COMPUTER BASED TRAINING FOR MODULAR FIXTURING DESIGN INSTRUCTION

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ABSTRACT

Computer base training (CBT) named ToolTRAIN© was developed by the author to use as a learning tool for modular fixturing design concepts. ToolTRAIN© consists of four main elements: Modular Fixturing, Components, Implementation, and Quiz. This study was designed to compare student knowledge gain from learning modular fixturing design concepts by CBT versus traditional lecture. Both groups were instructed on the same topics covered in this study. The post-test was administered to measure knowledge gain of modular fixturing design concepts after the instruction. This research indicated that there were significant differences between the CBT and the lecture method. The computer tutorial group achieved significantly higher improvement in scores than the control lecture group.

INTRODUCTION

Modular fixturing has become an essential issue in Flexible Manufacturing Systems (FMSs) and Computer Integrated Manufacturing (CIM) (Nee and Kamar, 1991). The engineering efforts required for custom modular fixturing design are growing with respect to the number of components per part. Without experience in tool design, modular fixturing design problems can probably be generated by human errors and the iterative manufacturing design process may result in a long development period. In order to address this issue, many colleges and universities in the United States are offering courses in tool design concepts. However, most textbooks and classroom teaching are verbal and sequential while an environment that is inductive and active better serves the need of the students. In reality, visualizing mechanisms in motion is an important aspect of student learning. Therefore, the author decided to develop a CBT tool to improve instruction for modular fixturing design concepts.

ToolTRAIN© RELEASE 4

A CBT entitled ToolTRAIN©, was developed by the author to explain the process of modular fixturing design concepts. ToolTRAIN© features multimedia capabilities, thus making it possible to represent many concepts such as 3D shapes, animation, and sound. It is difficult for a student to understand and learn a concept of modular fixturing design in a short amount of time. Therefore, the use of a series of computer-based lessons may be helpful. Many educators (along with engineering, science, and technology professionals) have developed training materials as an alternative to conventional classroom instruction [Rubaai (1994), Woolf, (1996), Krueger and Lieu (1997) and Herskowitz, (2000)]. The program was developed using a four phase instructional design process (Wilson, 1994) and consisting of a needs assessment, a design of instructional content, a production and evaluation of the software, and a validation of the computer tutorial program. The first phase in the development of the CBT software process was to complete a needs assessment. This assessment included an analysis of the learners for which the instruction was planned. During the second phase of development the instruction was designed through a storyboard technique.

This technique allowed the researcher to visualize a wide variety of solutions to instructional problems. The order of the instructional steps was selected and the script for instructional delivery written. The third phase of development involved the production of the software. In this step, the program was flowcharted and authoring of the software was carried out. Table 1 shows a list of the software packages and the purpose of using them to develop ToolTRAIN©.

After several trial versions, ToolTRAIN© release 4 was finally released with full multimedia capabilities. A hierarchy diagram of tutorial content is shown in Figure 1. There are four main units in the instruction system: (1) Modular Fixturing; (2) Components; (3) Implementation; and (4) Quiz. These instructions are usually given in a step-by-step format that allows students to assess their understanding of the fundamental concepts contained in each unit.

The modular fixturing unit provides definition, a historical perspective, a hierarchy of workholders; it briefly shows 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 (see Figure 2).

Table 1: A list of the software packages and the purpose of using them to develop ToolTRAIN©.

Software	Purpose
Macromedia Authorware® 5.1	Authoring System
Pro/ENGINEER® 2001	Solid Modeling
3D Studio MAX® R3	Animation
Adobe Photoshop® 5.5	Digital Illustration
Adobe Premiere® 5.1	Video Editing
Goldwave® 4.02	Sound Editing

