Enhancement of CAM Course Using 3D Emulation Software

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Abstract

The Virtual Training Environment for Computer Numerical Control (VTE-CNC) software makes the machine operating situation as close to reality as possible by emulating the actual equipment, controls, and manufacturing processes in a 3D virtual environment. *The main outcome of this study is a qualitative and quantitative analysis of a Treatment Group of students exposed to the software before operating the actual CNC machine equipment compared to a control group, called a Comparison Group, using the traditional textbook approach.* The focus of the study is aimed towards assessing student perceptions of advantages and/or disadvantages of the 3D emulation software in creating what-if scenarios without worry of damage of expensive equipment prior to students having actual hands-on laboratory experiments to mimic industrial manufacturing applications.

Introduction

The Michigan based organization, Immersive Engineering, Inc. offers the VTE-CNC software as an online simulation-based tool designed to develop, run and learn CNC programs and procedures with virtual control panels, 3D machine tools and equipment used in the industrial manufacturing environment. The main theory behind the use of a simulation-based tool is the belief that learning activities that recreate work situations foster better transfer of learning. (Albanese, M. A. and Mitchell, S., 1993) Through the process of experimentation, application of theoretical concepts to the simulated environment and feedback providing important insights impossible through other learning methods, simulations can enhance the learner's ability to make quick progress in skill development.

To remain competitive, industry requires that today's graduate have sound knowledge of industrial applications and have the ability to apply this knowledge in manufacturing and production settings. Rapidly training highly skilled agile learners using a variety of instructional strategies can make the difference. This study highlights the advantages and disadvantages of using the 3D emulation software to rapidly prepare students prior to or during exposure to actual hands-on CAM processes and procedures.

Emulation and Simulation Software

As identified in the Manufacturing Engineering publication (Waurzyniak, Patrick, 2003) , in recent years CAD/CAM developers have continued to add more functionality aimed at machining 3D solid models, high speed machining, automatic feature recognition, tool path verification/simulation, and estimating job costs. As in the example shown in Figure 1, Unigraphics software is used to model the part, create the tool-path, simulate the tool-path, and check for machine/tooling interferences before post processing the program for the CNC mill or lathe.

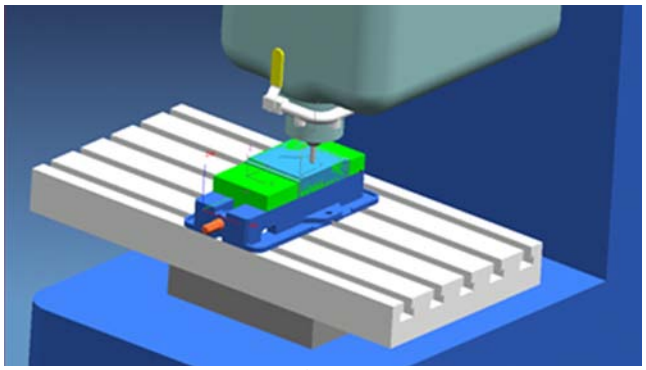

Figure 1, Unigraphics Manufacturing Simulated Tool Path

Similarly, the emulation software is utilized prior to the students performing a lab where they operate the CNC lathe and/or mill. The lab becomes a hands-on verification supportive of the lessons learned through the simulation and emulation software. The VTE-CNC software interface shown in figure 2 is equipped with a Haas mill and lathe 3D emulator (right hand side of screen) and a teach pendant that is interactive with the Haas control panel.

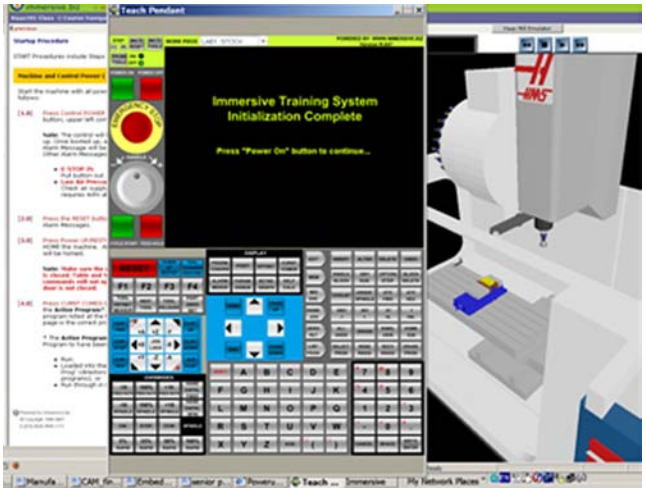

Figure 2, VTE - CNC Software Interface

The training course topic for Haas Basic VF-Series Milling Machine Setup contains 10 modules covering topics in terminology, machine motion, mill control panel, machine startup, manual operations, job setup, edit capabilities, program entry and program run. In addition to this course topic, the Haas 101 Basic Course contains 3 additional topics which are Milling Machine Programming, Lathe Setup, and Lathe Programming. Each module has pre and post tests, example animated sequences for steps and procedures and the opportunity to use the 3D emulator to practice the machining procedures. Several Community Colleges and High School Technical Centers in North America have employed the use of this software to teach CNC operators.

