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An Advanced Technology Classroom for Engineering Education*

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The Advanced Technology Classroom adopted by the University of Missouri–Rolla's School of Engineering in December 1989 is a sophisticated, computer-integrated, learning environment implemented to aid in teaching engineering curricula. The system integrates multimedia (computer graphics, videotape, laserdisc, audio tape) and interactive keypads directly into the lecture hall. The goal is to improve instruction through greater visualization, problem breakdown and student participation. This paper presents initial research findings on the systems' impact on short-term retention rates. The study was conducted on 37 engineering and science faculty staff from around the USA who participated in a CIM Manufacturing for Engineering Faculty Enhancement course sponsored by the National Science Foundation during the summer of 1990 at UMR's Engineering Management Department

INTRODUCTION

JOHN NAISBITT, a futurist, was quoted on the topic of education as saying: 'We have essentially the same education system we had in the industrial society and we are trying to use it to equip us for the information age' [1]. This statement is of particular significance when applied to engineering education. In the United States institutions of higher learning are often held in high regard in their ability to teach high technology; however, many are criticized for their inability to use high technology in teaching.

Current technological advances have not only increased the demand for engineers and scientists but also the knowledge base they must acquire [2, 3]. Yet teaching methodology in engineering has changed very little. For this reason some new techniques in instruction for engineers are being explored. The University of Missouri–Rolla's School of Engineering has adopted the Advanced Technology Classroom (ATC)—a sophisticated, computer-controlled learning environment. The ATC is an attempt to apply several new areas of research in engineering education, including the following:

1. Scientific visualization (applying visualization techniques to 'non-imaging' data) [4].
2. Sequential process building (computerized breakdown and sequencing of problems) [5].
3. Enhanced student interaction/participation [5].

This paper describes the ATC implementation at UMR and gives the results from an initial empirical study. The study was conducted during a short course on Computer-Integrated Manufacturing (CIM) for Engineering Faculty Enhancement sponsored by the National Science Foundation during the summer of 1990 at UMR's Engineering Management Department.

DESCRIPTION

The ATC at UMR is a sophisticated, fully integrated, computer-controlled learning environment. This futuristic classroom is comprised of six main hardware assemblies: a smart lectern, a student response subsystem with interactive keypads, a presentation subsystem with a 10×12 ft rear projection screen, an audiovisual electronics system, an alternate computer, and a document camera, as depicted in Figure 1 [6, 7].

The smart lectern features a touch-screen laser panel and houses an IBM personal computer with 512 K of memory, a 20 Mbyte fixed disk, and a 1.2 Mbyte $5\frac{1}{4}$ in. floppy disk drive. The smart lectern can also be controlled by a hand-held remote control device. Mounted on one side of the lectern is the alternate computer, an IBM PC model 6152 with 640 K of memory in DOS and 5 Mbytes of memory in OS/2, a 70 Mbyte fixed disk, and a $3\frac{1}{2}$ in. floppy disk drive. On the other side is a document camera, which can display any picture on a wide sceen with medium resolution.

The interactive keypads are used to obtain

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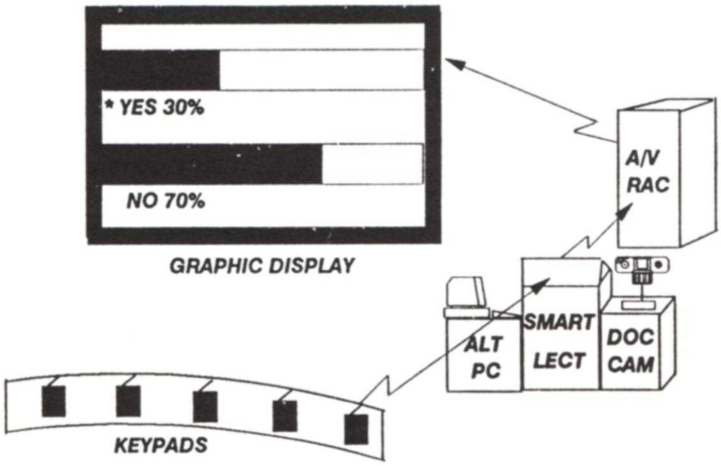

Fig. 1. Advanced Technology Classroom.

student responses to numerous types of questions posed by an instructor. Each keypad contains 10 numbered buttons, 0–9, allowing the student to send data for immediate display, plus the following keys to:

- Respond to 'True/False', 'Yes/No', 'Multiple Choice', and 'Numeric Entry' questions.
- Clear change an answer.
- Recall or review a previous answer.
- Help.

