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Effectiveness of Computer Assisted Laboratory Instructions: Learning Outcomes Analysis

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Abstract: This study investigates the impact of computer assisted instructions on learning effectiveness in computer aided design and manufacturing modules which are integral to mechanical engineering related courses. These courses require learners to understand and know the basics of design and manufacturing processes as well as use specialist software and CNC machines. Use of computer assisted instructions enables learner to grasp complex information in an easier way because of the embedded visual element in such instructions. To quantify the effect of integration of computers in traditional teaching three groups of students were exposed to different teaching methodologies as given below. 1. Traditional classroom lecturing and laboratory work in classroom. 2. Traditional teaching with supervised exposure to available computer simulation. 3. Traditional teaching with un-supervised exposure to available computer simulation. At the end of teaching learning process these students has been evaluated for their proficiency in CAD/CAM/CNC applications. The learning outcomes the students have been measured using blooms taxonomy in knowledge, comprehension, application, analysis, synthesis and evaluation cognition levels. The analysis of the data indicates that groups exposed to computer assisted instructions performed better than the group taught using traditional teaching method. Further supervised exposure to computer simulations gave better results as compared to unsupervised exposure to computers.

Keywords: Computer Technology, Numerical Control Machine, Computer Aided Drawing, Computer Aided Manufacturing (CAD/CAM/CNC)

Introduction

THE ADVENT OF computers and their increased use in industry resulted in computer aided design and manufacturing modules becoming integral to mechanical engineering related courses (James, 2001-2002; Suresh and Bonnie, 2000; R.C.F. Dye. 2003). These courses came in to prominence in early eighties and resulted in extensive modifications in course contents of traditional design and manufacturing courses (Abbott, Mary, Greenwood, Charles, Buzhardt, Jay, Tapia, and Yolanda. 2006). These courses required learners to understand and know the basics of design and manufacturing processes as well as use specialised software and CNC machines. Although learning outcomes for these courses have been developed to suite industrial requirements very little has been done in terms of integrating various learning resources available for optimum benefits. Computer aided learning and computer aided instructional design have been used successfully in human and natural science related courses and a lot of literature is available on the use of computer assisted learning methodologies for such courses (Bourne and Daw.

2000; Baillie & Moore. 2004; Jony and Sarti. 1994). Engineering courses have also begun to use technology for optimum learning benefits (Wang, Paul, Contino, Ramirez, Gustave , and W.Levy. 2000). These studies however indicate that the computer assisted instructions need to be integrated with traditional teaching-learning process with care for optimum benefits (James, 2001-2002; Suresh and Bonnie, 2000; R.C.F. Dye. 2003; Van Dijk L.A, Van Der Berg G.C, Van Keulen H, 2001; A.H. Maslow, 1970; F.T. Lee 1997; J.A. Smith, K. Baker & S. Higgins, 1993; and R. Zaczewski 1994). Through this paper it is proposed to examine in detail various issues related to integration of computer assisted teaching methodologies to traditional teaching methods for optimum benefits.

Experimental Setting

Computer aided learning and computer aided instructional design was implemented for the Engineering Drawing Design and Manufacturing which comprises Computer sketching, Developing the necessary program for manufacturing the prototype and product manufacture & analysis.



The Engineering Drawing Design and Manufacturing is one year course of 2 terms, 12 weeks for each term, with two lectures and a three hour lab every week.

The content of the course is outlined Table 1 below:

Table 1: Activities and Learning Outcomes

Activities and learning outcomes/Modules and time	Module No
Computer sketching) creation of design & drawing). Set up the sketch plane units and grid parameters; demonstrate all 2-D sketching primitives; demonstrate all line editing features; make simple extrusions and revolutions to get 3-D geometry. Demonstrate the creation and editing of dimensions; set geometric constraints; make simple extrusion and revolution to get 3-D; render the parts.	1Module
Computer sketching) modeling utilities). Create 3-D parts; add feature-based, parametric design features; use advanced sweep operations; edit the geometry in 3-D; render the part.	2Module
Computer (sketching) assembly modeling and mating). Create individual 3-D parts; assemble parts as mechanical assembly; mate features as appropriate; check for clearance and interference of parts; create colour rendering of assembly.	3Module
Computer sketching) engineering drawing). Create section views in 3- D and 2-D; create individual 3-D parts; make different 3-D section views of the parts; export acceptable colour image files of 3-D section views for presentation purpose. Project 2-D section views of model; incorporate the 2-D section views into a technical drawing. Generate and dimensioning three-view drawing on a suitable drawing sheet style; add centrelines where appropriate; dimension the drawing; add a title block and appropriate notes. Save each part as DXF file.	4Module
Rapid prototyping) using data exchange format- DXF and setup check and final manufacturing). Create cutting parameter for each part (cutting tool, tool size, tool materials, and work materials). Generate tool paths for different layers for each part (X, Y, Z direction, cutting loop, and depth of cut, feed and speed). Save each part as numerical control (NC) file and send the file to the prototyping machine. Set the work piece; set the tool at zero position; check direction of rotation for the chuck and the cutter; check the work piece and the cutting tool is securely clamped; verify the NC program for any shaft and any gear, and simulate the motion of assembly file of the shaft and gear); run the machine and then the program.	5Module
Project and Analysis (manufacturing). Generate final checklist for prototype (dimensions, assembly, motion, tolerance and fit). Submit final report of the project.	6Module