Study Problem Statement and Methodology

The research problem statement is to investigate the student reactions, advantages and/or disadvantages of utilizing this 3D emulation software prior to students performing actual hands-on laboratory experiments to mimic industrial manufacturing applications. The context of the study is a University, School of Technology, senior level Computer Aided Manufacturing course, which will utilize the VTE-CNC Haas 101 Basic Course VF-Series Milling Machine Setup Module only. Post-tests will be administered to two groups, (Treatment Group and Comparison Group), after receiving instruction on CAM milling procedures.

The Treatment Group will be using the VTE-CNC software activities to enhance the traditional methods of instruction. The Comparison Group will be receiving the traditional methods of instruction *only*, which consists of reviewing the Haas Controls Manual, textbook reading, and lab demonstration called, Haas Milling setup procedures. Also, an open-ended survey questionnaire will be administered to both groups at the completion of the course.

The transformation of data will be through the reporting of statistical significant differences between the Treatment and Comparison student group post-test scores. The student ratings of satisfaction in meeting course outcomes will be reported. Also, common themes that arise during examination of the questionnaire will be reported to illustrate the student perceptions of the advantages and/or areas of improvement in the recitation, lab and use of the 3D emulation software.

Student Subjects

The subjects in the study are ten students divided into two groups: Group 1) is the Comparison Group and Group 2) is the Treatment Group. The Treatment Group used the VTE-CNC software outside of class time and was given the log-in necessary to access the milling module. The Comparison Group only used traditional "textbook-styled" learning materials.

Table 1 characteristics of the Comparison and Treatment Groups show a fairly homogenous Group. Since this is a very small sampling of the general population, the study results may not be generalized.

Characteristics	Comparison - 7 Subjects	%	Treatment - 3 Subjects	%
Year in School	Seniors	100	Seniors	100
Prerequisites	Parametric Modeling = 7 Design and Manufacturing = 5 or Maching Methods = 2	100 100	Parametric Modeling = 3 Design and Manufacturing = 2 or Maching Methods = 1	100 100
Internship / co-op / or machine shop Expertise	Three students used lathes and mills at work minimally	38	One student used machines at a friends machine shop	33
Other experience in high school or clubs	NONE	0	One student used CNC lathe and mill in student club	33
Self-rating of prior CNC programming	Fairly competent = 5 Competent = 1 Incompetent = 1	71 14 141	Fairly competent = 1 Competent = 1 Incompetent = 1	33 33 33

Table 1, Subject Characteristics

Quantitative Results

The post test used to evaluate students on their knowledge and comprehension of VF-Series Milling Machine Setup administered after the Comparison and Treatment Groups had attended approximately 6 weeks of class studying topics in recitation and lab demonstration. The Treatment Group had completed the VTE-CNC module without performing any of the online pre or post tests. The 25 questions used for the study consists of 21 multiple-choice and three short answer questions from the VTE-CNC module pretests. *Table 2 indicates the Comparison and Treatment Group results on post test- showing group averages in the Treatment above the Comparison Group.*

Using the T-test statistical measurement and a two tailed level of significance of .05, a value greater than 2.306 indicates that the null hypothesis should be rejected. Therefore, the resultant t-value of 3.005 shows there is a significant difference in the scores from the two groups.

Test Results	Comparison Group	Treatment Group	Difference + / (-)
Average	17.63	21.33	3.7
Median	17.30	21.60	4.3
Std. Deviation	2.01	1.51	.5
T-value	3.005		

Table 2, Post Test Scores

Survey Results

Students at the completion of the course were surveyed for their perceptions of the effectiveness of the course in meeting objectives on a scale of 1-4 with the value of 4 as excellent. *Table 3 shows the results of the Comparison and Treatment Group reactions.*

Course Objectives	Comparison Group	Treatment Group	Difference + or (-)
Create CAM programs and simulate tool paths for Sequential Milling	3	3.7	.7
Create CAM programs and simulate tool paths for Surface Contouring	2.7	3.3	.6
Create CAM programs and simulate tool paths for Planar and Cavity Milling	2.5	3.3	.8
Create CAM programs and simulate tool paths for Turning and Drilling	2.5	2.7	.2
Utilize post processing CAM programs and use of machining center controllers	2.5	3	.5

Table 3, Student Survey Perceptions

The remaining questions on the end of course survey were open-ended intended to provide formative feedback for course improvement. *Table 4 includes a sampling of student perceptions from the Comparison and Treatment Groups.*