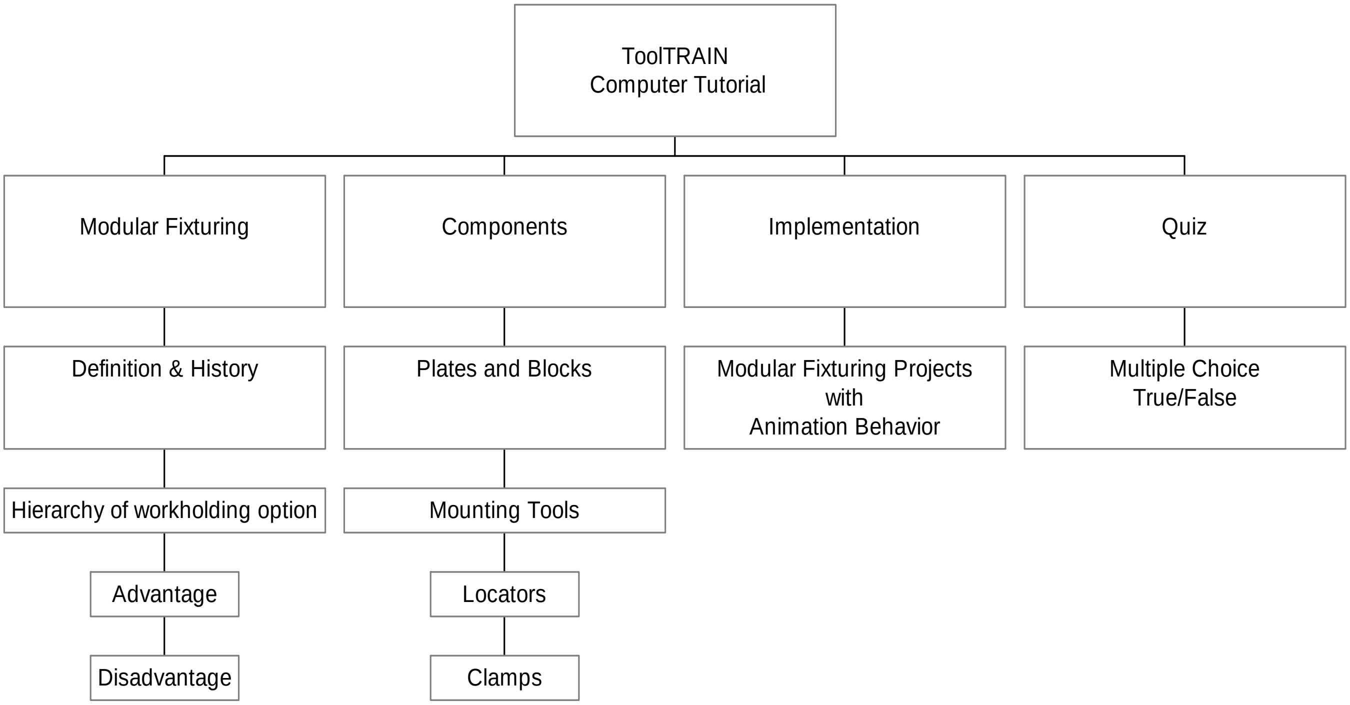

Figure 1 Hierarchy diagram of tutorial content

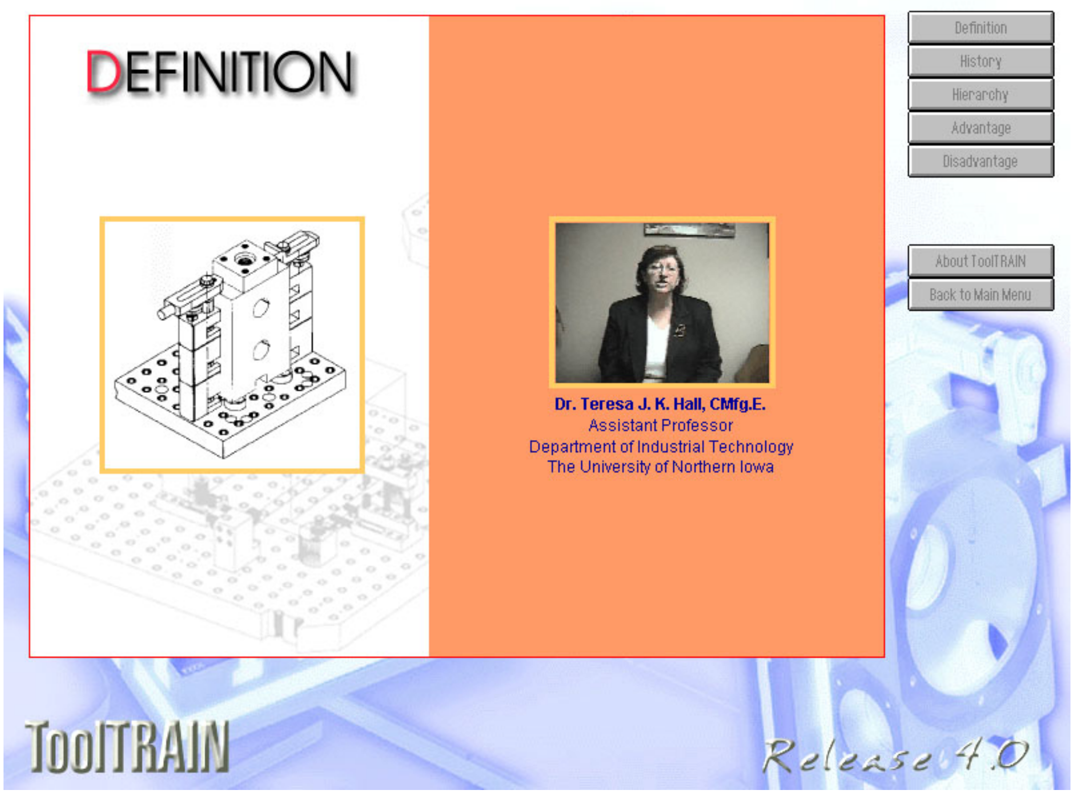

Figure 2 Video clip combined with the instruction

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 accessories; (3) locators; and (4) clamps. Figure 3 shows an example screen of the component unit.

Traditionally, the instructor lectured on the topic emphasized by videos and/or slide-graphics of the tooling elements. Some physical components of modular fixturing could be passed around in the classroom. This requires some level of cost to acquire a physical item. In addition, a tour of local manufacturing operations with a process of modular fixturing systems may be provided if time is available.

The intent of the implementation unit in ToolTRAIN© is to introduce rules and methods to simplify modular fixturing functions by using a series of animations in each modular fixturing configuration. The animation features make it possible for the student to understand the concept of modular fixturing. The implementation unit contains four projects that demonstrate how several modular fixturing components can be assembled with a wide variety of workpieces. Figures 4 and 5 show a process of instruction and example screen of the implementation unit, respectively. A group of students who utilized ToolTRAIN© were assigned to complete all projects in the implementation unit.