Group 1 students were exposed traditional teaching style, Group 2 students were exposed to computer assisted teaching and Group 3 students were exposed to Unsupervised CAD/Supervised CAM/CNC instructions.

Most lecture time is dedicated to introducing students to the theory and practice of creating engineering design and drawings (reading drawings, visualization of shape from multi view drawings, layout of multi view drawings, detailing and sectioning practice and standards etc.). Half the weekly lab activities

are devoted to CAD/CAM/CNC tasks and activities such as sketching pictorial views, layout of multi view drawings, sectional and solving drawing problems (eg. missing view problems). The other half of the lab each week is spent working with

CAD/CAM/CNC theoretical concepts. Students must spend an additional 2 to 3 hours per week with these tutorials to improve their skills after they get familiar with both CAD and CAM/CNC.

The tutorials consist of the following:

Table 2: 2-1 Term 1 CAD

Week	Module	les- son	Time /Module		Activities
			lecturing	lab	
1-7	1. Com- puter Sketching	1-7	14	21	Creation of - design & drawing
8	2. Com- puter Sketching	8	2	3	Modeling utilities
9-10	3. Com- puter Sketching	9&10	4	6	Assembly modeling and mating
11-12	4. Com- puter Sketching	11&12	4	6	Engineering drawing
Total time			24	36	

Table 3: 2-2 Term 2: CAM/CNC

Week	Module	les- son	Time /Module		Activities
			lecturing	lab	
1-8	5. Rapid pro- tototyping	13-20	16	24	Creating prototype (manufactur- ing)
9-12	6. Project and Analysis	21-24	8	12	Product manufacture and analysis (manufacturing)
Total time			24	36	

Each of these tasks takes between 2 to 4 hours to complete (thus requiring some time spent out of the regularly scheduled computer lab time). The time required will vary depending on the ability and background of the student. Moreover, additional time would be beneficial for experimentation and exploration of the program. Most of the material can be done by the student on their own time; however there are a few "tricky" bits in some of the lessons. Therefore, it is important to have teaching assistants

available (preferably right in the computer lab) who can answer special questions and especially bailout students who get into trouble. Most common causes of confusion are due to not completing (or even doing!) the lessons or digesting the material. This is not surprising given the volume of new information or the lack of time in students' schedules.

Control Group and Experiment Group Characteristic

Through this paper it is proposed to investigate how individual learners learn the above operations in a group setting and how computer assisted instructions

affect various learning outcomes as compared to traditional teaching instructions.

To investigate the above three student groups were formed each having 15 students with almost similar average marks in pre class examination as shown in table 2.

Table 4: Pre-Test Ability

Group	Teaching methods	No of students	Level of student Marks	
			Average Marks	Standard Deviation
1	Traditional Classroom Lecturing and Laboratory work in Classroom	15	67	5.84
2	Classroom Teaching with Available Computer Support (Simulation)	15	66.13	13.22
3	Supervised/Unsupervised Exposure to Available Computer Simulation	15	66	12.57

The group 1 students (having low standard deviation in marks indicating an almost homogeneous group) were exposed to traditional teaching where as groups 2 students (having high standard deviation indicating heterogeneous group) were allowed to learn with available of computer simulation and Group 3 students were exposed to CAD computer simulation without teacher supervision and CAM/CNC computer simulation with teacher supervision for safety purpose.

Subject Modules

To learn skills required to satisfy outcomes as shown pictorially in figure 1, various learning activities were formulated in a modular pattern. The required learning activities have been categorised under six

modules as explained in Table 1. Students were required to acquire skills in all the learning activities. Out of these six, four sections are for computer sketching which require 10 hours each and one section is for prototyping which requires 30 hours of lecturing and demonstration. The last section requires 25 hours within which project, analysis, and evaluation of student's skills is carried out.