An eight-character LCD display on the keypad shows the data entered; a ready light indicates that the keypad has been activated.

The audiovisual electronics subsystem features a video cassette player, a Pioneer laserdisc player, a VideoShow graphic processor, an audio cassette recorder and an input/output panel for connecting the smart lectern and the projection unit, and other devices.

The rear projection screen is used to display all electronic visuals:

- Alternate computer screen.
- Video graphics.
- Videotape.
- Laserdisc.
- Document camera.
- Graphic display of keypad answers.

INITIATIVES

IBM developed a prototype ATC a number of years prior to UMR's adoption and expansion of the system. IBM's initial classroom lacked many of the main hardware assemblies used in the ATC at UMR, including the document camera and the alternate computer. In 1989 IBM conducted unpublished research on this prototype ATC. The research was conducted within IBM's corporate and division management schools. Results suggested the ATC substantially reduced classroom time and improved learning up to 40% [8]. This was followed by a study at Western Connecticut State University in the Management Department that led to inconclusive results on the effectiveness of the ATC in teaching management [9].

Since the UMR adoption and expansion of the system in December of 1989, it was decided that further research was necessary to determine the significance of the new system and with specific regard to its impact on engineering education. Three studies have since been conducted at UMR. This paper presents the results of the first study conducted in the summer of 1990 in a CIM Workshop for Faculty Enhancement. Two other studies were conducted at UMR in the fall of 1990 in two engineering curricula, Mechanics of Materials [10] and Production/Operations Management [11]. Results of these studies are under current analysis to determine the ATC's effect on long-term retention.

RESEARCH DESIGN

In the summer of 1990 the ATC was preprogrammed and run in full format for two one-week short courses. Empirical research was conducted during the short courses to determine:

1. The ATC's effectiveness in teaching engineering based curricula.
2. The ATC's impact on short-term retention.

The study used a quasi-experimental design in which two experimental treatments are entreated to two naturally assembled groups in a counterbalanced fashion [12, 13]. An X represents exposure of a group to an experimental treatment and an O represents some observation or measurement as depicted in Table 1. In this design each group is equally exposed to each experimental treatment X1 and X2 at opposite times (X1 = instruction via ATC, X2 = instruction via traditional or non-ATC lecture format).

The power of the design lies in its ability to demonstrate all the effects in all the comparison

Table 1. Experimental design [12]

Group	Time 1		Time 2	
A	X1	O	X2	O
B	X2	O	X1	O

groups as opposed to a standard control group design where only one group receives the experimental treatment. The design also acquires strength through the consistency of the internal duplication of the experiment. However, this may lead to a limitation in which the ascertained variation among the experimental variables could instead represent a specific, complex interaction between the group differences and the occasions [12]. Yet this design typifies the greatest control suited for the situation in which a pretest is inappropriate and groups cannot be randomized to the extent of a laboratory study.

Experimental design

On 4–8 June 1990, Week 1, UMR's Engineering Management Department held a CIM Workshop for Engineering Faculty Enhancement. Nineteen faculty members from various colleges and universities around the United States participated. Five short courses on CIM, CAD/CAM, Intelligent Manufacturing, Simulation, and CIM Justification were given on each of the five days of the workshop. The courses were taught by various Engineering Management Professors.

On 11–15 June, Week 2, the workshop was repeated for another group of 18 faculty members, again from several different colleges and universities from around the nation. Exactly the same course material was taught during the Week 2 session as during the Week 1 session.