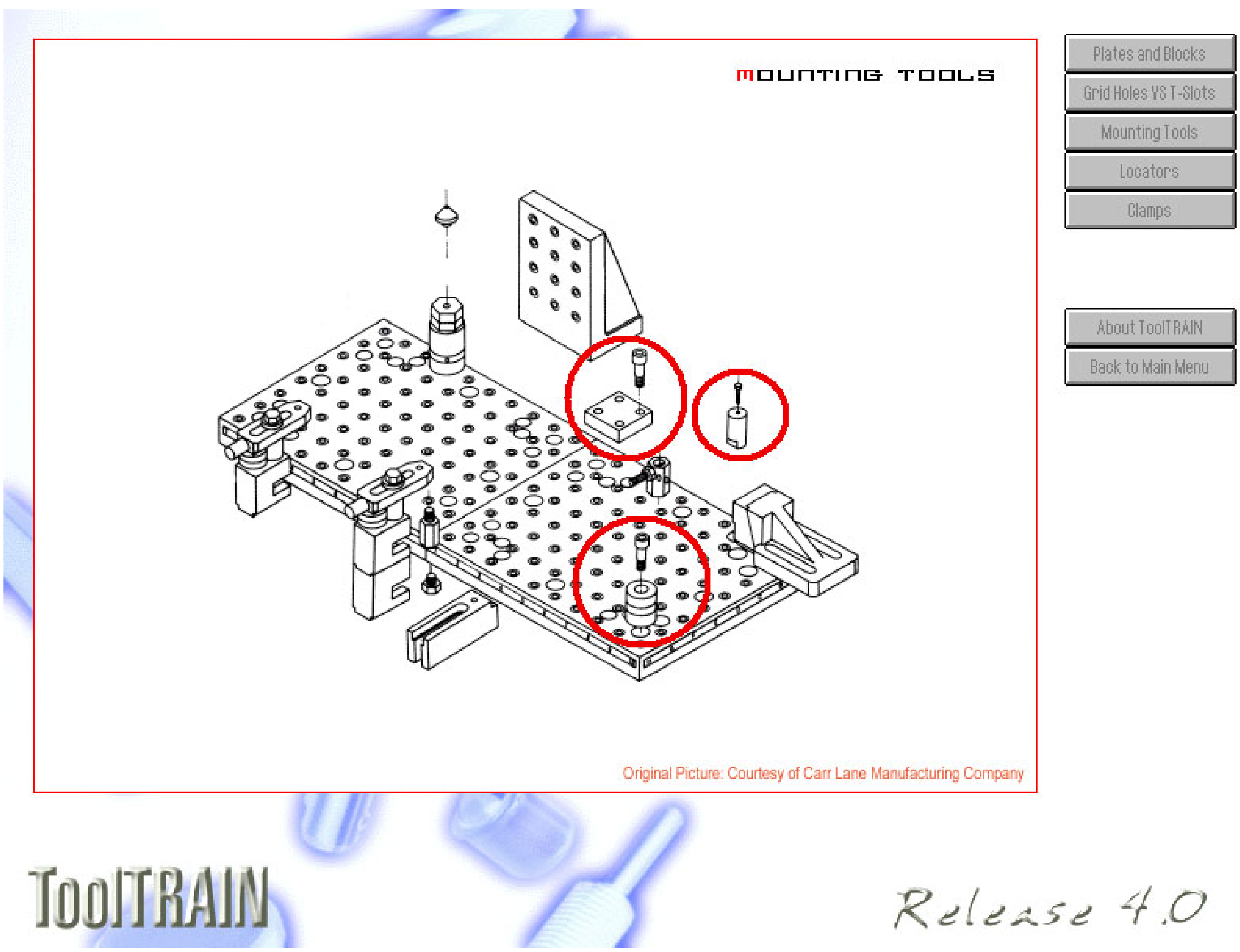

Figure 3 Components unit

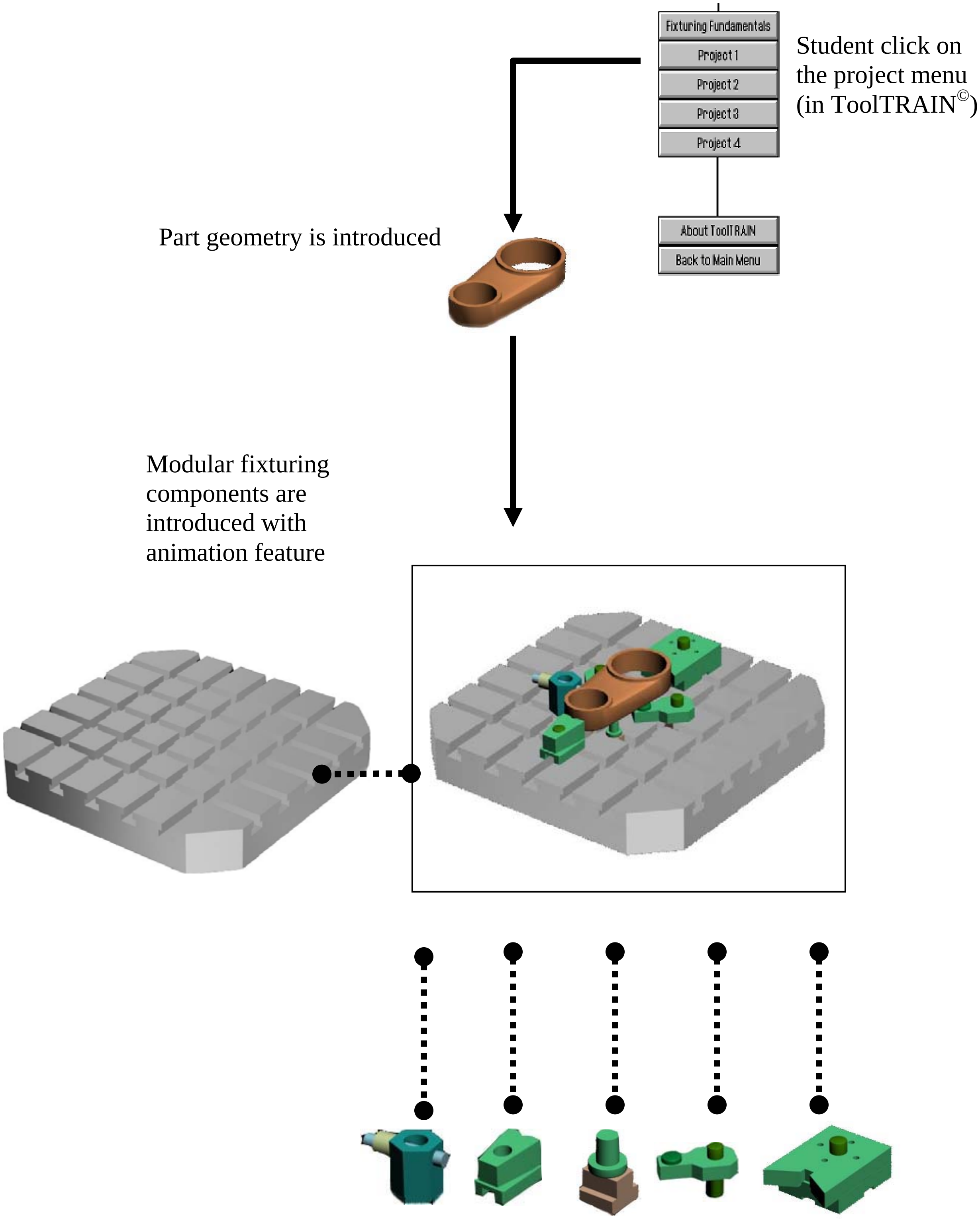

Figure 4 Example of implementation project (modular fixturing configuration) in ToolTRAIN© All components were modeled and rendered by the Veekit O'Charoen, original fixture design concept from Halder Norn+Technik, Flexible Fixturing System Inc., East Granby, CT 06026-0787.

The last unit of ToolTRAIN© is a quiz unit where responses are both multiple choice and true/false. This unit allows students to test their knowledge of the material just covered inside the software tutorial (see Figure 6).

ToolTRAIN©'s USER INTERFACE

The user interface of ToolTRAIN© is designed based on the concept of menu-based interaction. According to Newman and Lamming (1995), menu-based interaction is the user interface that presents the user with a display of options, and the selection of an option may generate a further set of options. In another words, menu-based interaction provides a means for inexperienced users to navigate through extensive system functionality, using simple forms of technology.

The functions provided by the ToolTRAIN©'s user interface (menu picks) show up to the right corner of each page, with commands arranged vertically. As users move the mouse pointer up and down within command menus, a small-hand symbol under the pointer appears at the same time. The symbol ensures that users