All the prescribed modules (Table 1) were incorporated in teaching design and manufacture of a Gear Box assembly as shown below (figure 1). This Gear Box assembly consists of different parts and students were taught computer aided design of individual components, assembly and manufacture using three different teaching methodologies described in next section.

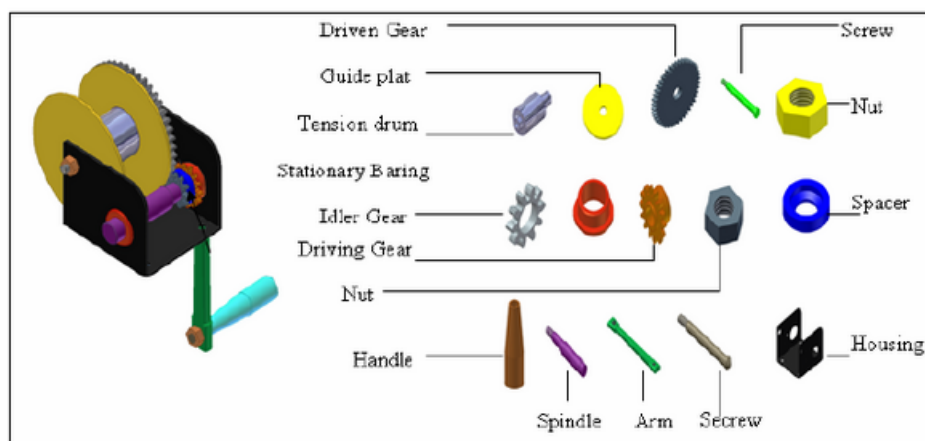


Figure 1: Gear Box

Table 5: Activities Covered

Part No	Part Name	Module Covered	Activities Covered
1	Driving Gear	1, 2, 3, 4, 5, 6	Drawing and manufacturing on (CNC)
2	Handle	1, 2, 3, 4, 6	Drawing
3	Screws	1, 2, 3, 4, 6	Drawing and manufacturing on (CNC)
4	Gears	1, 2, 3, 4, 5, 6	Drawing and manufacturing on (CNC)
5	Guide plate	1, 2, 3, 4, 6	Drawing
6	Spacer	1, 2, 3, 4, 6	Drawing
7	Tension drum	1, 2, 3, 4, 6	Drawing
8	Housing	1, 2, 3, 4, 6	Drawing
9	Driven gear	1, 2, 3, 4, 5, 6	Drawing and manufacturing on (CNC)
10	Stationary bearing	1, 2, 3, 4, 5, 6	Drawing and manufacturing (Traditional Machine)
11	Spindle	1, 2, 3, 4, 5, 6	Drawing and manufacturing on (CNC)
12	Handle arm	1, 2, 3, 4, 5, 6	Drawing and manufacturing (Traditional Machine)
13	Idler gear	1, 2, 3, 4, 5, 6	Drawing and manufacturing on (CNC)

Attempted Methods***Traditional Classroom Lecturing and Laboratory Work in Classroom***

Various features of traditional classroom teaching are shown in the figure 2. The important features of this process are given below.

1. The instructor delivers the lecture with the use of computer interface of spectra light linked with projector.
2. The students were given manual, hand book and access to computers to work with teacher.
3. Teacher helped them in case of any difficulty.
4. The above steps (a) to (c) were used in teaching of CAD, CAM and CNC applications