Two lecture hours were chosen for empirical research:

Lecture 1 Introduction to Simulation Modeling.
Lecture 2 Simulation modeling in CIM System Design.

During Week 1 the 19 conference participants became the experimental group. Lecture 1 material was presented to this experimental group using the ATC. All lecture notes were presented to the group using computer graphics via the ATC's graphics processor. Lecture notes were specifically highlighted with colors to relay importance and visual metaphors used to conceptualize the message. Keypad questions were also interjected into the lecture to invoke interest and participation. Keypad questions were immediately followed by graphical representations of participants' answers to the questions. At the end of the lecture the participants were given a 15 minute short-term retention quiz.

The Week 2 (control) group received the identical Lecture 1 material by the same instructor as Week 1, in the same classroom (Room 103), only without using the ATC. Typed notes were projected by an overhead projector on to a large screen. Identical questions were asked orally of the participants with interaction through hand raising. At the end of the lecture the Week 2 participants were given the identical 15 min short-term retention quiz as Week 1.

Lecture 2 became an identical experiment in reverse order. Week 1 became the control group receiving Lecture 2 from typed notes projected on an overhead, while Week 2 became the experimental group receiving Lecture 2 via ATC format. Thus a schedule of the two experiments would appear as displayed in Table 2.

Table 2. Experimental setup

Group	Lecture 1	Lecture 2
Week 1	non-ATC	ATC
Week 2	ATC	non-ATC

The same room was used throughout the study to avoid experimental contamination from environmental change or what is better known as the 'Hawthorne' effect [14]. This control of environment helps to separate the possibility of increased participant retention or enhanced learning from occurring as a result of being exposed to a novel learning environment as opposed to the 'true' experimental treatment.

Group equivalence

The group's participants from Week 1 and Week 2 were asked to give information on their age, degree, previous knowledge of Lecture 1 material, previous knowledge of Lecture 2 material, interest in Lecture 1, interest in Lecture 2, and effectiveness of the instructor who presented the two lectures (the same instructor presented both Lectures 1 and 2 both weeks). For each of the aforementioned variables, statistical significance was determined using the t-test. The t-test showed no statistical significance ($\alpha = .05$) between any of the means (all results presented in this paper were analysed using the Statistical Analysis System [15] program on an IBM mainframe computer). Thus the population of the study proved to be homogeneous in relation to the variables listed in Table 3.

These findings provide some degree of assurance that the group participants formed for the purpose of this study were essentially equivalent. This is a necessary precondition to the experiment. Thus section differences that occur on the quizzes during the study may be attributed to the conditions under the study and not to inherent differences in the groups participating.

RESULTS

An independent evaluation of the responses to the quizzes given at the end of each lecture yielded four sets of quiz results:

Table 3. Group comparison of variables shows no significant difference

Variable	Week 1 mean	Week 2 mean	Scale
Age	42	43	
Degree	2.32	2.06	0 = other, 1 = BS, 2 = MS, 3 = PhD
Previous knowledge Lecture 1	2.16	1.88	1 = limited, 3 = moderate, 5 = extensive
Previous knowledge Lecture 2	2.11	2.05	
Interest Lecture 1	3.80	4.24	1 = low, 3 = moderate, 5 = extensive
Interest Lecture 2	3.47	4.22	
Instructor evaluation	1.59	1.39	1 = excellent, 3 = average, 5 = poor

Table 4. ANOVA

Source	*DF*	*SS*	Mean square	*F*	*PR* > *F*	R^2
Model	3	1031.09	343.70	4.47	0.0063	0.163
Error	69	5311.24	76.98			

1. Week 1, Lecture 1, results—mean score 17.526.
2. Week 1, Lecture 2, results—mean score 12.667.
3. Week 2, Lecture 1, results—mean score 15.5.
4. Week 2, Lecture 2, results—mean score 23.0.

Comparison of Lecture 1 and Lecture 2 results are depicted graphically in Fig. 2.