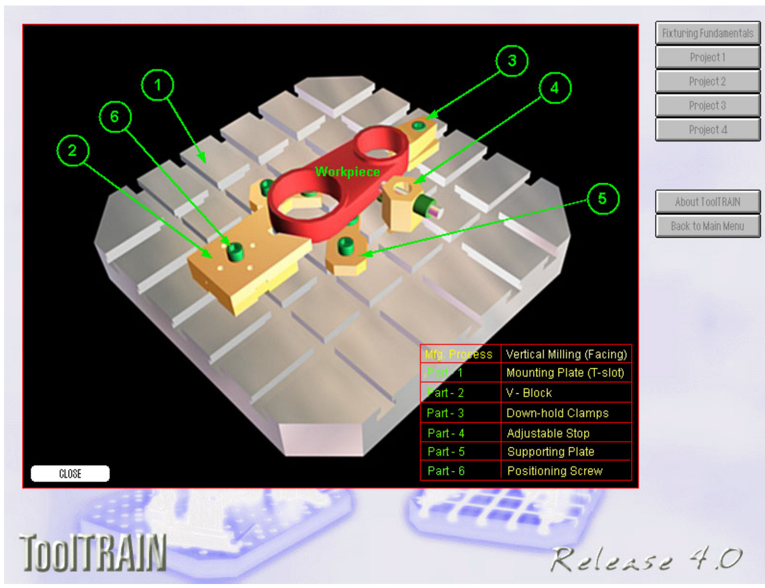

Figure 5 Implementation unit with 3D animation

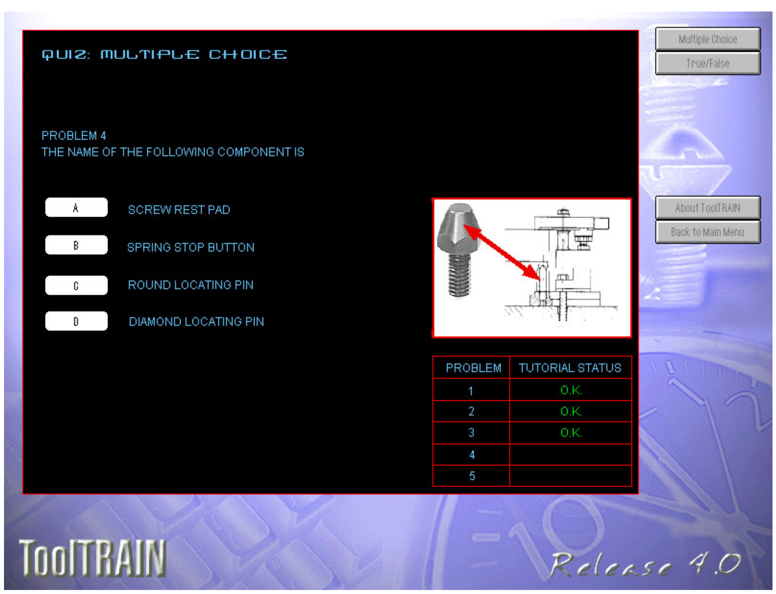

Figure 6 Multiple choice questions in the quiz unit.

selected the right choices. This prevents the user from issuing an inappropriate or unavailable command. The sub-screen will appear after users picked the menu interface prior to the tutorial to begin the training process. Figure 7 shows the architecture of ToolTRAIN© user interface.

EXPERIMENTAL RESEARCH DESIGN

A quasi-experimental design of the non-equivalent control group was used for this study. The samples from the population for this study were 15 students enrolled in the experimental group and another 15 students enrolled in the control group. This study was designed to test the following null hypotheses.

Major null hypothesis. There is no significant difference between the genera l performance on test scores of students who used the computer tutorial and those who experienced traditional teaching methods.

- Sub-null hypothesis 1. There is no significant difference between the performance on knowledge test scores of basic concepts and principles of modular fixturing of students who used the computer tutorial and those who experienced traditional teaching methods.
- Sub-null hypothesis 2. There is no significant difference between the performance on knowledge test scores of modular fixturing components of students who used the computer tutorial and those who experienced traditional teaching methods.
- Sub-null hypothesis 3. There is no significant difference between the performance on knowledge test scores of modular fixturing implementation of