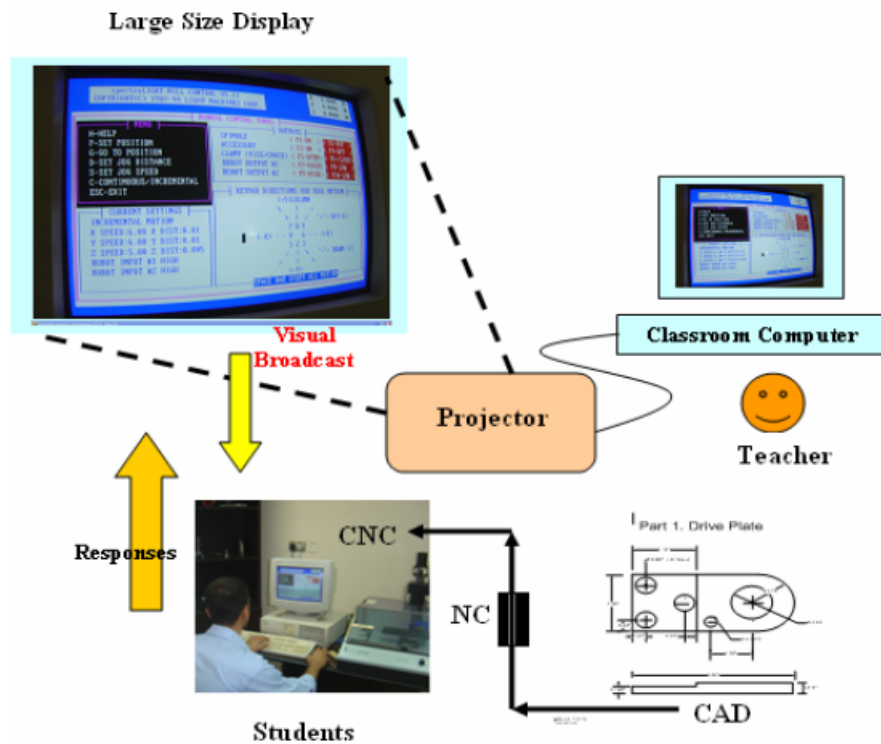


Figure 2

Class Room Teaching with Available Computer Support (Simulation)

Various features of computer assisted instructions are shown in figure3. Various important features of this teaching methodology are as given below.

1. The instructor delivers the lecture with the use of computer interface of spectra light linked with projector.

2. The students were given manual, hand book and access to computers to work with teacher. Along with these computers simulation software is provided to students which describe step by step procedure dynamically.
3. Teacher helped them in case of any difficulty.
4. The above steps (a) to (c) were used in teaching of CAD, CAM and CNC applications

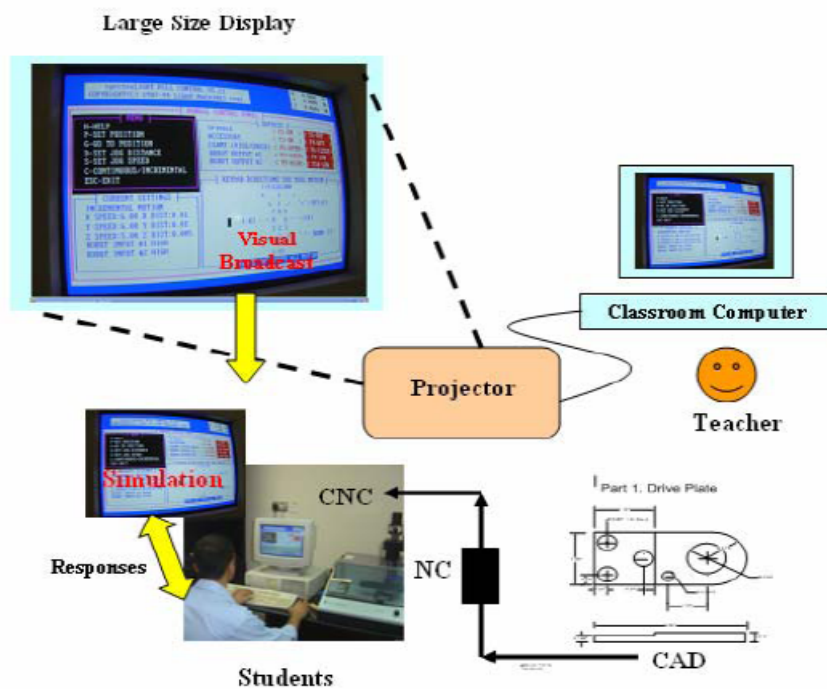


Figure 3

Supervised/Unsupervised Exposure to Available Computer Simulation

In this method students were exposed to computer assisted instructions for CAD part of the

syllabus unsupervised and then supervised computer assisted instructions for CAM and CNC sections.

