get feedback on the various functional components of the software. This questionnaire was given to the students after they used the ToolTRAIN© program. All students answered the questionnaire without being able to re-access the ToolTRAIN© program. Questions included in this questionnaire were divided into two categories: program evaluation as a learning enhancement tool, and user interface evaluation.

Question 3: *Would you like to see more of this kind of software tutorial in different classes?*
This question was intended to test the general concept of accepting computer tutorial in classroom activity. It appears that students found the experiment very effective. The results showed that 97.5 % were in favor of using this kind of program in the next classroom activity. Most students explained their answer by adding that, it is quick and easy to learn modular fixturing concepts from the software tutorial. However, in open comments at the end of the survey, most students were not satisfied with sound effects. They found them distracting and suggested to "get rid of cheesy sound effects" with the next version of the software. Figure 7 shows the frequencies of student responses: See more of this software?

Question 4: *Was it difficult to know how to operate the program?*
This question covers one of the issues in Human Computer Interaction (HCI). In response, students were highly satisfied with the ToolTRAIN© interface (Figure 8).

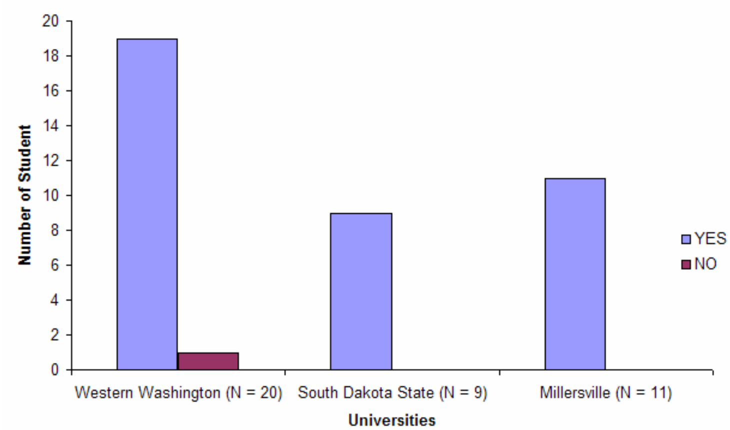


Figure 7. See more of this type of software

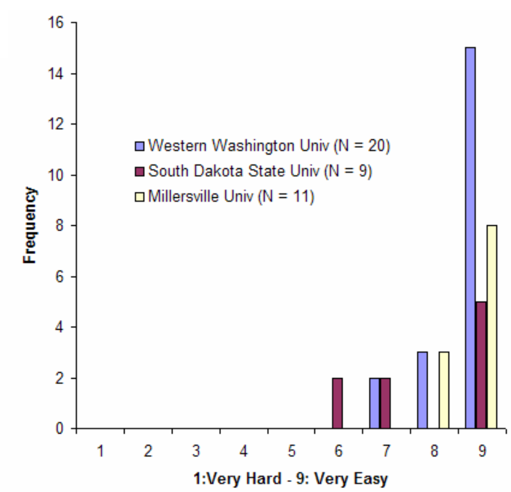


Figure 8. Rate difficulty of interface

Question 5: *Was it difficult to remember the meaning of the commands to run the program?*
It was important to get user views on their understanding of selection and icon representations. It is also important to design the display and select terms that can help students to remember what each icon does. The results (Figure 9) showed that most students from the three universities had no problem remembering the meaning of all the terms provided in the interface.

Question 6: *Was the layout of the screen helpful to understand how to use the program*?
Arranging information on the screen is very important in learning. A good screen should have the minimum information that conveys maximum meaning to the user. This question was asked to determine how students react to the screen design. The result showed that there was a positive response to the question. Results of this item are shown in Figure 10. Figure 11 shows ToolTRAIN© screen layout and the user interface representations.