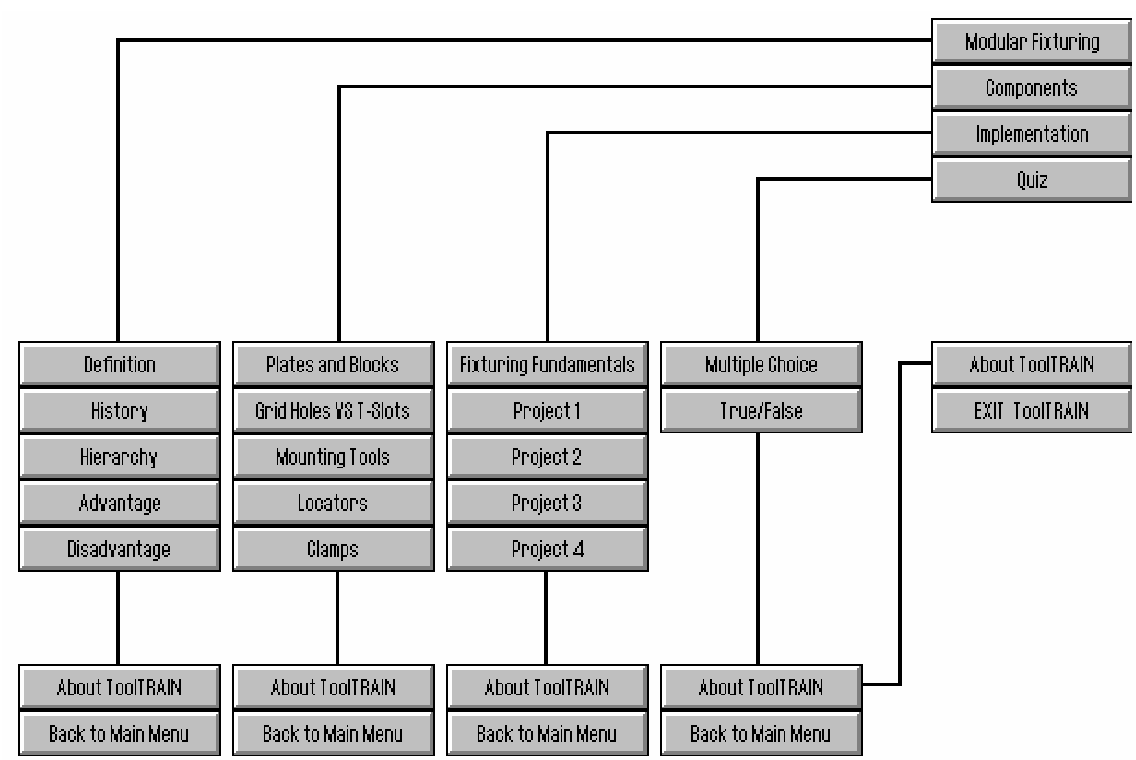

Figure 7 Architecture of ToolTRAIN's User Interface

students who used the computer tutorial and those who experienced traditional teaching methods.

To test each hypothesis, a separate independent group's t-test was computed comparing the change scores obtained by the experimental 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.

RESEARCH SCHEDULE

The research schedule is shown in both Table 1 and Table 2. The experimental phase of the study was implemented during the seventh though ninth week of a sixteen-week semester. Both groups were instructed on the same basic topics covered in this study.

For the control group, the general course content for this research study was discussed with a Tool Design instructor before a pre-test was administered in the seventh week of the tool design class. A copy of pre-test and the post-test were given to the Tool Design instructor which helped him to better present the same content and terminology as the treatment group. During the 8th week, students in the control group were given a three hour lecture on the concept of modular fixturing design. During the ninth week, a post-test was administered to all subjects to measure the knowledge gained of modular fixturing design concepts.

Table 1. Time schedule of the research design for control group

Week	Activities
7th week	Pre-test (1 hour)
8th week	Lecture (3 hours) by Tool Design Instructor
9th week	Post-test (1 hour)

Table 2. Time schedule of the research design for experimental group

Week	Activities
7th week	Pre-test (1 hour)
8th week	Utilize CBT (3 hours)
9th week	Post-test (1 hour)

On the other hand, an experimental group utilized the computer based training program (ToolTRAIN©) for 3 hours. During the ninth week, a post-test was administered to all subjects to measure knowledge gained of modular fixturing design concepts.

DATA COLLECTION INSTRUMENTS

Pre-test and pos-ttest instruments were designed to measure a student's knowledge regarding the concept of modular fixturing design. These instruments were used to collect data pertinent to this study:

- The pre-test and post-test consist of 25 multiple-choice items. Seven items were developed to measure knowledge of basic concepts and principles of modular fixturing theories; eight items were developed to measure modular fixturing component knowledge; ten items were developed to measure knowledge of modular fixturing implementation.
- The content of the post-test was the same as that of the pre-test except that the questions were reordered.
- Change from pre-test to post-test reflected whether students acquired knowledge of modular fixturing design during instruction.
- No questions relating specifically to any computer software were posed to either group.

Validation of the instrument (computer tutorial, pre-test and post-test) was established through a jury of experts. To accomplish this, three industrial technology faculty, one mechanical designer, and one information systems analyst were contacted one semester prior to the experimental group utilizing the computer tutorial program. The jurors were given a briefing on the research study and were asked to (a) examine the instructional objectives, and (b) to use the computer tutorial program 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 8 out of a possible 9. These ratings suggest that the comprehension evaluation test has content validity. It also suggests that the computer tutorial program is accurate and therefore suitable for use in a college setting.

RESULTS

Table 3 shows the mean and standard deviation on the change in scores based on four areas of knowledge. The knowledge examination consisted of 25 multiple-choice items. Seven items were developed to measure knowledge of basic concepts and principles of modular fixturing theories; eight items were developed to measure modular fixturing component knowledge; and ten items were developed to measure knowledge of modular fixturing implementation. Subjects in both groups (experimental and control) took the knowledges test before and after the instruction. Change scores representing the post-instruction score minus the pre-instruction score were computed for each subject on items comprising the three content domains, and the overall scale. The content of the post-test was the same as that of the pre-test except that the questions were re-ordered.

The means and standard deviations for the control and experimental groups in the area of basic concepts and principles of modular fixturing were 0.60(1.18) and 2.27(1.10); for the area of modular fixturing components they were 1.53(2.29) and 3.67(2.61); for the area of modular fixturing implementation they were 0.33(1.72) and 2.27(1.58); and for the general performance (full scale or overall score) they were 2.47 (2.47) and 8.20(3.59), respectively.