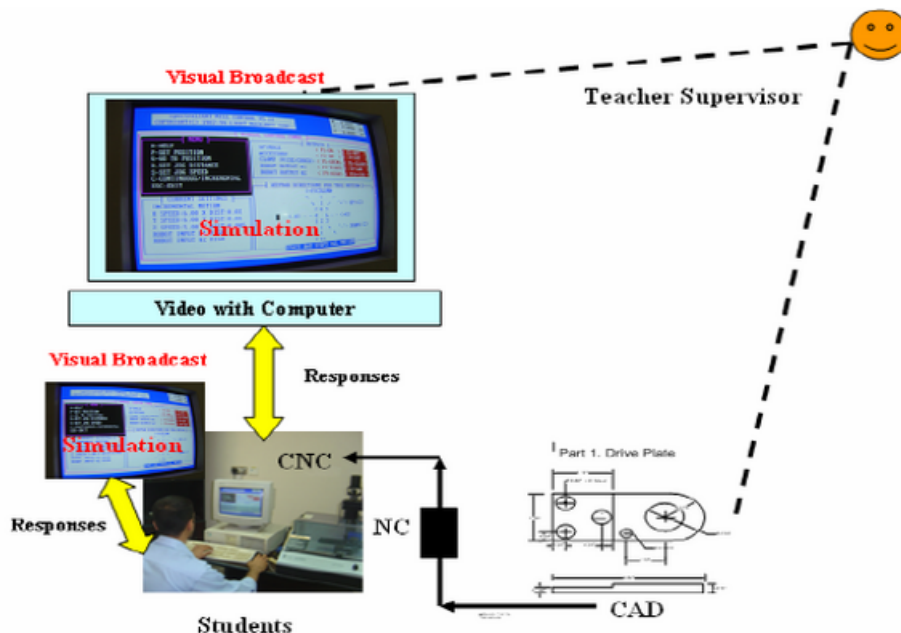


Figure 4

Students Evaluation

At the end of three teaching methods traditional teaching method, computer assisted instruction

teaching method, supervised/unsupervised teaching with computer simulation the following five learning outcomes were evaluated.

1. Creation of drawing and design using Computer aided design
2. Using data exchange format (DXF) to create numerical control file
3. Final setup check of computerised numerical control machine.
4. Final manufacturing of the product using CNC.
5. Quality evaluation.

After having undergone teaching and learning in the use of CAD/CAM/CNC students were tested for their abilities in this subject area by asking them to draw and manufacturing the following parts.

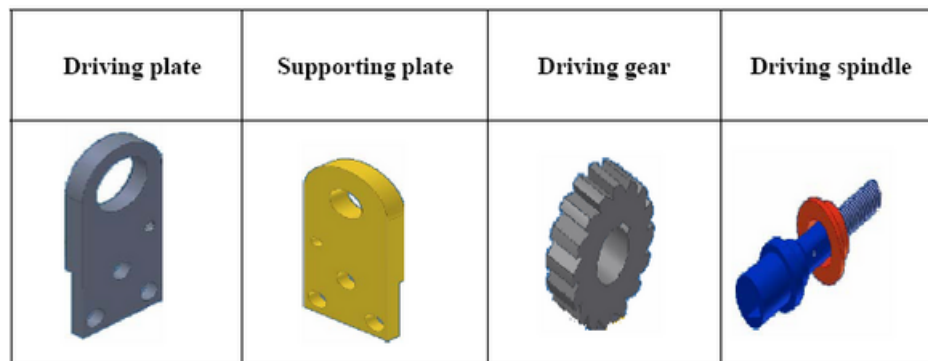


Figure 5: Parts used for Evaluation

All the results have been analyzed under six categories namely, knowledge, comprehension, application, analysis, synthesis and evaluation. Various skills observed under the six categories are mentioned below.

Level 1: Knowledge (Recall Data)

Level 2: Comprehension (Understanding Information)

Level 3: Application (Applying knowledge to a new situation)

Level 4: Analysis (Separates information into part for better understanding)

Level 5: Synthesis (Builds a pattern from diver's elements)

Level 6: Evaluations (Judges the value of information)

Description of Various Cognition Levels

Table 6 shows various activities associated with various cognition levels

Table 6: Description of Various Activities Associated with Various Cognition Levels

High level	Level	Elements	Tasks
	6	Evaluations	Judges the value of the information Example (Evaluate assembly drawing to judge final shape of the drawing with given dimension also to judge final product's fitness, shape, movements and quality.
	5	Synthesis	Builds a pattern from diverse elements Example (Arrange the view of the engineering drawing 1 st angle and 3 rd angle, assemble different parts to create project in final shape, design a new shape and modify the shape to another shape, arranging machine tools, materials and instruments for final manufacturing.

	4	Analysis	Separates information into part for better understanding Example (Analyzing and drawing parts during assembly drawing and using program facilities to calculate missing dimensions of engineering drawing. Analysing verifying the manufacturing operations.
	3	Application	Applying knowledge to a new situation Example (sketching, applying, demonstrating, modeling, assembly, demonstrating and verifying the manufacturing operations.
	2	Comprehension	Understanding information Example (Select program feature, locate design and drawing geometry, select and locate cutting parameters, setting the tools and the work piece.
Low level	1	Knowledge	Recall of data Example (Memorizing program operations, feature used in part creation, saving DXF file, creating NC file, set up the machine and run the machine for manufacturing.