Analysis of the variance

An analysis of the variance, given in Table 4, was conducted on the four mean quiz scores. The model showed a statistical significance of 0.0063 (α = .05), at a confidence level of 95%. This indicated that the increase in quiz scores for both groups was statistically significant when the ATC was used to present the lecture material.

PARTICIPANTS' REACTION

The 37 participants of the study were asked to agree or disagree with the following statement: 'the ATC improves instruction.' On a scale of:

1 = strongly agree
2 = agree
3 = no opinion
4 = disagree
5 = strongly disagree

the average rating was 1.76 with 80% of the participants answering either 'agree' or 'strongly agree'. The participants were also asked to comment on 'What advantages do you see in taking a course with the ATC'. Most comments on the ATC's performance were favourable. A 32 year old PhD in Industrial Engineering commented, 'The student participation capabilities are extremely useful. It does tend to keep one alert. The

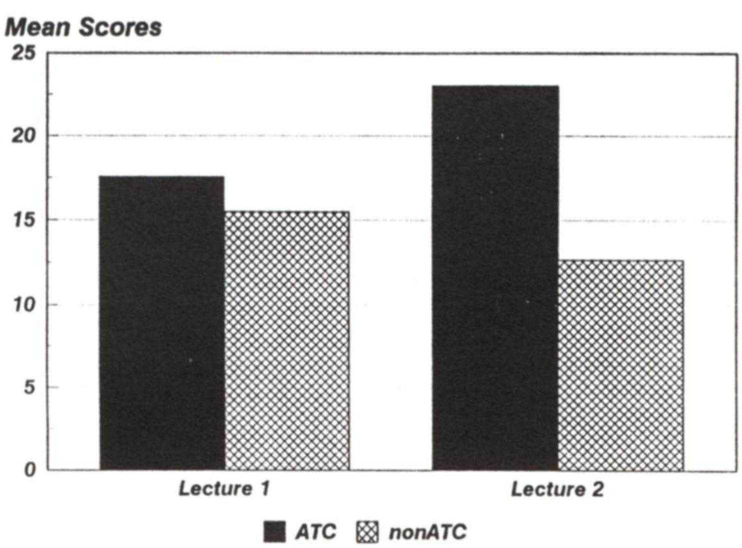

Fig. 2. Mean quiz scores.

various media forms aid in the presentation of an increased amount of information (easily) by not requiring all the presentation to be in one format or another.' A minority of responses did, however, reflect a different opinion. A 33 year old PhD in Engineering Management stated that, 'This [improved instruction] depends on the instructor not the classroom.'

LIMITATIONS

According to these preliminary research findings it would appear that the ATC is an effective pedagogical tool for presenting engineering curricula. However, several limitations on the scope of this study must be discussed. Firstly, the study only tested the ATC's effectiveness on a very narrow window of engineering subject matter. Secondly, the study gave no indication of long-term retention rates, thus no conclusion can be drawn as to the long-term success or credibility of using the system in engineering education. Thirdly, the study participants were not representative of typical engineering students. As engineering and science faculty staff, the participants showed an increased motivation and interest in using the technology to enhance their learning. And, fourthly, the instructor who used the system in this particular study was extremely well versed and efficient in his implementation of the system. Lack of instructor experience and failure to use the ATC effectively was cited in the Western Connecticut Study [9] as a possible reason for inconclusive findings in that institution's experimentation.

CONCLUSIONS

This study cannot represent all teaching situations in engineering. The scope of the study and resultant data must be viewed from the particular setting, instructor and participant body used in the experimentation. However, the increased short-term retention rates achieved with the ATC (Lecture 1 increase of 5%; Lecture 2 increase of 25%) cannot be disregarded. These positive retention rates demonstrate that sophisticated teaching environments such as the Advanced Technology Classroom offer considerable potential for enhancing the effectiveness of engineering education. In conjunction with these findings the study found among engineering and science faculty staff participants that there was an overwhelming perception that the ATC improves instruction. Thus, the ATC may be one answer to fulfilling the increasing need to expand the horizons of teaching methodologies used in engineering education.

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