For the basic concepts and principles of modular fixturing scale, there were significant differences between group means, $t(28) = -$

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

	Control			Experimental		
Areas	$\overline{X}$	σ	n	$\overline{X}$	σ	n
Basic Concept	0.60	1.18	15	2.27	1.10	15
Component	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

3.996, $p < 0.001$ with the experimental group improving more. For the modular fixturing components scale, 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 with the experimental group improving more. 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, $t(28) = -5.093$, $p < 0.001$.

STUDENT EVALUATION

A 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. Effective courseware not only functions very well but is easy to use. Therefore, human computer interaction (HCI) is one of the issues that was covered in the experiment. It is clear that it is very hard to get a user interface that satisfies the tastes of every user; however, some degree of satisfaction is expected. Arranging information on the screen is also very important in learning. A good screen should have the minimum information that conveys maximum meaning to the user. This questionnaire asked students to react to the screen design and to moving back and forth between screens of ToolTRAIN©. The last issue of interest was learning time. When a student accomplishes a certain job in less time, it can be concluded that the student has high cognitive skills (Airir, 1995) i.e., has the ability to learn fast.

Two bar charts based on the students' attitudinal assessments are presented in Figures 8 and 9. Figure 8 represents the evaluation score based on the question: are you satisfied with the way the information is arranged on the screen? 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 results were positive;

the students found that information was well organized on the screen. Figure 9 represents the evaluation score based on the question: is it easy to go back and forth between screens of the program? This question was presented to test if students have difficulties going between screens.

The questionnaire was given out to the experimental group (15 students) after they completed the experiment. The purpose was to obtain student feedback on the effectiveness of ToolTRAIN©, especially on the various components of the software. However, this evaluation procedure was not considered part of the primary experimental research.

CONCLUSIONS

ToolTRAIN© was developed to provide a new method for teaching modular fixturing concepts. This research found that there were significant differences between the computer based training (CBT) program and lecture method. The experimental group who experienced ToolTRAIN© achieved significantly higher improvement change in scores on the knowledge test as a whole, and in its subscales, than the control group. Based on these results it could be concluded that this study lends support to the position that ToolTRAIN© can be used as an effective teaching method for modular fixturing concepts when taught to undergraduate

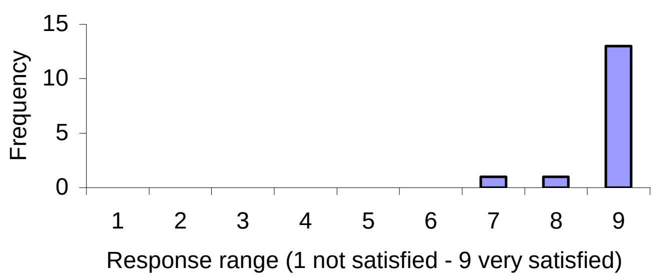

Figure 8. Evaluation score based on the question
Are you satisfied with the way the information is arranged on the screen?

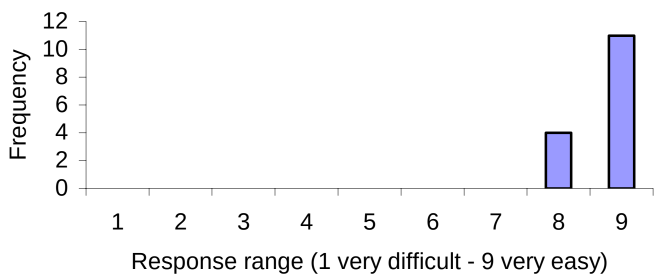

Figure 9. Evaluation score based on the question
Is it easy to go back and forth between screens of the program?

industrial technology students. Future research should expand the sample size used in the investigation. ToolTRAIN© also can be used for more complex concepts of modular fixturing system and applications.

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BIOGRAPHICAL INFORMATION

Veekit O'Charoen is an Assistant Professor in the Department of Engineering Technology at Western Washington University. He received his Doctor of Industrial Technology (DIT) from University of Northern Iowa. His research interests include constraint based modeling, animation behavior, visualization and interactive multimedia tutorials as it relates to tool design and engineering instruction.