The students were than marked out of 100 for each cognition level and performance results of this survey for all the responding students traditional teaching method (G1 N=15), computers assisted instruction

teaching method (G2 N=15), and supervised /unsupervised teaching method (G3 N=15) are shown in chart 1.

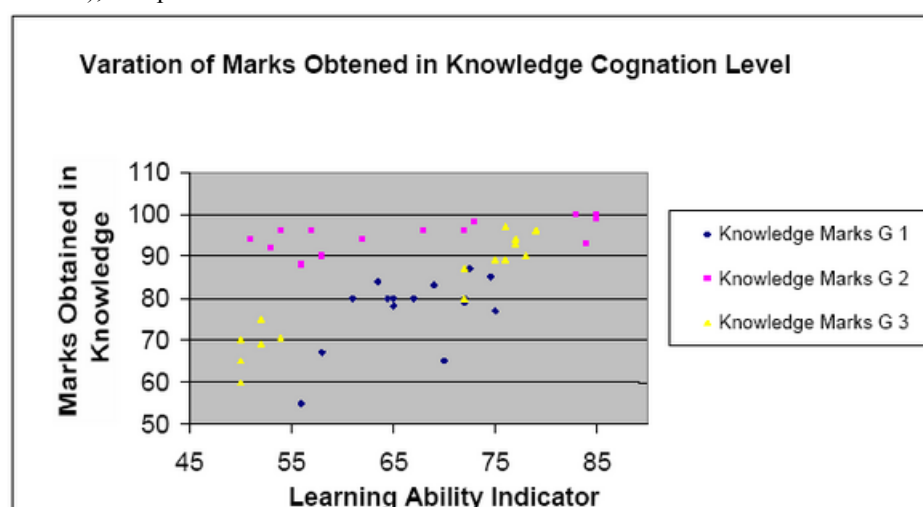


Figure 6: Comparison between Teaching Methods in Knowledge Cognition Level

Figure 6 shows correlation between learning ability indicators with the marks obtained for the three groups in the knowledge cognition level. It can be seen that both groups show considerable improvement in knowledge. The distribution of marks for group2 students indicates that the difference between high achievers

and low achievers is quite small. The distribution of marks for group 1 and group 3 students however indicates that although overall learning is satisfactory low ability students do not benefit as much as high ability students. This indicates that for heterogeneous group of student's computer assisted instructions help in satisfactory achievement of learning outcomes.

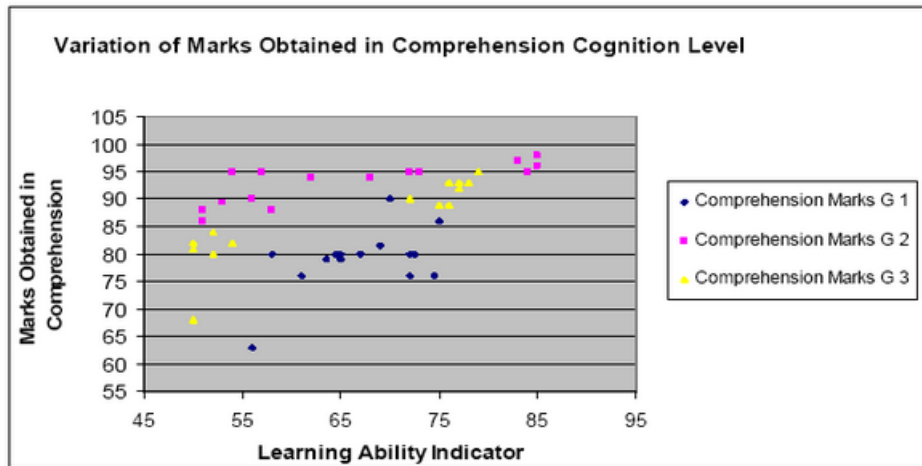


Figure 7: Comparison between Teaching Methods in Comprehension Cognition Level

Figure 7 shows variation of marks obtained in comprehension cognition level for the three groups. In the comprehension level students were required to understand the information like drawing geometry, selecting and locating cutting parameters, setting the tools and the

work piece. The figure indicates that the overall trends are similar to that seen in knowledge cognition level although the scatter in the marks has increased for the three groups. But there are big difference in learning ability between low level of group 2 compared with low level of group 1 and group 3.