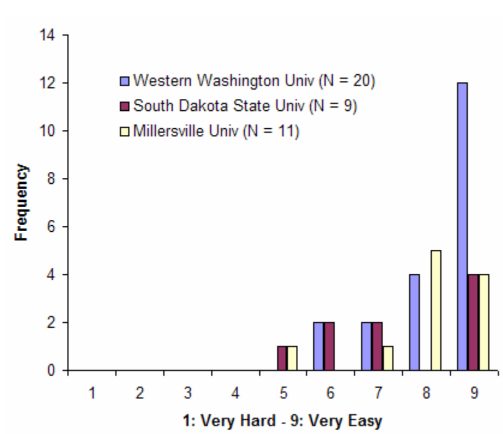


Figure 9. Ease of remembering commands

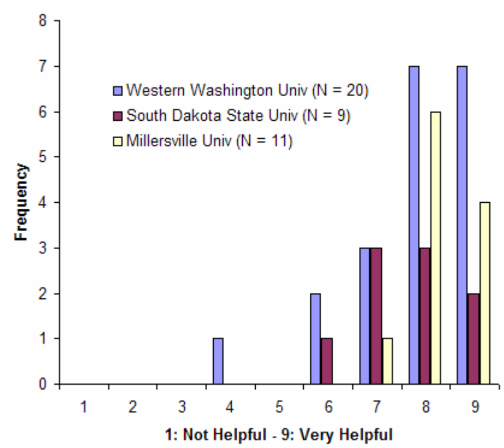


Figure 10. Screen layout helpful

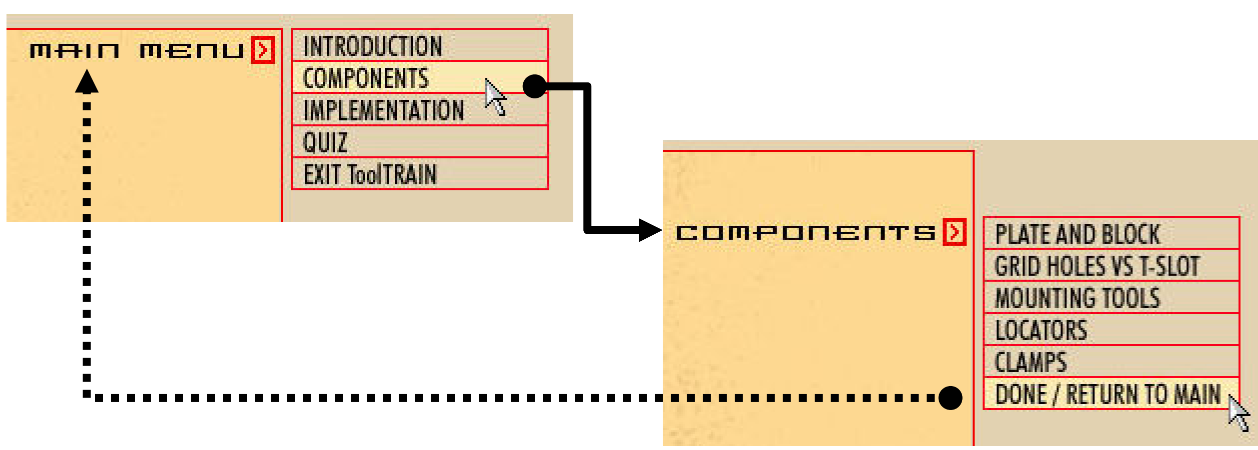


Figure 11. ToolTRAIN© screen layout and the user interface representations.

Question 7: *Did you feel comfortable with the color of the screen?*
There is little doubt that color makes software more attractive, and conveys more information on process control information. For example, color is conventionally needed to indicate all components and warning lights. However, the ultimate confirmation of this question is up to the user not the designer. Therefore, the question was intended to see how users felt about the color of the screen in the experiment. Overall results were acceptable. Only three students were not comfortable with color schemes used (Figure 12).

Question 8: *Is it easy to go back and forth between screens of the program?*
When the information to be presented to the user is greater than the size of the display, paging is preferable compared to scrolling (Airir, 1995)[8]. However, paging could have disadvantages if the user gets lost between different screens. In ToolTRAIN©, the primary author (developer) designed a sub-screen under each unit to eliminate this type of problem (see Figure 11). This question was presented to test if students have difficulties going between screens. Results are presented in Figure 13.

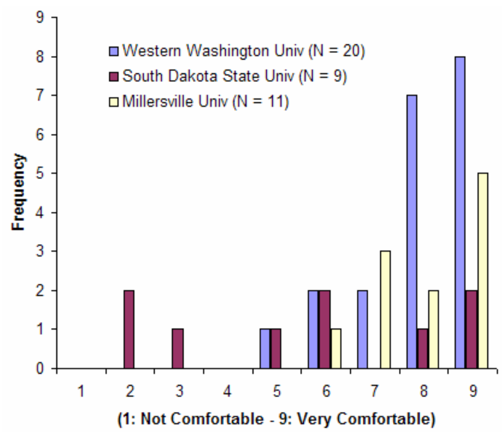


Figure 12. Comfort with color scheme

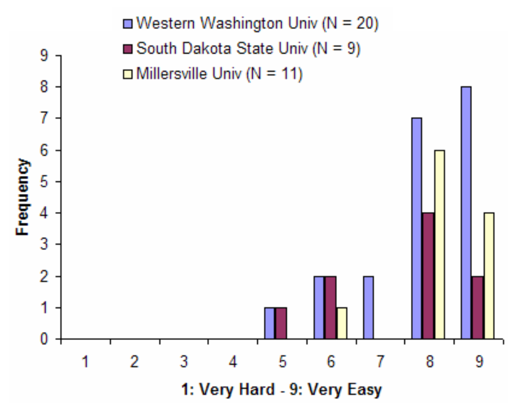


Figure 13. Ease to move between screens

Question 9: *Were the terminology used throughout the system clear and meaningful?*
Although ToolTRAIN© is designed to employ a "menu picks" user interface, some concepts are difficult to represent in a graphical manner. Therefore, text and terminology were attached to each menu item. However, these terms themselves can be misleading in meaning; therefore this question was intended to get user assessment on the clarity of meaning of these terms. The results indicated the students had no trouble with the meaning of terminology (Figure 14).