Question	Control Group Comments	Treatment Group Comments
Advantages of recitation component	"Advantage of the recitation are that we can go over problems that occur when creating a program. They also help walk through operations to better understand them."	"Working thru machining methods as a class and helping each other thru them. You can't understand the programming process just watching someone do the operations."
Areas of improvement for recitation component	"The software that models the HAAS contol looks like it would be very helpful. Its really hard to keep up in the lab when you only get to do a small part of the total setup."	"Have more time focusing on learning the program in Unigraphics and ensure that everyone is keeping up."
Advantages of lab components	"The lab sessions were the best part of the class because it gave us the hands-on experience. All labs did that. We actually got to do parts from start to finish. We were able to make fixtures and programs that could be used in the real world."	"The lab was very helpful in giving a good introduction to CNC machines.I really liked this part of the class and wish we had more time to spend on projects. With very little machining experience, the plumb bob and can-opener projects were good stepping stones."
Areas of improvement for lab components	"I feel that there should be more time put into learning how to use the mill. That's where using the online CNC emulator would be very effective, because students may be slow at running the actual machine and pushing the button. If we went through the online virtual program, we would have at least know why our instructor was always pushing."	"More lab time would definitely help the learning environment. Having a dedicated shop guy who knew the machines and is available at every lab would be helpful."
Emulation software advantages	"If we had access to the emulator software, we would be able to be experts on the Haas CNC mill. Similar to UG, we could have gone through tutorials on our own time to help us learn."	"Yes. I think it is an advantage to have the virtual CNC training software available online. It is helpful when used in conjunction with actual 'hands-on' machining."
Would you utilize the emulator software	"Maybe, depending on the type of assignments we were given and the time we had to complete them. If there was ample time then, 'yes'. Otherwise, extra time would be used for other work outside of class."	"It depends on how well I understood the class material. If I had a good handle on machine operation, I would use it less. If I needed to learn the machines better, I would definitely use it."

Table 4, Student Feedback

Conclusion

The quantitative post test results from the study show a significant difference in the scores of the Comparison and Treatment Group of students in the CAM course. The results from the small sample of students in this study cannot be a generalized over the entire population, but in this particular situation the students given exposure to the VTE-CNC software performed better on the Milling Setup Module questions than the group only receiving the lecture and lab component.

The ratings of course effectiveness in meeting the objectives were higher by the Treatment Group of students than the Comparison Group, which indicates a positive influence in student perceptions after using the virtual CNC panels and 3D machining software. Also, the reactions from students in both the Comparison and Treatment Group at the completion of the course indicate that 3D simulation and/or emulation software should be used to reinforce the learning process and actual hands-on machine operation. Several comments referred to "not having enough time" being an issue in the lab component of the course, and it could be possible that the VTE-CNC software would be helpful in utilizing their lab time more efficiently, because the students would be better prepared to independently operate the Haas controls without repeated lab demonstrations.

Students at the CNC 3-axis mill control panel

Implications and Recommendations

For most institutions it is cost prohibitive to support a machine shop with enough CNC machines for an entire class of students to experience the setup, operation and troubleshooting of part manufacturing in a lab component of a CAM course. So, a software tool that emulates virtual CNC controls and simulates actual 3D machine motion is a solution that can provide all students the opportunity to become more familiar with machine operating procedures prior to lab sessions.

The expense of the VTE-CNC software is much less than the addition of extra CNC machines, and the software can be accessed online at any time and on any computer with Internet access which makes it more convenient than scheduling machine shop lab time, not to mention the issue with machine safety.

The statistical measurement of effect of using the VTE-CNC software verses traditional lecture and demonstration needs further testing on a larger sample of students in future research. Also, it would be interesting to measure VTE-CNC effect on building student confidence in student behavior with respect to using the actual machines. The VTE-CNC software is a viable option to assist in educating the manufacturing engineers, production engineers and industrial technologists of 2020 in CAM methods and CNC machine operating procedures.

Glossary of Terms

3D: in 3D computer graphics, a 3D model is a mathematical representation of any three-dimensional object (either inanimate or living). It can be displayed as a two-dimensional image through a process called 3D rendering or used in a computer simulation of physical phenomena. Source: Random House Unabridged Dictionary, Random House, Inc. 2006

Emulation: to imitate one system with another, so that the imitating system accepts the same data, executes the same programs, and achieves the same results as the imitated system. Source: Dictionary of Computing, Oxford Paperback Reference 2005.

Recitation: the act of reciting memorized materials in a public performance; the material so presented; oral delivery of prepared lessons by a pupil; the class period within which this delivery occurs; oral delivery of prepared lessons by a pupil; the class period within which this delivery occurs. Source: The American Heritage Dictionary of the English Language, Fourth Edition 2006.

Simulation: attempting to predict aspects of the behavior of some system by creating an approximate (mathematical) model of it. This can be done by physical modelling, by writing a special-purpose computer program or using a general simulation package. Typical examples are aircraft simulators , electronic circuit simulators, or graphical process verification. See also, emulation. Source: The Free On-line Dictionary of Computing 1995.

Dr. Irwin and student with finished part

Presentation

The technical paper, "Enhancement of CAM Course Using 3D Emulation Software" is an unsolicited, independant study. It was presented at the National Associate of Industrial Technology Conference, Panama Beach City, Florida 2007.

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