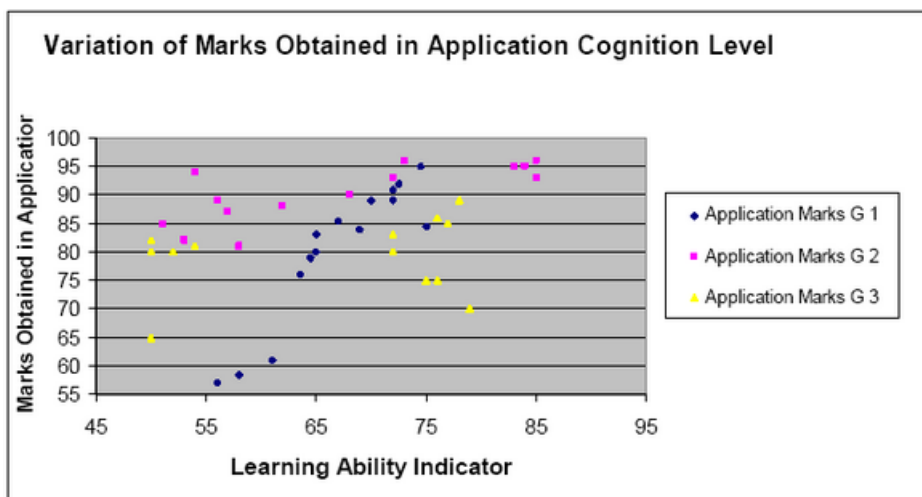


Figure 8: Comparison between Teaching Methods in Application Cognition Level

Figure 8 shows the variation of marks in application cognition level. This level evaluates students' ability to sketch, apply, demonstrate, model, assemble as well as demonstrate and

verify the manufacturing operations. Again in this cognition level group 2 students did better than group 1 and group 3 students although the most scatter in marks is almost similar.