Question 10: *Are you satisfied with the way the information is arranged on the screen?*
The arrangement of material on the screen plays a major role in locating information. This question was intended to test screen layout such as the sub-screen in each unit, the position consistency, text, color, and screen background. The overall results were positive; the students found that information was clearly organized on the screen. There were three students did not satisfied for this arrangement. Figure 15 shows the answer of the students to this question.

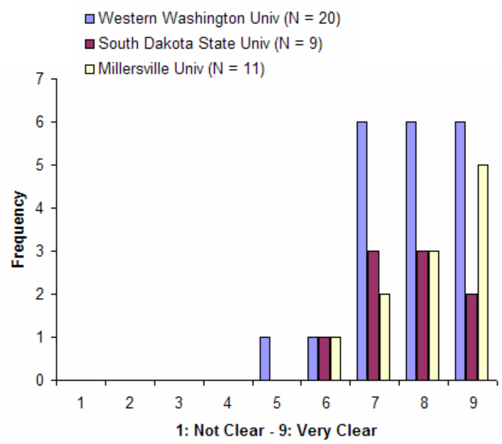


Figure 14. Terminology used is clear

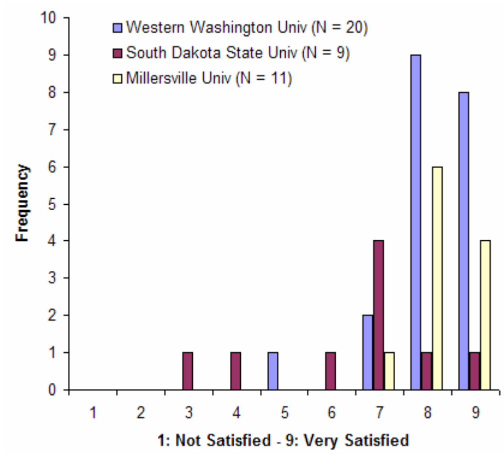


Figure 15. Satisfaction with information arrangement

Question 11: *How would you rate ToolTRAIN© software for the ease of use?*
The ease of use question reflects both the effectiveness and the efficiency of the interface and software. The range of the questions was given from 1 "very difficult" to 9 "very easy". 37 students answer ranged between 7 and 9. The results indicate that the interface was effective and the system was easy to use (Figure 16).

Question 12: *Were you satisfied with the time the experiment took using the software?*
Time is a critical issue in learning. When a student accomplishes a certain job in less time, it can be concluded that the student has high cognitive skills i.e. has the ability to learn fast. This question was presented to students so that they could give their opinion about the time the experiment took using the computer. The results in Figure 17 indicate that the 34 students were satisfied (ranged between 7 and 9) with the time the experiment took.

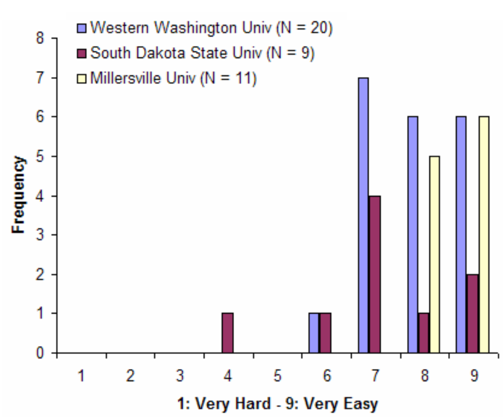


Figure 16. Overall ease of software use

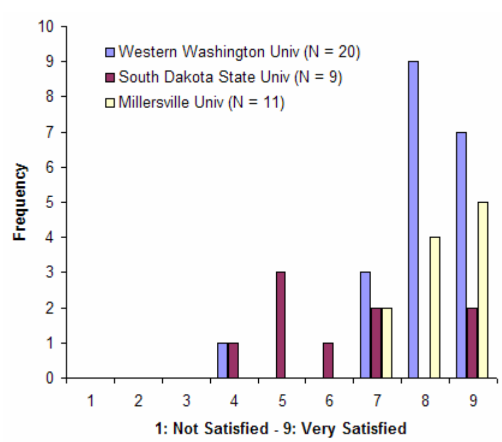


Figure 17. Length of time to test software

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Conclusion
The need for graphics based teaching tools for the manufacturing curriculum has been established in the literature. The development of a dedicated software program that teaches modular fixturing for manufacturing tooling applications has value for the engineering technology and industrial technology educator. The complex components used in tooling applications and the subtle differentiation of application make it important to use graphical user interface teaching tools. ToolTRAIN© software was developed to address this need.

In a limited case study involving students in Manufacturing Engineering Technology and Industrial Technology programs at three institutions, the results indicate students liked and would use this type of teaching tool if it were made available. To verify the software graphical interface was a positive experience and to determine that the modules developed were appropriate, the students were allowed to test the software without instructor interference. The survey instrument administered afterward sought to determine student reaction. The results found that ease of use, navigation, presentation of information and terminology, and layout of the ToolTRAIN© software were positive. In open comments, students stated the sound effects were distracting and not desirable. These results indicate the software has promise as a teaching tool for manufacturing modular fixturing applications in the undergraduate engineering and technology curriculum.

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