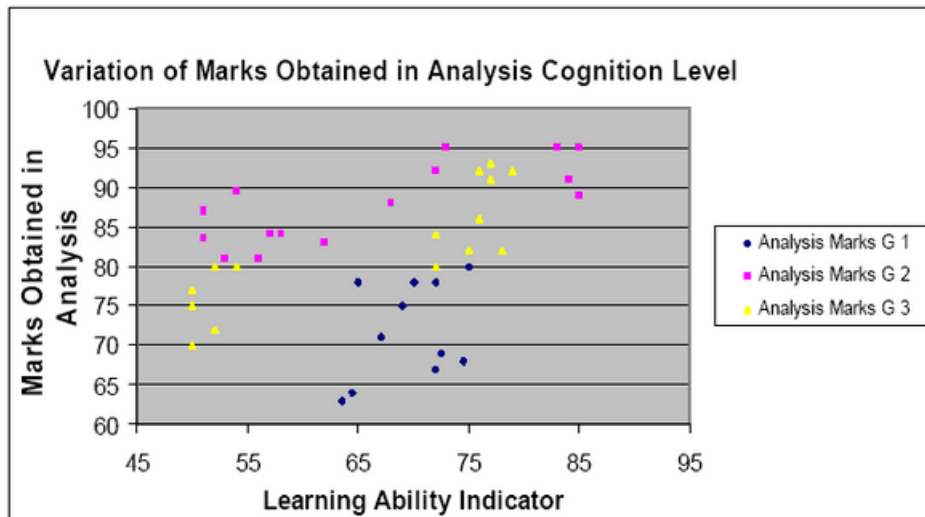


Figure 9: Comparison between Teaching Methods in Analysis Cognition Level

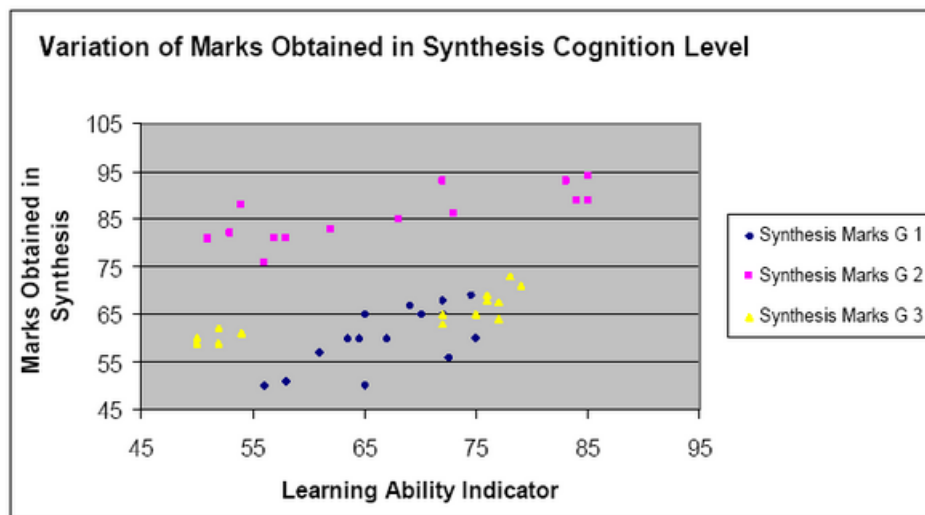


Figure 10: Comparison between Teaching Methods in Synthesis Cognition Level

Figures 9 and 10 show variation of marks obtained in the analysis and synthesis cognition levels for the three groups. These figures again shows effectiveness of computer assisted instruction as compared to the traditional teaching. In these cognition levels students were evaluated for their abilities in analyzing drawing parts during assembly drawing and using program facilities to calculate missing dimensions of engineering drawing. This also requires students to be capable in analyzing and verifying the manufacturing operations, assembling different parts to create prototype in final shape, designing a new shape and modifying one shape to another shape, arranging

machine tools, materials and instruments for final manufacture.

It can be seen in the figures that the scatter in marks for group 1 students has considerably increased. This indicates that traditional teaching methodology has serious limitations in improving analysis capability in students with low learning ability. The group 1 students who were exposed to traditional teaching are in average lagging behind by about 20 marks in the synthesis cognition level. This shows that computer assisted instructions are for more useful in delivering learning outcomes as compared to traditional teaching methods.

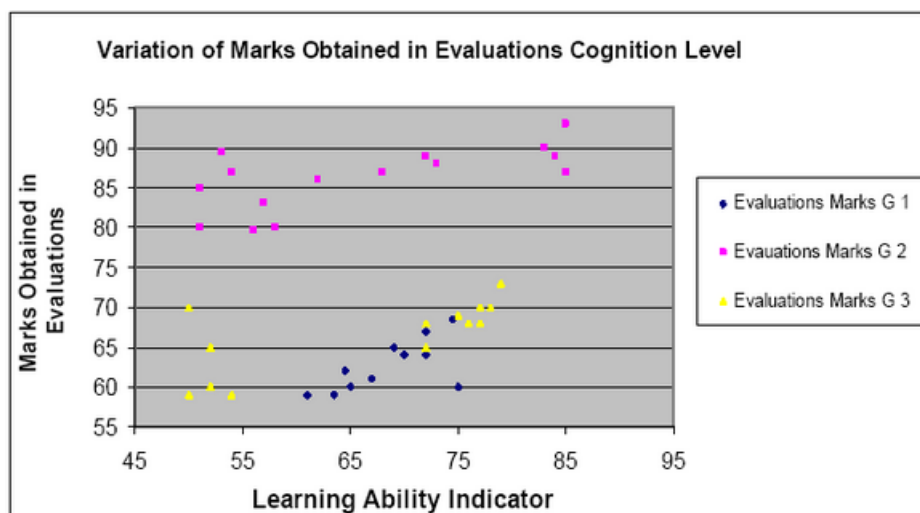


Figure 11: Comparison between Teaching Methods in Synthesis Cognition Level

The performance of the three groups in the evaluation cognition domain has been depicted in figure 11.

This cognition level tests students' ability to judge the value of the information with regard final products fitness, shape, movements and quality.

This figure shows that group 2 students have performed much better as compared to group 1 students also it can be seen in the figures that the scatter in marks for group 3 students has considerably increased. It can be further seen that although group 2 has students with widely varying learning abilities, the computer assisted instruction helped them achieve all the learning outcomes in a satisfactory manner and the difference between high achievers and low achievers is small. This indicates that computer assisted instructions are much better in handling a heterogeneous group of students.

Conclusions

This study has clearly demonstrated the effectiveness of computer assisted instructions in a heterogeneous group learning activity. It has been seen that the group exposed to computer assisted instructions performed much better than the group exposed to traditional teaching. Further computer assisted instruction helped students widely differing pre-learn-

ing abilities to satisfy various learning outcomes CAD/CAM subject area.

This study has clearly demonstrated the effectiveness of computer assisted instructions in a heterogeneous group learning activity. It has been seen that the group exposed to computer assisted instructions performed much better than the group exposed to traditional teaching. Further computer assisted instruction helped students with widely varying pre-learning abilities to satisfy various learning outcomes in CAD/CAM/CNC subject area.

This study has also indicated that a computer assisted teaching methodology works better when students are closely supervised in all aspects of use of software and other computer resources. It has been noticed that group 2 students has done far better than either of group 1 and group 3 students. It can therefore be recommended that computer assisted instruction can be used in teaching CAD/CAM/CNC subject area to achieve higher levels of learner satisfaction.

Acknowledgement

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